South Asia Forum For Infrastructure Regulation (SAFIR) Working Group On

"Regulatory Cooperation to Facilitate Knowledge sharing, addressing Cross cutting Energy/Electricity Regulatory Issues and Capacity Building in South Asia"

SAFIR Working Group Study Report on Regulatory Interventions for Grid Discipline and Grid Reliability in the South Asian Region (SAR)

South Asia Regional Initiative for Energy Integration

SARI-EI-IRADE

SAFIR Working Group

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Disclaimer

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Message

Increased energy demands combined with large penetration of variable renewable energy sources (wind and solar) and electric vehicles, have necessitated the need for secure, safe, reliable integrated grid operation through a robust regulatory framework.

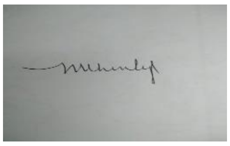
Safe and secure grid operation is the collective responsibility of all players connected to the grid. Reliable grid operation requires **grid discipline** wherein all the participants connected to the grid adhere to the pre-decided rules.

In order to ensure that the grid operates in a smooth and stable manner, it is important for all stakeholders connected to the grid, to follow certain common technical rules. For this, each country has a Grid Code, which is to be followed diligently. However, these rules or Grid Codes need to be harmonious across the interconnected countries, to ensure seamless power trade across the borders in a safe and secure manner.

Considering the importance of this matter, SARI/EI/IRADe has undertaken a study on Regulatory Interventions for Grid Discipline and Grid Reliability in the South Asian Region for the South Asia Forum for Infrastructure Regulation (SAFIR) Working Group on “Regulatory Cooperation to Facilitate Knowledge sharing, addressing Cross Cutting Energy/Electricity Regulatory Issues and Capacity Building in South Asia”.

This report evaluates the existing relevant electricity regulations, mechanisms and technical frameworks with respect to grid discipline and grid reliability of each South Asian country. In order to undertake the recommended set of regulatory measures/interventions, this report also recommends specific technical capacity building measures for each of the aforementioned countries.

This Report would enable the South Asian countries to objectively assess the existing relevant electricity regulations, mechanisms and technical frameworks with respects to grid discipline and grid reliability. I hope that the regulatory measures/ interventions suggested in this Report will ensure grid discipline and grid reliability in South Asia region, and lead to a safe, secure and reliable power grid.



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FOREWARD

South Asia is one of the fastest growing regions in the world and energy plays a significant role in its socioeconomic development. Ensuring access and availability of energy, especially in the form of electricity, is central to sustaining the region's expanding economies and its people's rising aspirations. The United States Government is deeply committed to enhancing energy security within South Asia. Since 2000, the U.S. Agency for International Development (USAID) has been working towards this goal by promoting regional energy cooperation through its South Asia Regional Initiative for Energy (SARI/E) program.

The program's first three phases focused on building trust, raising awareness, and assessing potential transmission connections. Phase four, launched in 2012 and called the South Asia Regional Initiative for Energy Integration (SARI/EI), is furthering regional energy integration through cross-border power trade. Integrated Research and Action for Development (IRADe), a leading South Asian think tank, is our partner in implementing SARI/EI's interventions. Countries in the Bhutan-Bangladesh-India-Nepal (BBIN) region are already trading power—efforts expected only to increase in the coming years as the region transitions to tri- and multilateral power trade.

Regional institutions such as the South Asia Forum for Infrastructure Regulation (SAFIR) have a critical role to play in enhancing regulatory energy cooperation. The SAFIR working group, supported by the SARI/EI program, aims to facilitate transparent regulatory frameworks, strengthen stakeholder capacities, and enhance knowledge sharing in the region.

For an integrated regional grid to operate in a smooth and stable manner, all stakeholders connected to the grid must follow certain shared technical standards. These standards need to be harmonious between countries to ensure seamless power trade. This study, the *Regulatory Interventions for Grid Discipline and Grid Reliability in the South Asian Region*, conducted by SARI/EI for the SAFIR working group, delves into various aspects of grid discipline, identifying regulatory interventions required in each country to achieve reliable and secure grid operations across South Asia.

I would like to commend the SARI/EI secretariat at IRADe for their excellent work in preparing this report. I am confident this study will serve as a valuable resource for regulators and other power sector stakeholders throughout the region.

Sincerely,

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Preface

We are pleased to present the report on "**Regulatory Interventions for Grid Discipline and Grid Reliability in the South Asian Region (SAR)**" developed for the South Asia Forum for Infrastructure Regulation (SAFIR) Working Group. This report was developed under the South Asia Regional Initiative for Energy Integration (SARI/EI) project, supported by the USAID and implemented by Integrated Research and Action for Development (IRADe).

This report evaluates the existing relevant electricity regulations, mechanisms and technical frameworks with respect to grid discipline and grid reliability of each South Asian country, both from the perspective of integration/ unification of regional grids of domestic power system of a country, as well as cross-border power grid interconnection. Based on the in-depth review of grid discipline and grid reliability aspects in the SAR and the international best practices, this report recommends a detailed set of regulatory measures/ interventions and mechanisms such as system planning, system construction and safety, grid connection, system protection, testing & commissioning, system operation, scheduling & dispatch, information & communications technology, monitoring & compliance that are needed for enhancing grid discipline and grid reliability and a roadmap to improve grid discipline and grid reliability for each of the countries in the SAR i.e., Afghanistan, Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan, and Sri Lanka.

The draft Report was circulated to the key officials and decision makers in South Asian Country governments (Energy/Power Ministries), Electricity Regulatory Commissions, Planning Authorities etc. Their feedback and thoughts have helped make this report more robust and relevant to all the stakeholders.

I hope that this report will be a useful reference point for facilitating enriching discussions on regulatory measures/intervention needed for ensuring grid discipline and grid reliability in the SA region. I am grateful to USAID for their continued support in the preparation of this report. I would like to acknowledge the excellent work done by PwC, India in developing the report. I sincerely thank the research team at SARI/ EI Secretariat /IRADe for their valuable inputs for the Report, through sustained efforts in ensuring that the report is completed despite the restrictions posed by the lockdown.

Dr. Jyoti Parikh
Executive Director
Integrated Research and Action for Development (IRADe)

List of Acronyms/ Abbreviations

Acronym/ Abbreviations	Meaning
AC	Alternating Current
ACE	Area Control Error
ACER	Agency for the Cooperation of Energy Regulators
ACSR	Aluminum conductor steel-reinforced
ADB	Asian Development Bank
ADMS	Advanced Distribution Management System
AGC	Automatic Generation Control
ALS	Automatic Load Shedding
AMR	Automatic Meter Reading
APSCL	Ashuganj Power Station Company Ltd.
AREP	Alternative Renewable Energy Policy
ATC	Available Transfer Capability
AVR	Automatic Voltage Regulators
BA	Balancing Authority
BEA	Bhutan Electricity Authority
BERC	Bangladesh Energy Regulatory Commission
BERF	BIMSTEC Energy/Electricity Regulators Forum
BIMSTEC	Bay of Bengal Initiative for Multi Sectoral Technical and Economic Cooperation
BPCL	Bhutan Power Corporation Limited
BPDP	Bangladesh Power Development Board
BPSO	Bhutan Power System Operator
BREB	Bangladesh Rural Electrification Board
BRP	Balancing Responsible Parties
CACM	Capacity Allocation and Congestion Management
CAPM	Capital Asset Pricing Model
CBET	Cross Border Electricity Trade
CC	Connection Code
CCC	Compliance and Certification Committee
CCMP	Cyber Crisis Management Plan
CDGU	Centrally Dispatched Generating Units
CDSO	Closed Distribution System Operator
CEA	Central Electricity Authority
CEB	Ceylon Electricity Board
CEERE	Council of Experts of Energy Regulators (Electricity)
CERC	Central Electricity Regulatory Commission
CERT|CC	Computer Emergency Readiness Team | Co-ordination Centre
CGS	Central Generating Stations
CII	Critical Infrastructure
CIPC	Critical Infrastructure Protection Committee
CM	Code management
COD	Commercial Operation Date
CPGCBL	Coal Power Generation Company Bangladesh Limited
CPPA-G	Central Power Purchasing Agency - Guarantee
CTU	Central Transmission Utility
CY	Calendar Year
DABS	Da Afghanistan Breshna Shekat
DAM	Day Ahead Markets
DC	Direct current
DCSD	Distribution and Customer Service Department
DESCO	Dhaka Electric Supply Company Limited
DGPC	Druk Green Power Corporation Limited
DHMS	Department of Hydro-Meteorological Service
DHPS	Department of Hydropower & Power System

Acronym/ Abbreviations	Meaning
DISCOs	Distribution Companies
DoP	Department of Power
DOT	Department of Trade
DPDC	Dhaka Power Distribution Company
DRE	Department of Renewable Energy
DSM	Deviation Settlement Mechanism
DSO	Distribution System Operator
DVC	Damodar Valley Corporation
EA & CEI	Electric Advisor and Chief Electrical Inspector
EGCB	Electricity Generation Company of Bangladesh
E-ISAC	Electricity Information Sharing and Analysis Center
ELDC	Eastern Load Dispatch Centre
EMS	Energy Management System
EMTP	Electromagnetic Transients Program
ENCS	European Network for Cyber Security
ENS	Energy Not Served
ENTOS-E	European Network of Transmission System Operators for Electricity
EPRC	Environment and Population Research Centre
ER	Eastern Region
ERA	Energy Regulatory Authority
ERCOT	Electric Reliability Council of Texas
ERO	Electric Reliability Organization
ESCC	Electricity Subsector Coordinating Council
ETPSR	Electricity (Transmission) Performance Standards Regulation
EU	European Union
EV	Electric Vehicle
FACTS	Flexible AC Transmission System
FDI	Frequency Deviation Index
FGMO	Free Governor Mode of Operation
FOLD	Forum of Load Despatch Centre
FRCC	Florida Reliability Coordinating Council
FRO	Frequency Response Obligations
FRSG	Frequency Response Sharing Group
FY	Financial Year
GCMC	Grid Code Management Committee
GDP	Gross Domestic Product
GDR	Grid Discipline and Grid Reliability
Genco	Generation Company
GOD	Grid Operation Department
GoN	Government of Nepal
GPRS	General Packet Radio Services
GPS	Global Positioning System
GridEx	Grid Security Exercise
GW	Gigawatt
GWh	Gigawatt-hour
HEP	Hydro Electric Power
HFO	Heavy fuel oil
HVAC	High-voltage Alternating Current
HVDC	High-voltage Direct Current
ICT	Inter connecting Transformer
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IEGC	Indian Electricity Grid Code
IEX	Indian Energy Exchange
INPS	Integrated Nepal Power System
IPPs	Independent Power Producers
IRBGS	Intermittent Resource Based Generating Systems

Acronym/ Abbreviations	Meaning
ISGS	Inter-State Generating Station
ISMS	Information Security Management System
ISTS	Inter-State Transmission System
JICA	Japan International Cooperation Agency
JTT	Joint Technical Teams
kWh	kilo watt hour
LBB	Local Breaker Back-up
LDC	Load Dispatch Centre
LECO	Lanka Electricity Company Private Limited
LFC	Load-frequency control
LV	Low voltage
MCC	Main Control Centre
MEA	Maldives Energy Authority
MEB	Maldives Electricity Bureau
MEDREG	Mediterranean Energy Regulators
MENA	Middle East and North Africa
MEW	Ministry of Energy and Water
MNRE	Ministry of New and Renewable Energy
MOD	Merit Order Despatch
MoP	Ministry of Power
MoPEMR	Ministry of Power, Energy and Mineral Resources
MRO	Midwest Reliability Organization
MSSC	Most Severe Single Contingency
MV	Medium Voltage
MVA	Mega Volt Amp
MW	Megawatt
MWh	Megawatt-hour
MWSC	Male' Water and Sewerage Company
NCIIPC	National Critical Information Infrastructure Protection Centre
NEA	Nepal Electricity Authority
NEMO	Nominated Electricity Market Operator
NEP	National Electricity Plan
NEPRA	National Electric Power Regulatory Authority
NEPS	North East Power System
NER	North Eastern Region
NERC	North American Electric Reliability Corporation
NESC	National Electrical Safety Code
NESCO	Northern Electricity Supply Company Limited
NIS	Network and Information Systems
NLDC	National Load Despatch Centre
NPCC	Northeast Power Coordinating council
NPEDF	National Power and Energy Demand Forecast
NPSEP	National Power System Expansion Plan
NR	Northern Region
NRLDC	Northern Regional Load Despatch Centre
NRPC	Northern Regional Power Committee
NTDC	National Transmission & Despatch Company Ltd
NTGMP	National Transmission Grid Master Plan
NVE	Norwegian Water Resources and Energy Directorate
NVVNL	NTPC Vidyut Vyapar Nigam Ltd
NWPGCL	Northwest Power Generation Company Limited
OC	Operation Code
OCC	Operation Co-ordination Committee
OMS	Outage Management System
OPGW	Optical Ground Wire
OSI	Open Systems International, Inc.
PBS	Palli Bidyut Samity

Acronym/ Abbreviations	Meaning
PCGC	Personnel Certification Governance Committee
PDC	Phasor Data Concentrator
PEPCO	Pakistan Electric Power Company
PFR	Primary Frequency Response
PGCB	Power Grid Company of Bangladesh
PGCIL	Power Grid Corporation of India Limited
PLCC	Power Line Carrier Communication
PMU	Phasor Measurement Unit
POSOCO	Power System Operation Corporation Limited
PPP	Public private partnerships
PSMP	Power System Master Plan
PSS	Power System Stabilizers
PSSE	Power System Simulators for Engineers
PTC	Power Trade Corporation
PUCSL	Public Utilities Commission of Sri Lanka
PV	Photovoltaic
PXIL	Power Exchange India Ltd.
QCA	Qualified Coordinating Agency
RAOCM	Relevance of Assets for Outage Management
RAS	Remedial Action Schemes
RE	Renewable energy
RED	Renewable Energy Directorate
RF	Reliability First
RGMO	Restricted governor mode of operation
RIO	Regional Inspectorate Offices
RISC	Reliability Issues Steering Committee
RLDC	Regional Load Despatch Centre
RMEM	Regional Mediterranean Electricity Market
RPC	Regional Power Committee
RPCL	Rural Power Company Limited
RPGCL	Rastriya Prasaran Grid Company Ltd
RRAS	Reserves Regulation Ancillary Services
RSC/RSCSP	Regional Security Coordination Service Provider
RSTC	Reliability and Security Technical Committee
RTM	Real Time Markets
S&TU	SCADA and Telemetry Division
SA	South Asian
SAARC	South Asian Association of Regional Cooperation
SAFER	South Asia Forum of Electricity / Energy Regulators
SAFIR	South Asia Forum for Infrastructure Regulation
SAFSO	South Asian Forum of System Operators
SAFTU	South Asia Forum of Transmission Utilities
SAMAST	Scheduling, Metering, Accounting and Settlement of Transactions
SAPP	Southern African Power Pool
SAR	South Asian Region
SARI/EI	South Asian Regional Initiative for Energy Integration
SARTSO	South Asian Regional Transmission System operator
SASEC	South Asia Sub regional Economic Cooperation
SBP	single buyer plus
SCADA	Supervisory Control & Data Acquisition
SDC	Scheduling and Despatch code
SEB	State Electricity Boards
SETUF	SASEC Electricity Transmission Utility Forum
SLDC	State Load Despatch Centre
SLSEA	Sri Lanka Sustainable Energy Authority
SO	System Operator
SOC	Systems Operation Committee

Acronym/ Abbreviations	Meaning
SoP	Standard Operating Procedure
SPS	System Protection Scheme
SPTL	Special Purpose Transmission Licensee
SR	Southern Region
SREDA	Sustainable and Renewable Energy Development Authority
STATCOM	Static Synchronous Compensator
STELCO	State Electric Company Limited
STU	State Transmission Utilities
SVC	Static VAr compensation
TDD	Total Demand Distortion
THD	Total Harmonic Distortion
TSAIDI	Transmission System Average Interruption Duration Index
TSAIFI	Transmission System Average Interruption Frequency Index
TSEP	Transmission System Expansion Plan
TSO	Transmission Service Operator
TTC	Total Transfer Capability
UCTE	Union for the Coordination of Transmission of Electricity
UFLS	Under Frequency Load Shedding
UfM	Union for the Mediterranean
UI	Unscheduled Interchange
UMPP	Ultra-Mega Power Plants
UPCL	Uttarakhand Power Corporation Limited
URTDSM	Unified Real Time Dynamic State Measurement
USAID	United States Agency for International Development
UVLS	Under-Voltage Load Shedding
VDI	Voltage Deviation Index
VLC	Voluntary Load Curtailment
VRE	Variable Renewable Energy
VSAT	very-small-aperture terminal
VWO	Valve Wide Open
WAMS	Wide Area Management System
WAPDA	Water and Power Development Authority
WAPECA	Water and Power Engineering Consultancy Authority
WECC	Western Electricity Coordinating Council
WG	Working Group
WR	Western region
WZPDCO	West Zone Power Distribution Company Limited

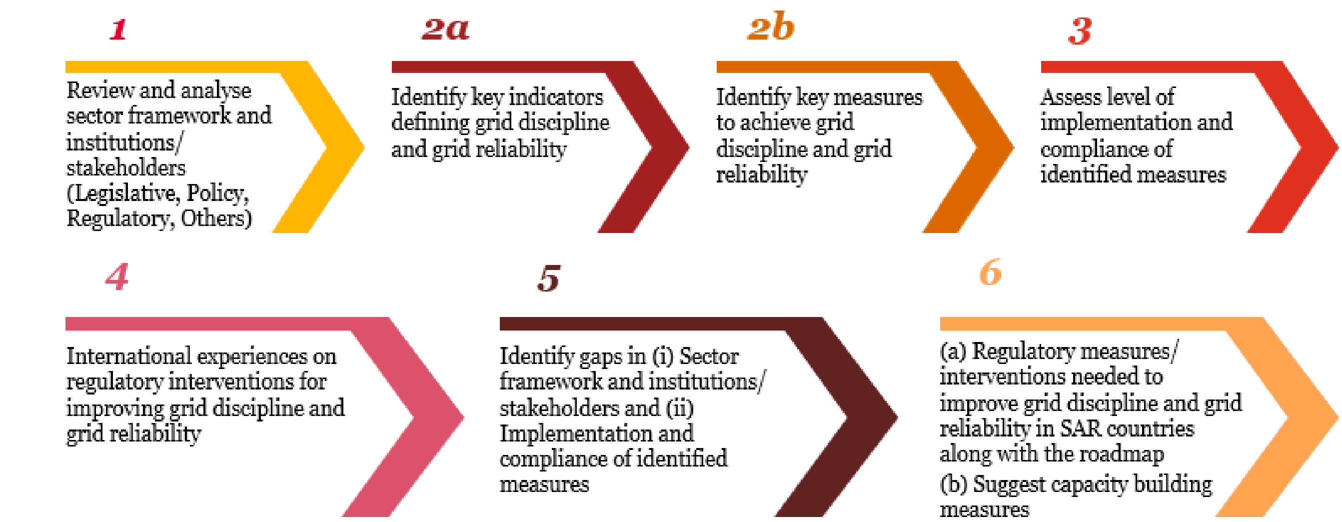
Executive Summary

South Asian Regional Initiative for Energy Integration (SARI/EI) is a long-standing program of United States Agency for International Development (USAID) started in the year 2000. The program covers eight countries of the South Asian Region (SAR), i.e., Afghanistan, Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan, and Sri Lanka. The study on regulatory interventions for grid discipline and grid reliability in the SAR is being conducted by SARI/EI/IRADe for the South Asia Forum for Infrastructure Regulation (SAFIR) Working Group on "Regulatory Cooperation to facilitate knowledge sharing, addressing cross-cutting energy/electricity regulatory issues and capacity building in South Asian countries".

Safe and secure grid operation is the collective responsibility of all players connected to the grid. The issue of **grid discipline** arises when various participants connected to the grid do not adhere to the pre-decided rules. For example, when a generating station over injects or under injects in the grid compared to the pre-decided schedule or when a consumer (such as distribution company) overdraws or under draws from the grid compared to the pre-decided schedule. Therefore, in order to maintain grid discipline, a set of rules prescribing the practices to be followed and accompanied by consequences of non-adherence to the same in the form of penalty / incentive mechanisms are specified. In most of the countries, grid code and/ or specific regulation(s) specifies the set of technical standards, operating philosophy and the commercial mechanisms applicable for grid discipline. **Grid reliability** is typically viewed as the ability of the power system components to deliver electricity to all points of consumption, in the quantity and with the quality demanded by the customer.

Owing to rapid economic growth in the South Asian (SA) region, energy demand is expected to grow at a rapid pace. The growth of renewable energy (RE) sources in particular is poised to grow significantly within the SA region. While India is responsible for most of the RE growth currently in the SA Region, RE is expected to grow substantially in other countries of the Region as well, in the coming decade. The demand will be further heightened by the increase in penetration of Electric Vehicles (EVs) and Cross Border Electricity Trade (CBET). The CBET in SA region has seen manifold increase in past five years and is expected to increase significantly in future. Increasing penetration of renewable, EV etc. present significant challenges in respect of maintaining grid discipline and grid reliability from the perspective of integration/ unification of regional grids of domestic power system of a country as well as cross border power grid interconnection.

The objective of the study is to review and analyse all the existing relevant electricity regulations, mechanisms and technical frameworks with respects to grid discipline and grid reliability of each South Asian Countries, both from the perspective of integration / unification of regional grids of domestic power system of a country, as well as cross-border power grid interconnection, and come up with suggested regulatory measures / intervention needed for ensuring grid discipline and grid reliability in SAR. The following six-step approach is adopted to conduct the study:



Chapter 1 introduces the key concepts of grid discipline and grid reliability and emphasizes on why they matter in the SA region perspective.

Chapter 2 covers an in-depth review of grid discipline and grid reliability aspects for each of the eight SAR countries (covering step 1, 2a and 2b from six-step approach). The review has been conducted across following eight identified parameters namely:

1. System planning,
2. System construction and safety,
3. Grid connection,
4. System protection, testing and commissioning,
5. System operation,
6. Scheduling and despatch,
7. Information and communications technology, and
8. Monitoring and compliance.

Chapter 3 covers country-wise assessment of level of implementation and compliance across the identified parameters (covering step 3 from six-step approach).Chapter 4 covers the international experience and best practices on regulatory interventions for grid discipline and grid reliability (covering step 4 from six-step approach).The chapter presents international case studies from Nord Pool Region, Regional Mediterranean Electricity Market (RMEM) and the North American Region to distill the key lessons learnt and minimum set of regulatory requirement/ ingredients.

In chapter 5, country-wise gaps with respect to the above listed eight parameters are identified (covering step 5 from six-step approach). Chapter 6 covers detailed set of regional and country-wise regulatory measures/ interventions and mechanism needed for enhancing grid discipline and grid reliability (covering first part of step 6 from six-step approach). The country-wise gaps identified in chapter 5 and the international best practices in grid discipline and grid reliability identified in chapter 4 form the basis for suggesting the detailed set of regional and country-wise regulatory measures/ interventions and mechanisms. In order to carry out these country-wise regulatory measures/ interventions, country-wise roadmap consisting of short-term interventions (upto 3 years), medium-term interventions (3 to 6 years) and long-term interventions (beyond 6 years) are specified. Since the regulatory regime in the SAR countries is at different levels of maturity, the regional regulatory measures/ interventions provide broad principles while the country-wise regulatory measures/ interventions and roadmap are more specific to each of the SAR country.

Chapter 7 covers the suggested specific technical capacity building measures (covering last part of step 6 from six-step approach). The chapter lists country-wise suggested specific technical capacity building measures and details of those technical capacity building measures.

1. Chapter 1 – Introduction

1.1. Background

South Asian Regional Initiative for Energy Integration (SARI/EI) is a long-standing program of United States Agency for International Development (USAID) started in the year 2000. The program covers eight countries of the region i.e., Afghanistan, Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan, and Sri Lanka. The program has consistently strived for enhancing energy security of South Asian nations. The SARI/EI program entered its fourth phase in 2012 and is being continued till 2022.The SARI/EI program aims to promote regional energy integration as well as increase cross-border electricity trade in the region. The overall objective of SARI/EI is to create the right "enabling" environment to support the establishment of a South Asian electricity market, and gain consensus and support from the key decision makers and stakeholders. SARI/EI program focuses on three developmental outcomes, i.e., coordination of policy, legal and regulatory framework; advancement of transmission systems interconnection; and establishment of South Asia Regional Electricity Markets. SARI/EI/IRADe is providing the technical knowledge support /assistance to the South Asia Forum for Infrastructure Regulation (SAFIR) Working Group on "Regulatory Cooperation to Facilitate Knowledge sharing, addressing Cross Cutting Energy/Electricity Regulatory Issues and Capacity Building in South Asia" under South Asia Regional Initiative for Energy Integration (SARI/EI) Program being funded by USAID.

The objective of the SAFIR Working Group is to work towards enhancing regulatory cooperation to facilitate knowledge sharing, addressing cross-cutting energy/ electricity regulatory issues and capacity building of stakeholders in South Asian countries, to facilitate transparent regulatory framework, promoting investment in the South Asia Region (SAR). The study on regulatory interventions for grid discipline and grid reliability in the SAR is being conducted by SARI/EI/IRADe for the SAFIR Working Group.

1.2. About grid discipline

Typically, a transmission grid helps transmit electricity from the generating stations to the load Centres. A transmission grid interconnects grid users / participants such as generating stations – conventional and non-conventional (Renewable Energy based), consumers which mainly comprise of distribution companies serving a large mass of consumers and large industries and commercial establishments drawing power from transmission grid for self-use. In such an interconnected transmission grid, certain rules, regulations, guidelines, and standards are required to be defined and followed by various grid users / participants in the power system to plan, develop, maintain, and operate the power system in the most secure, reliable, economic, and efficient manner.

Normally, the transmission grids develop in respective regions with no or limited interconnections between regions. As the grid users / participants in a transmission grid increases and the regional grids start becoming more complex, a need arises to interconnect various regional grids for multiple purposes. The regional interconnections are established to enable transmission of surplus electricity from power surplus region to power deficit region (usually a load Centre), improve grid reliability, minimise grid frequency variation, reduce cost of maintaining reserve capacities, etc. With evolution in technology and to ensure reliability, the regional grids are interconnected to form a sub national and national grid operating at unified frequency. Such interconnections and exchange of power requires a high degree of technical compatibility and operational coordination. For example, when systems are interconnected, even if they are otherwise fully compatible, levels of fault currents (the current that flows during a short circuit) generally increase, requiring the installation of higher capacity circuit breakers to maintain safety and reliability of electrical equipment. The issue of grid discipline arises when various participants connected to the grid do not adhere to the pre-decided rules. For example, when a generating station over injects or under injects in the grid compared to the pre-decided schedule or when a consumer (such as distribution company) overdraws or under draws from the grid compared to the pre-decided schedule, this causes a deviation in the operating frequency from the nominal, depending on the extent of deviation from schedule. Therefore, in order to maintain grid discipline, a set of rules prescribing the practices to be followed and accompanied by consequences of non-adherence to the same in the form of penalty/ incentive mechanisms are specified. In most of the countries, grid code and/ or specific regulation(s) specifies the set of technical standards, operating philosophy, and the commercial mechanisms applicable for grid discipline.

Some of the notable cases of major power outages/blackouts caused due to various reasons in the recent history of the world in decreasing order of population affected are shown below:

Figure 1: Major power outages/ blackouts in recent history

Sr. No.	Countries affected	Date/Year	Population affected (22approx..)[1]	Restoration Time (22approx..)
1	India	31-Jul-2012	700 million	8 hours 30 minutes[2]
2	India	02-Jan-2001	230 million	16-20 hours
3	Bangladesh	01-Nov-2014	150 million	10 hours[3]
4	Pakistan	24-Jan-2015	140 million	8 hours 17 minutes
5	Java/Bali (Indonesia)	18-Aug-2005	120 million	6 hours 30 minutes
6	South Brazil	11-Mar-1999	97 million	5 hours
7	Brazil & Paraguay	10-Nov-2009	67 million	2-4 hours
8	Turkey	14-Apr-2015	70 million	9 hours[4]
9	USA and Canada	4-15-Aug-2003	50 million	2 days
10	Italy	28-Sep-2003	57 million	18 hours

To prevent such outages / blackouts, it is imperative to put in place a robust regulatory framework consisting of institutions with clearly defined roles and responsibilities to maintain grid discipline and grid reliability as well as set of regulations, rules, codes, and standards laid down by the regulatory authorities that enable achieving grid discipline and grid reliability. Further, the framework should also enable and facilitate strict monitoring and compliance of the defined regulations, rules, codes and standards by the utilities and other grid users.

Further, the increase in Cross Border Energy Trade (CBET) presents its own set of challenges to grid discipline. For trading of electricity among countries, a high degree of technical compatibility and operational coordination is required as well. The different sets of rules, standards and commercial mechanisms across the trading countries may hinder CBET and may adversely impact the grid stability. Such interconnections may lead to problems such as voltage collapse, transient instability, cascading tripping, etc.

1.3. About grid reliability

North American Electric Reliability Corporation (NERC) defines[5] reliability of the interconnected bulk power system / transmission grid in terms of two basic and functional aspects as follows:

1. **Adequacy:** The ability of the electric system to supply the aggregate electric power and energy requirements of the electricity consumers at all times while considering scheduled and reasonably expected unscheduled outages of system components.

2. **Operating Reliability:** The ability of the electric system to withstand sudden disturbances, such as electric short circuits or unanticipated loss of system components.

Osborn and Kawann (2001) viewed reliability as "the ability of the power system components to deliver electricity to all points of consumption, in the quantity and with the quality demanded by the customer.[6]

The ISO New England defines Grid Reliability as the ability to supply electricity when the consumer needs it and to withstand disturbances on the system.[7]

The Draft Indian Electricity Grid Code 2020 outlines transmission reliability as the ability to ensure that the interconnected transmission network is secure under a reasonable range of uncertainties in system conditions.

The U.S. Department of Energy has consolidated the standards and regulations for governing grid reliability into four rules.[8] These are as follows:

1. Power generation and transmission capacity must be sufficient to meet peak demand for electricity:

   Power system planner estimates the total peak demand for electricity for each period / season in advance for many years in the future. This is called load/demand forecasting. The generation and transmission capacity of the power system is then designed to meet this peak demand. Since there are uncertainties in forecasting demand and the possibility of generation and transmission outages, the total generation and transmission capacity required shall exceed the expected level of demand by a given fraction known as the reserve margin.

   The transmission grid allows various regions in a country/ state to share resources so that if a generator(s) fails in one region, generators in another region can provide power to the affected area. Transmission can also link regions with non-coincident peak demand for electricity and reduces the need for peaking capacity. Thus, the transmission grid can effectively act as a source of reliable capacity even without adding new generation within a particular area. This is achieved through planning of the system considering (N-1) contingency, i.e., outage of any one element in the transmission corridor. Further, system robustness can be achieved through planning of the system considering (N-2) contingency also referred sometimes as (N-1-1) contingency, i.e., outage of any two elements in the transmission corridor simultaneously. Under such contingencies, system should remain stable and system parameters within the predefined limits.

2. Power system must have adequate flexibility to address variability and uncertainty in demand (load) and generation resources:

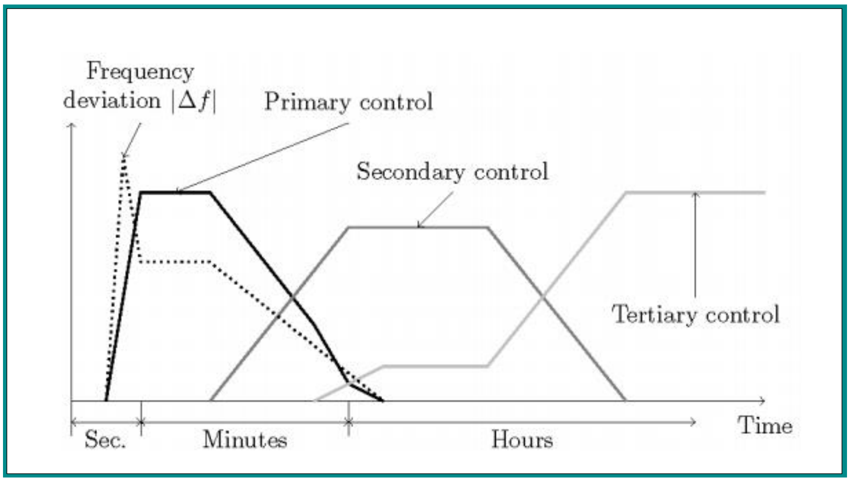
A change in weather such as increase in heat and humidity or change in seasons can send demand soaring in a region. The RE sources of generation such as solar power plants and wind power plants are inherently intermittent and variable in nature due to their dependence on availability of solar irradiation and wind. Transmission grid is subjected to such variability and uncertainty in demand and generation. In order to manage this variability and uncertainty, power systems must have adequate flexibility across value chain. This is mainly achieved through primary and secondary response from supply side. Primary and secondary response are an automatic increase or decrease in generation when the frequency deviates from predefined value. Usually, primary response is delivered within few seconds, while secondary response is delivered within 30 seconds of a low frequency event and maintain delivery for 30 minutes. Normally power generating stations having quick ramping rates such as hydro power stations (including pumped storage plants) and gas power stations are used extensively to address the variability and uncertainty in the power system.

3. Power system must be able to maintain steady frequency:

The power system uses what is called alternating current (AC) where the electricity reverses direction fifty times per second (50 Hz is the frequency in SAR countries.). If this frequency of oscillation were to deviate significantly from 50 Hz, it could damage electrical machines and electronic equipment. Any mismatch between the supply and demand of electricity can cause this sort of deviation, and a number of mechanisms operating on different timescales (a few seconds to few hours) are used to maintain a steady frequency.

In a country/ region usually the transmission grid uses reserve and response services to increase system frequency (Regulation Up services) or decrease system frequency (Regulation Down services). A regulation up service provider will either increase its power export, provide power from a standstill generating source or reduce its grid demand, while a regulation down service provider will do the opposite. Response services provide response within seconds and are automatically triggered by a local frequency reading, whereas reserve services provide response within minutes triggered by receipt of an instruction from Transmission Service Operator (TSO)/ System Operator (SO). Inertial response (inertia of turbine-generator due to large rotating mass) is the immediate response to a power disturbance that causes a frequency change, such as the loss of a large generator or a large loss of load. Inertial response is important because it reduces the rate of change of frequency after a disturbance, which can lead to avoidance of underfrequency load shedding or worse issues, including blackouts. Primary frequency response (also called frequency responsive reserve and governor droop service) follows inertial response. It is the action by turbine governor controls, to change output to balance generation, load and ensure system frequency returns to a stable level following a disturbance. Secondary frequency response is used to help continuously balance the system, maintain a constant frequency, and eliminate area control error[1].

Figure 2: Frequency control mechanism in transmission grid[9]



4. <u>Power system must be able to maintain steady voltage at various points on the grid:</u>

   In addition to maintaining a steady frequency, the electric grid must also deliver electricity at a rated voltage. This voltage varies throughout the power grid with transformers used to change voltages. Voltage fluctuations and unbalance affects the power quality of the system and may result in malfunction or damage to electrical devices. Correct voltage can be maintained by use of Automatic Voltage Regulators at the generating units, management of reactive power through capacitors / SVC / STATCOM, etc.

Thus, power systems are planned and operated in such a way that a credible disturbance, event, equipment failure, or other contingency do not cause operation of any element of the system outside specified voltage and frequency limits. It also ensures that the generation or transmission equipment operates within normal limits. The participants in the grid follow rules and principles to ensure reliability for planning and operating the interconnections. These rules and principles form the basis for reliability standards.

[1]Area control error is the difference between scheduled and actual electrical generation within a control area on the power grid, taking frequency bias into account.

1.4. Why Grid discipline and Grid reliability matter?

The economic impact of sustained outages is well documented. Various studies and academic research around the world have tried to estimate the impact of these outages to a nation's economy. Some of them are highlighted below:

- A study[10] by PwC India, Shakti Sustainable Energy Foundation and Federation of Indian Chambers of Commerce & Industry (FICCI) for six Indian states across five consumer categories tried to test the hypothesis that – the economic impact inflicted upon consumers due to unreliable supply of electricity is far greater than the perceived benefits of load shedding to the governments and electric utilities. The key findings of the report were as follows:
  - The loss to the consumer due to unavailability of power is much higher than the perceived financial benefit to the utility due to power outage i.e. an average of about 3-4 times higher across evaluated states.
  - In the same sample, a portion of consumers are willing to pay more (average of 7%-9% higher relative to nationwide average) for uninterrupted power from the utility.
- A 2015 study[11] by Jamia Millia Islamia, Delhi estimated that the total annual impact of outages in 2014 on Indian GDP was approximately INR 4,324.11 billion (~4.8% of India's GDP in 2014).
- A study [12]published in 2016 simulated the blackout of September 28, 2003 in Italy (3-16 hours depending on the region) and estimated the economic impact of the outage for 266 European regions and nine economic sectors. The single blackout was estimated to have resulted in losses of EUR 1182.4 million or 0.083% of Italy's GDP in 2003 with Service sector accounting for ~31% of the loss.
- Another study[13] published in 2015 which studied the macroeconomic effects of outages on Hungarian economy concluded the following:
  - In one of the base case scenarios (no price discrimination in the market for energy), it was estimated that a 2.08% decrease in the supply of energy leads to 0.53% decrease in GDP and 0.84% decrease in consumption.
  - In scenarios with higher price discrimination (households and government pay a different price for energy than firms do), it was estimated that a 2.08% decrease in the supply of energy leads to 0.86% decrease in GDP and 0.38% decrease in consumption.

The studies above provide a broad picture of the tremendous impact outages have on an economy. Sustained outages virtually bring economic activities in the affected regions to a halt. Assuming agriculture as the only sector that is relatively unaffected by an outage, we can estimate the approximate economic value impacted in a day to get a general sense of the scale involved. Further, as per the 2015 study by Jamia Millia Islamia cited above, we can assume that as a thumb rule, the SAR countries incur a loss of around 5% of their respective GDPs as a conservative estimate. Accordingly, in the event there is

24-hour outage, the estimates for approximate value of economic activity impacted and estimates for approximate annual loss of economic value from an outage are as follows:

Table 1: Estimates of value of economic activity impacted and loss of economic value from an outage from 24-hour outage (in million USD)

Country	Annual GDP*	Approx. value of GDP impacted from a 24-hr. outage	Approx. annual value of GDP loss from outages (5% of GDP)
Afghanistan	19101	41.27	955.05
Bangladesh	302571	723.85	15128.55
Bhutan	2447	5.64	122.35
India	2875142	6619.52	143757.10
Maldives	5729	14.82	286.45
Nepal	30641	63.59	1532.05
Pakistan	278222	594.24	13911.10
Sri Lanka	84009	213.09	4200.45

**GDP data as per 2019 World Bank Estimates*

It is immediately apparent from the estimates presented above of the mostly avoidable harm inflicted by outages on the economy.

In the recent past, the South Asian region countries have experienced crippling grid outages. The list is indicative.

Table 2: Indicative list of recent outages in SAR

Country	Details of date and duration of outage	Reasons for outage/root case of outage
India[14]	30th July 2012 - 02:33 hrs. to16:00 hrs. (approximate duration of 13.5 hrs.) 31st July 2012 - 13:00 hrs. to 21:30 hrs. (approximate duration of 8.5 hrs.)	1. The load generation scenario in the synchronous Northeast-East-West-North (NEW) grid was highly skewed in the month of July. 2. Grid indiscipline in the form of under drawal/ over injection and over drawal was a major cause for both the grid disturbances. 3. Reliability margins were depleted. 4. In both the grid disturbances, failure of defence mechanisms/safety net in the form of load shedding schemes through Under Frequency Relays, Rate of change of frequency relays and islanding schemes in the Northern and Eastern Region were observed.

Country	Details of date and duration of outage	Reasons for outage/root case of outage
		5. Absence of the primary response from the generators was evident in both the grid disturbances. 6. Visualization and situational awareness at the Load Despatch Centres in the antecedent condition as well as during restoration was severely constrained owing to non-availability of real time data at the Load Despatch Centres from a large number of locations. 7. Inadequate appreciation of Transfer Capability vis-a-vis transmission capacity, 8. Inadequate dynamic reactive reserves. 9. The prevalent provisions in the regulations for (Grant of Connectivity, Long-term Access and Medium-term Open Access in inter-State Transmission and related matters) permitted connectivity to the grid even without identification of beneficiaries at the time of application resulting in unforeseen power flows across the synchronous grid. 10. Excessive reliance on unscheduled interchange: Some utilities prefer to draw power from the grid in the form of Unscheduled Interchange rather than availing power from organized market through long-term, medium-term, and short-term contracts without much consideration to the grid security. 11. The stipulated range of Grid Frequency was not narrow enough to enforce grid discipline. Ministry of Power published a report of the enquiry committee on these grid disturbances. The reasons for outage/ root cause stated in the report are as under: 1. Weak Inter-regional Corridors due to multiple outages: The system was weakened by multiple outages of transmission lines in the WR-NR interface. Effectively, 400 kV Bina-Gwalior-Agra (one circuit) was the only

Country	Details of date and duration of outage	Reasons for outage/root case of outage
		main AC circuit available between WR-NR interface prior to the grid disturbance. 2. High Loading on 400 kV Bina-Gwalior-Agra link: The over drawal by some of the NR utilities, utilizing Unscheduled Interchange (UI), contributed to high loading on this tie line. 3. Inadequate response by SLDCs to the instructions of RLDCs to reduce over drawal by the NR utilities and under drawal /excess generation by the WR utilities. 4. Loss of 400 kV Bina-Gwalior link: Since the interregional interface was very weak, tripping of 400 kV Bina-Gwalior line on zone-3 protection of distance relay caused the NR system to separate from the WR. This happened due to load encroachment (high loading of line resulting in high line current and low bus voltage). However, there was no fault observed in the system.[15]
Pakistan[16]	12th December 2014 - at 12:50 hrs. (duration of 7 hrs. and 44 minutes)	Faults occurred around 11 am at Tarbela powerhouse, which affected 500 KV transmission lines. Power production from Ghazi Barotha was also disrupted, causing the Northern Transmission line to trip. The tripping of the main transmission line also resulted in the breakdown of supply from other power plants. Technical fault in Tarbela was triggered because of production being unable to match levels of demand. As per WAPDA the power outage might be an issue of low frequency by NPCC which resulted in a technical failure at various power stations.
Sri Lanka[17]	27th September 2015 - 23:57 hrs. to (not mentioned) (duration more than 4 hrs.)	1. The system steady state voltages on many 220 kV and 132 kV buses were above 105% (1.05pu). Allowing 110% voltage at steady state led to bringing system devices dangerously close to their overvoltage protection limits. 2. There were no 'must run units' for voltage support.

Country	Details of date and duration of outage	Reasons for outage/root case of outage
		3. Devices such as 'Shunt reactors' for controlling steady state voltages and aiding in improving the system dynamic response were not installed.
Bangladesh[18]	1st November 2014 - 11:30 hrs. to 1:00 hrs. on 2nd November 2014 (approximate duration of 25.5 hrs.)	The tripping of the 400 kV transmission line at Bheramara amounted to a loss of about 445 MW of power imported from India. As the national grid lost about 445 MW of power, an uncontrolled chain reaction set in. All the power plants of the country were forced to shut down.

As outages tend to be worse in rural areas, they exacerbate the already existing inequities and poverty in the society. The consequences of inadequate grid discipline and reliability however goes beyond the cost of outages. Frequency and voltage fluctuations in the grid are routinely linked to equipment damage among households and industries in addition to higher losses and shortening of useful life of machines and equipment. Variations in frequency causes fluctuations in the speed of motors which impacts quality of products. Unreliable supply of electricity is also linked to health and safety risks which are harder to measure. This is especially true in regions with extreme weather and temperature conditions. All developing economies need to have reliable and quality power supply as a basic requirement if they expect their economies to grow at a steady pace.

1.5. Regulatory measures/ interventions in grid discipline and grid reliability

In order to explain what constitutes regulatory measures/ interventions for improving grid discipline and grid reliability following case study from India is used to elaborate the point.

In 2012 India encountered major grid disturbances on 30 and 31 July 2012 which affected large parts of the Indian electricity grids. Post this major grid disturbance, the central regulator, viz., Central Electricity Regulatory Commission initiated slew of measures to strengthen grid discipline and grid reliability in Indian power grid. In this case study, we are covering regulatory measures/ interventions in following areas:

1. Regulatory measures to tighten the stipulated range of operational grid frequency,
2. Regulatory measures to maintain steady state voltage in the grid,
3. Regulatory measures to strengthen system protection,
4. Regulatory measures to manage outages,
5. Regulatory measures to strengthen cyber security, and
6. Regulatory measures for reducing variability through accurate forecasting of generation from RE sources.

1.5.1. Regulatory measures to tighten the stipulated range of operational grid frequency

Power grid uses alternating current, meaning that the flow of electricity in a power line switches direction rapidly. This change in direction is measured by its frequency, the number of times per second the current changes direction. The frequency is determined by how fast the electrical generator is spinning. All conventional power generators stations including fossil fuel based thermal, nuclear, and hydroelectric generators are “synchronous” generators, meaning they are all “synchronized” with each other.

Frequency also reflects the load generation balance in the grid at a particular instant. The grid frequency needs to be maintained at level so that the system is able to bear the impact of such large but credible contingencies, even if it is with the help of suitable protection schemes such as load shedding schemes initiated by Under frequency, Rate of Change of frequency and Under Voltage.

If the frequency changes significantly (increase/ decrease), machines and electronics may get damaged. If the frequency drops / rises beyond the limits, electrical machines (generators, motors, etc.) may get damaged leading to supply interruption. With such power supply interruption, the system will automatically try to redistribute the power flows on the network which may result in to tripping of other elements (such as power transformers, lines) due to overloading or overvoltage or undervoltage. If this chain reaction continues, it may cause cascade tripping of multiple elements resulting in partial / full blackout of the grid.. These events can be as short as a few seconds or minutes due to unexpected changes in load or generation, or as long as days or weeks in the event that a transmission line or power plant failure. Power sector (generation/ transmission/ distribution) bring capital intensive sector and mostly driven by government stakeholders result in loss of public money. Electricity being an essential commodity for economic activity, hence power failure may result into economic loss for the nation.

Regulatory Measures/ Interventions undertaken by CERC:

- CERC has been progressively narrowing the normal operational grid frequency range in Indian electricity grid code. The normal operational grid frequency range was 49.0 Hz. to 50.5 Hz. till 31st March 2009as shown in the chart below. CERC tightened it further to 49.2 Hz. to 50.3 Hz from 1st April 2009 onwards. In January 2014, CERC tightened it further to 49.90 Hz. to 50.05 Hz. This narrowing of operating grid frequency has cascaded impact on other regulation like operating procedure of RLDCs/SLDCs, Deviation Settlement Mechanism regulations, relay settings for under frequency cut-off and power system equipment manufacturing standards. CERC is further trying to tighten the nominal frequency band from current practice of 49.90- 50.05 Hz to 49.95-50.05 Hz band in line with practices adopted in large power systems of the world through the ongoing ‘Expert Group Report: Review of IEGC, January 2020’[19].

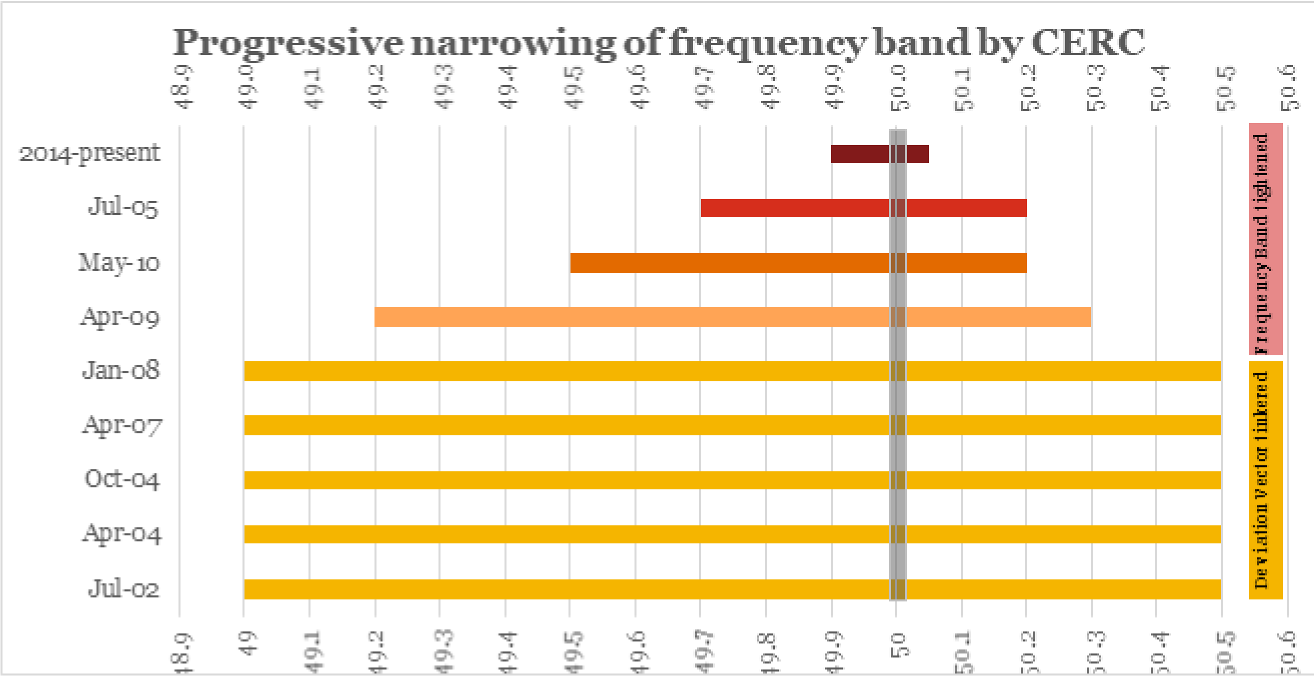


Figure3: Chart depicting progressive measures taken by CERC to narrow the normative grid frequency band

- CERC introduced Availability Based Tariff(ABT) in the year 2000, a three-part tariff mechanism. It consists of fixed charge, variable charge, and *Unscheduled Interchange of power (UI charges).* The quantum of deviation from schedule is known as Unscheduled Interchange (UI). That is settled at the pre-defined rate i.e., Unscheduled Interchange rate (UI vector). The UI vector at a certain point of time is dependent on the average frequency of the time block (1 time-block is of 15 mins.). Thus, the UI vector is linked to the frequency. The UI charges are payable/receivable depending upon who has deviated from the schedule and also subject to the grid conditions at that point of time. This is the element, which is expected to bring about discipline in the system.
- Indian electricity has provisions for under frequency automatic load shedding to arrest frequency decline that could result in a collapse/disintegration of the grid. RPCs are the nodal agencies to finalize such plans and to monitor their implementation. Also, SLDCs are impowered to plan demand management measures like load shedding, power cuts, etc. and shall ensure that the same is implemented by the SEB/distribution licensees.
- Introduction of Central Electricity Regulatory Commission (Deviation Settlement Mechanism and related matters) Regulations, 2014 and its amendment thereafter. A passive commercial penalty-based mechanism, under which UI vector (unscheduled interchange rate) was linked to average grid frequency of the time-block (1 time-block is of 15 mins.) and charges for deviation to be paid by buyer/ seller (injecting entity or drawal entity) based on average frequency of the time-block at dynamic UI vector (earlier static) i.e., rates are linked to day ahead regional market clearing price of the power exchange.
- Earlier CERC (Unscheduled Interchange) Regulations, 2009 mandated NLDC to provide ancillary services. Ancillary services are those functions performed by the equipment and people that generate, control, transmit, and distribute electricity to support the basic services of generating

capacity, energy supply, and power delivery. Later CERC introduced Ancillary Services Operations Regulation, 2015 to restore the frequency at desired level and to relieve the congestion in the transmission network.

- Central Electricity Regulatory Commission (Communication System for inter-State transmission of electricity) Regulations, 2017 provides that Communication infrastructure shall be planned, designed, and executed to address the network security needs as per standard specified by CEA and shall be in conformity with the Cyber Security Policy of the Govt. of India, issued from time to time. NLDC, shall monitor case of cyber security incidences and discuss them at RPC level and take necessary action as deemed fit. RPC shall ensure that third party cyber security audits shall be conducted periodically (period to be decided at RPC) and appropriate measures shall be implemented to comply with the findings of the audits. The audits shall be conducted by CERT-In certified third-party auditors.

Impact of initiatives introduced for improving grid frequency:

The below graphs represent all India regional average of *percentage of deviation from schedule*. The country has been able to reduce its average deviation from schedule quantum from 2.3% to 0.7%. This reduction of more than 70% over a period from FY 15 to FY 20 is a result of regulatory interventions and monitoring by CERC for compliance.

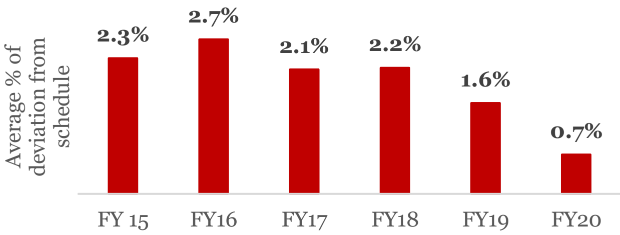


Figure 4: Average percentage of deviation from schedule for Indian grid (Source: Operational Performance Report published by POSOCO on monthly basis)

The key system performance indicators like percentage of time grid frequency remained in normal operating range and frequency deviation index also improved as a result of regulatory interventions.

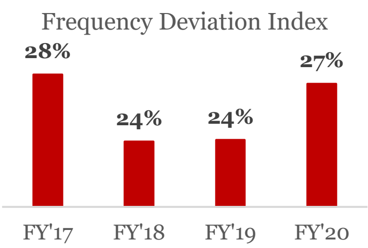


Figure 5:Percentage of time national grid frequency was in normal range (Source: Operational Performance Report published by POSOCO on monthly basis)

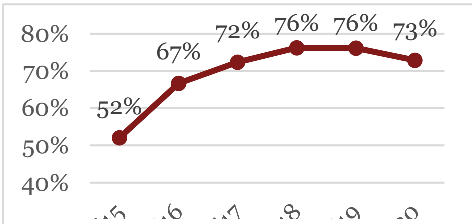


Figure 6: Frequency deviation index for Indian grid (Source: Operational Performance Report published by POSOCO on monthly basis)

During 2014-15, 52% of time the grid frequency remained in normal operating range and it was improved to 76% during 2018-19 and during 2019-20 it was 73%. In the same manner frequency deviation index has also dropped from 28% during 2017-18 to 24% 2018-19 and in last financial year it was at 27%.

1.5.2. Regulatory measures to maintain steady state voltage in the grid

Ensuring power system reliability requires maintaining voltage within a specified limit, because the voltage is not constant at every location (e.g., generator power evacuation 220/400 kV, transmission could be between 132 to 765 kV and distribution is between 220 v to 66 kV). In a sense, voltage in the electrical system is analogous to “pressure” in a fluid system, and each part of the grid is designed to work at a specific voltage level. Voltage that is too high or too low can result in malfunction or damage to electrical devices.

It is recommended to transmit electricity at higher voltage because higher voltage results in lower losses allowing energy to be efficiently transmitted over long distances. Voltage fluctuation/ variation beyond limit set by the Original Equipment Manufacturer or limit set by the technical organization (such as 3% as prescribed by Central Electricity Authority of India) is likely to cause damage to the insulation of the transformers and rotating machines. It can even generate spark/ flash over between phase and ground at the weakest point in the network, which may result in a blackout (partial/complete).

One of the importance parameters to maintain voltage level in operating range is managing the reactive power. It is essential for functioning of various electrical systems such as transmission lines, motors, transformer, etc. It is essential for operating electromagnetic energy devices for producing the magnetic field. In some cases, it is forcefully injected into the power system network to maintain higher voltage. Reactive Power is one of the total power components in an AC circuit that has its origin in the phase shift between a sinusoidal voltage and current waveforms. It is a consequence or by-product of an AC system that travel back and forth in the power conductor, i.e., flowing to reactive components from a source during one half cycle and back to the source during another half cycle of an AC waveform. When lines operate beyond surge impedance loading, reactive power is consumed by the line and voltage drops. High MW flow coupled with low MVAR leads to low voltage and high current. This may cause load encroachment in the relays, i.e., normal load may be seen as fault and tripping of lines would be a surprise in real-time operation. During 2012 blackout in India, one of the key reasons was skewed load generation balance among the regions due to planned outage, forced outage and transmission lines opened to control high voltages in the system. On both the occasions, i.e., on 30 and 31 July 2012, there was high loading on WR-NR corridor, especially on 400 kV Bina-Gwalior line, which was carrying power more than SIL (Surge Impedance Loading) limit and this led to low voltages at the Gwalior end in the event of high line loading.

Regulatory Measures/ Interventions undertaken by CERC:

- Indian electricity grid code specifies the minimum design and technical criteria for grid connection and specifies the voltage variation limits as +/- 5% for 765 kV & 400 kV and +/- 8% to 11% for 220 kV & 132 kV.
- Indian electricity grid code has provision for commercial compensation for consumption of reactive power (clause 6.6 Reactive Power and Voltage Control). It also empowers RLDCs to instruct generation/ consumption of reactive power. Reactive power management is essential for taking care of contingencies like fault, high line loading and large load throw-off. Therefore, RPCs/LDCs manages dynamic reactive reserve requirement at strategic locations in the grid.
- Central Electricity Authority (Technical Standards for Connectivity to the Grid) (Amendment) Regulations, 2019 mandated distribution licensee and bulk consumer shall provide adequate reactive compensation to compensate reactive power requirement in their system so that they do not depend upon the grid for reactive power support. It also mandates that that during the voltage dip, the supply of reactive power has first priority, while the supply of active power has second priority.

Impact of initiatives introduced for improving grid voltage:

One of the key system performance indicators is voltage deviation index which is known as percentage of time the voltage remained out of the normative range. It is computed as ratio of number of hours the voltage at all substations of specific voltage level were out of normative range during a day or week or month and number of hours in a day or week or month.

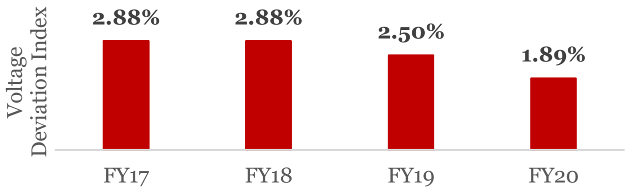


Figure 7: Voltage deviation index - Indian Grid (Source: Operational Performance Report published by POSOCO on monthly basis)

India has taken steps relentlessly after 2012 incident to improve power system operations. It is observed that it has improved the voltage deviation index quite considerably from 4.27% during 2016-17 to 1.89% during 2019-20.

1.5.3. Regulatory measures to strengthen system protection

Protection system failures can lead to a more severe system response as a result of longer fault clearing and more electric system elements being removed from service to clear the fault. Objective of protection system is to detach faulty section from the system to make rest of the portion work without any disturbance. In addition to this, it is used to prevent the flow of faulty current. It can help in preventing the continuation of flow by quickly disconnecting the short circuit. Under stressed network conditions, proper behaviour of protective systems installed on transmission lines and generating units are vital. However, in actual practice there are instances where settings of relays are corrected/changed with change in the fast-expanding network. Therefore, ensuring system protection thorough audit of protective systems and encompassing all related areas is required.

Regulatory Measures/ Interventions undertaken by CERC:

- Indian electricity grid code has empowered RPCs (clause 2.4 Role of RPCs) with a mandate to undertake protection studies for stable operations. RPCs also carry out periodic inspection of the protection system like under frequency relays.
- Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulation, 2007 define steps to be taken for implementation of protection systems for angular instability, voltage instability, under frequency load shedding and protection of bus bar & breaker.
- Central Electricity Authority (Grid Standards) Regulations, 2010 lays down methods for condition-based monitoring of equipment's which includes steady state and dynamic testing of protective relays.

Impact of initiatives introduced for improving grid frequency:

From the adjacent graph it is clear that steps taken by India have resulted in lowering of GD-1 (Grid Disturbance of category 1) and GI-1 (Grid Incidences of category 1) interruption duration. In 2014-15 GD-1 interruptions duration was 470 hrs. which reduced to 332 hrs. in 2018-19 and are presently at 427 hrs. in 2019-20. Similar GI-1 interruptions duration was 682 hrs. during 2014-15 which are reduced to 368 hrs. during 2019-20.

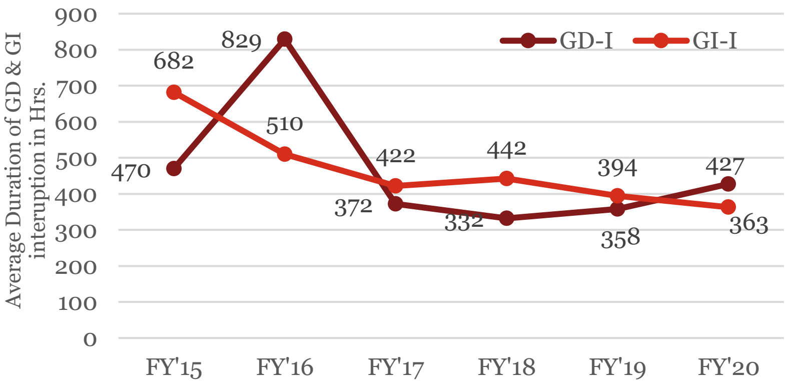


Figure 8: No. of Grid Disturbances (GD) and Grid Incidences (GI) of category 1 over the years (Source: Operational Performance Report published by POSOCO on monthly basis)

1.5.4. Regulatory measures to manage outages

Outages are known for high levels of risk, with a large potential for cost overruns. Improper planning of outages could result in declining power system performance, increase unplanned shutdowns, unavailability of space for work schedule for planned outages, risk of asset damage and reduction of asset life. An effective outage planning results in reduced outage durations and improves reliability of the system.

During 2012 incident inter-regional links between the Western and Northern Region were constrained due to forced/planned outage of certain transmission elements. Hydro generating station were also under forced outage due to presence of high silt level that could damage the turbine.

Regulatory Measures/ Interventions undertaken by CERC:

- Indian electricity grid code mandates preparation of annual outage plan by the RPCs Secretariat in consultation with NLDC and RLDCs and annual outage plan shall be reviewed by RPC Secretariat on quarterly and monthly basis in coordination with all parties concerned, and adjustments made wherever found to be necessary.
- Implementation of IT tools for outage management and coordination by RLDCs/SLDCs. Outage Management System (OMS) identifies outages and provides instant alerts. It also records the history of outages throughout the operations and provides real-time insight into the systems. OMS systems also provide customer assistance by alerting them about outages and status of repairs. OMS systems usually work in tandem with geographical information systems, CIS, or customer information systems.

Impact of initiatives introduced for improving grid frequency:

From the adjacent graph it is clear that, N-1 criterion violation have reduced over the years. During FY16-17 duration of violation were at 52 hrs. which reduced to 38 hrs. by FY 19-20. The reasons for this can be ascribed not only to better management of transmission assets and coordinated outage planning at regional and national levels but, also to the regulatory measures undertaken by CERC.

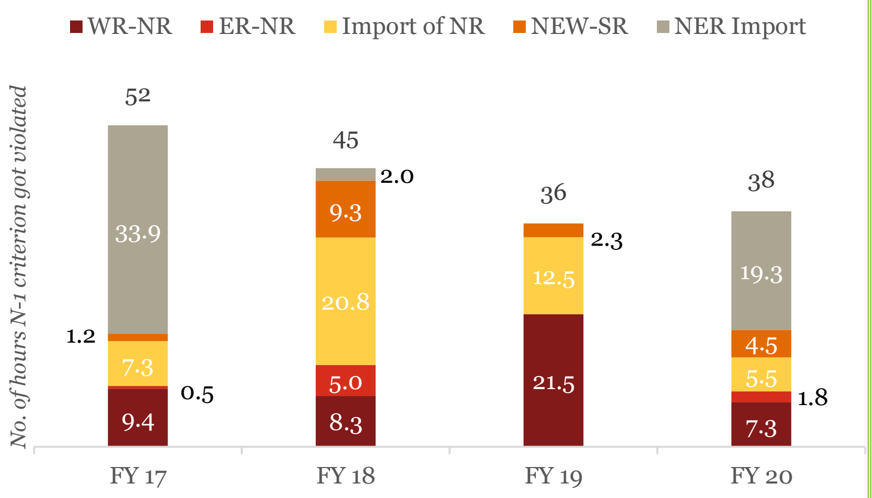


Figure 9: No. of hours of violation of N-1 criteria in Indian grid (Source: Operational Performance Report published by POSOCO on monthly basis)

1.5.5. Regulatory measures to strengthen cyber security

The power system is getting smarter each passing day this poses critical challenges, especially related to evolving cyber security threats. Cyber Security is definitely a key component of an Operator's Smart Grid deployment and of its Service Reliability strategy. The development of a Cyber Security program for the Smart Grid should not be an afterthought; it should be an integral part of the planning and design process involved with the deployment of Smart Grid initiatives. The Cyber Security program should also ensure that legacy systems receive the protection they require. A properly planned Cyber Security strategy will result in a highly secure environment that still delivers the operational flexibility and efficiency so crucial to the successful implementation of new Operational systems.

Regulatory Measures/ Interventions undertaken by CERC:

- Central Electricity Authority (Technical Standards for Connectivity to the Grid) (Amendment) Regulations, 2019 mandates for compliance of cyber security guidelines issued by the Central Government, from time to time, and the technical standards for communication system in Power Sector laid down by the Authority.
- Draft Indian electricity grid code, 2020 has introduces code for Cyber Security has been added. It provides for identification of Critical Information Infrastructure, appointment of Information Security Officer as per the Information Technology Rules 2018 and take necessary measures in accordance with guidelines by National Critical Information Infrastructure Protection Centre.
- Central Electricity Authority (Technical Standards for Communication System in Power System Operations) Regulations, 2020 mandates for compliance of the Information Technology Act, 2000 (21 of 2000) and National Cyber Security Policy, 2013 as amended from time to time. It also gives directives to the compliance of National Critical Information Infrastructure Protection Centre (NCIIPC) and Computer Emergency Response Team (CERT India) Guidelines. It also laid down

"MD5 Authentication, 3.SNMPv3, Radius/TACS+" a cyber security standard for interfacing to communication systems.

1.5.6. Regulatory measures for reducing variability through accurate forecasting of generation from RE sources

RE forecasting is critical for reducing the uncertainty associated with variable renewable energy (RE) generation. To develop wind and solar generation forecasts, system operators utilize a combination of weather observations, satellite data, numerical weather prediction models, and statistical analysis to inform estimates of the level and location of generation in the near future. Centralized forecasting coordinated by a system operator provides several benefits in comparison to relying exclusively on forecasts provided by individual generators. Namely, by aggregating uncertainty across all generators in a balancing area, centralized forecasting smooths forecasting errors, which in turn provides more accurate information at the system level where the information is needed to monitor current conditions and schedule future generation. This helps to reduce system level risk and thus improve reliability.

Regulatory Measures/ Interventions undertaken by CERC:

- Central Electricity Regulatory Commission (Indian Electricity Grid Code) (Third Amendment) Regulations, 2015 made relevant provisions for scheduling and dispatch of interstate renewable generating stations, RPCs empowered to prepare energy account for these renewable generating stations and provision for forecasting by RLDCs.
- Central Electricity Regulatory Commission (Deviation Settlement Mechanism and related matters) (Second Amendment) Regulations, 2015 introduced commercial penalty for deviation from schedule.
- Approved procedure by CERC for implementation of the framework on forecasting, scheduling, and imbalance handling for renewable energy (RE) generating stations Including power parks based on wind and solar at inter-state level.
- To enable forecasting and scheduling of renewable resources and efficient management of intermittent & variable renewable generation, 11 Nos. of Renewable Energy Management Centers[20] (REMC) co-located with 7 State Load Dispatch Centers (Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra, Madhya Pradesh, Gujarat & Rajasthan), 3 Regional Load Dispatch Centers (Bengaluru, Mumbai & New Delhi) and NLDC, New Delhi have been established. REMC in Telangana and an Energy Management Centre in South Andaman are under implementation.

1.6. The RE integration and CBET perspective

The World Bank reports that between 2013 and 2016, economic growth in South Asian countries increased from 6.2% to 7.5% while the economic growth rates of other developing nations remained flat or even went negative. South Asian countries are expected to continue a strong growth trajectory up to 6.7% in 2021. Owing to this rapid economic growth in the SAR, energy demand is expected to grow at a rapid pace. The International Energy Agency reports that the energy demand in South Asia will increase to double the global average demand in the next few decades.[21] The capacity of renewable energy (RE) sources in particular is poised to grow significantly within the SAR driving the global agenda of enhancing clean energy in the energy portfolio to minimise the carbon emissions.

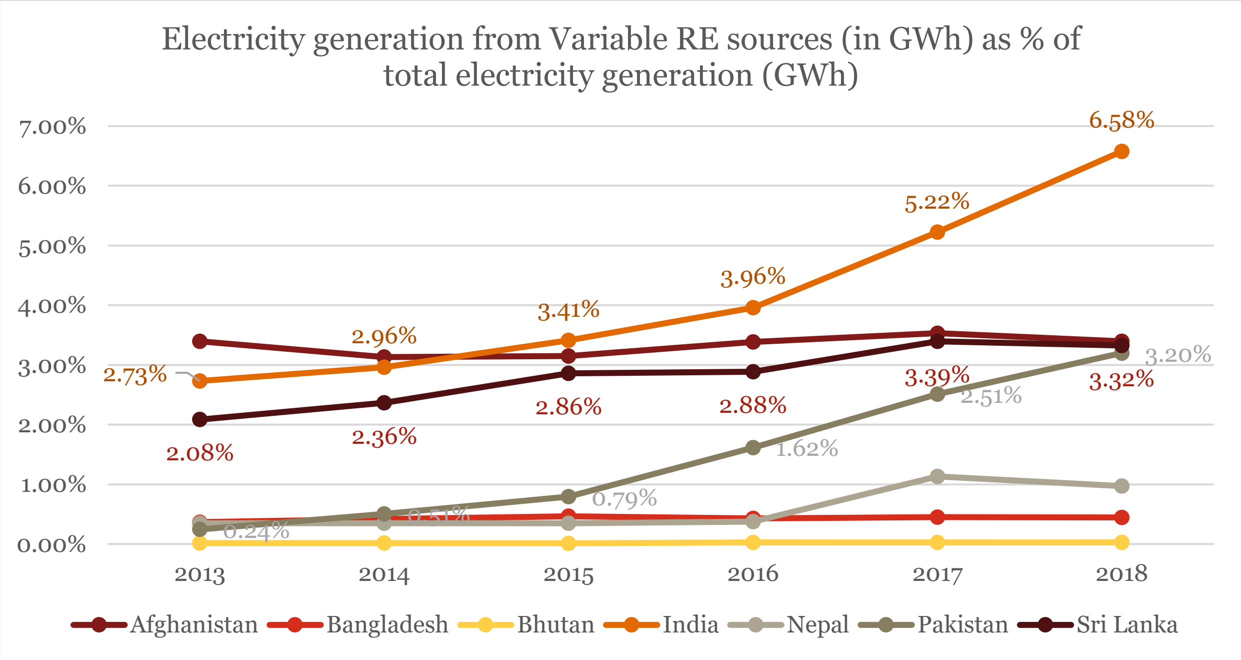


Figure 10: Electricity generation from variable RE sources (solar and wind) as %of total electricity generation (GWh)[22]

Table 3: Total electricity generation in GWh[23]

Year	Afghan istan	Bangladesh	Bhutan	India	Nepal	Pakistan	Sri Lana
2013	883	36,482	6,728	964,000	4,258	96,496	11,898
2014	1022	40,296	7,078	1,024,000	4,687	104,089	12,357
2015	1049	43,737	7,653	1,110,000	5,007	114,093#	13,090
2016	1034	52,193	7,865	1,173,000	5,077	120,622#	14,148
2017	1076	57,276	7,630	1,260,000	6,258	133,593#	14,671
2018	NA*	62,925*	7,980	1,309,000	7,058	137,019#	15,374

*Projected, (Maldives has not been considered in above graph and table as values are not comparable in GWh)

The key challenges in maintaining grid discipline and grid reliability due to variable RE integration (excluding hydro) in the SAR countries are:

1. High projected growth in RE generation as shown in the figures above.

2. Intermittent and variable nature of the wind and solar sources may lead to the need for increase in backup to address the variability,

3. Low or zero inertial frequency response of RE sources (excluding hydro).

4. Significant localized growth in Photovoltaic (PV) solar power can raise concerns such as voltage violations and reverse power flow in low-voltage distribution systems; and

5. Limited or no reactive power support during system faults.

The electricity demand will be further heightened by increase in penetration of Electric Vehicles (EVs) and Cross-border Electricity Trade (CBET). Electricity supply and demand patterns in some South Asian nations are complementary, especially at the sub-regional level. For example, wet seasons in Bhutan and Nepal, which produce hydropower, coincide with summer peak demand in India and Bangladesh, creating power export opportunities. Dry seasons in Nepal coincides with lower demand in India, offering an opportunity for Nepal to import power from India.[24]

The CBET in SAR has seen manifold increase in the last two decades and is expected to increase further in future.

Figure 11: Electricity Imports from other countries (billion kWh)[25]

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Afghanistan	1.57	2.25	3.07	3.62	3.71	3.78	4.4	4.61	NA*	NA*
Bangladesh			Nil			3.81	4.65	4.78	6.78	NA*
Bhutan	0.13	0.04	0.06	0.11	0.19	0.16	0.11	0.21	NA*	NA*
India	5.61	5.25	4.79	5.6	5.01	5.24	5.62	5.61	5.2	6.17
Maldives					Nil					
Nepal	0.69	0.75	0.79	1.32	1.37	1.78	2.18	2.58	2.81*	1.72
Pakistan	0.27	0.27	0.38	0.42	0.44	0.46	0.5	0.56	NA*	NA*
Sri Lanka					Nil					

**NA- Data not available in Public Domain*

Figure 12: Electricity Exports to other countries (billion kWh)[26]

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Afghanistan						Nil				
Bangladesh						Nil				
Bhutan	5.58	5.27	4.9	5.56	5.04	5.54	5.78	5.07	NA*	-

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
India	0.06	0.14	0.15	1.65	4.43	5.15	6.71	7.2	7.7	8.01
Maldives	Nil									
Nepal	0.075	0.029	0.004	0.003	0.003	0.003	0.003	0.003	0.035	0.107
Pakistan	Nil									
Sri Lanka	Nil									

**NA- Data not available in Public Domain*

The key challenges in maintaining grid discipline and grid reliability due to increasing CBET in the SAR countries are:

1. Different sets of regulations and technical standards (i.e., lack of harmonization) across countries involved in CBET.
2. Lack of adequate commercial mechanisms (incentive / penalty) for deviating from norms; and
3. The regulatory framework including regulatory institutions and regulatory statue are at different stage of maturity in each of the SAR countries. This poses varied levels of challenges for enforcement of grid discipline and grid reliability in interconnected grids.

Despite the numerous challenges involved in maintaining grid discipline and grid reliability, they can be mitigated and / or managed through evidence-based planning and supporting policy and regulatory framework. Under evidence-based planning Transmission Utility shall provide evidence that it has an Operating Plan to address potential System Operating Limits (SOLs), SOLs are identified as a result of the Operational Planning Analysis. Such evidence could include but, it is not limited to plans for precluding operating in excess of each SOL that was identified as a result of the Operational Planning Analysis. In evidence based planning Transmission Utility shall have an Operating Plan(s) for next-day operations to address potential System Operating Limit (SOL).

1.7. Objective of the study and scope of the report

The objective of the study is to review and analyse all the existing relevant electricity regulations, mechanisms and technical frameworks with respects to grid discipline and grid reliability of each South Asian Countries both from the perspective of integration/unification of regional grids of domestic power system of a country, as well as cross-border power grid interconnection and come up with suggested regulatory measures/intervention needed for ensuring grid discipline and grid reliability in SAR.

1.8. Approach and methodology adopted for the study

This report discusses in detail the regulatory interventions/ measures needed for enhancing grid discipline and grid reliability in SAR and suggests a roadmap and action plan for implementation of the same.

We have adopted the following six-step approach to conduct the study:

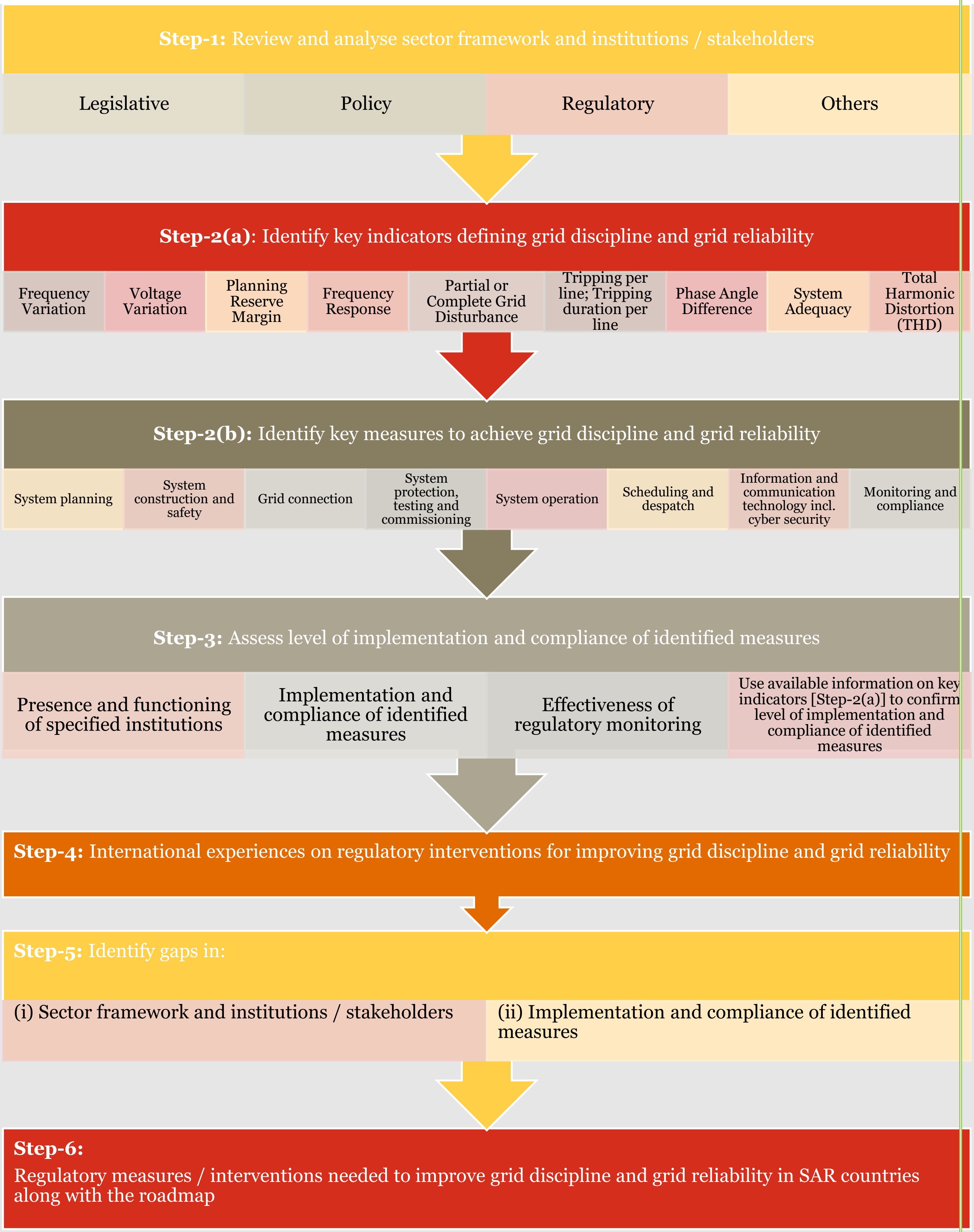


Figure 13: Block diagram of our approach

End Notes on Chapter1.

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2. Chapter 2:In-depth review of grid discipline and grid reliability aspects in South Asian region (Step-1 & Step-2)

2.1. Step-1: Review and analyse sector framework and institutions / stakeholders

2.1.1. Afghanistan

2.1.1.1. Snapshot of the power sector

The power sector of Afghanistan is governed by the Ministry of Energy and Water (MEW) and operated by Da Afghanistan Breshna Sherkat (DABS), which controls and operates power sector throughout the country. The Afghanistan power system is comprised of four independent networks, namely, North East Power System, South East Power System, Herat Zone System and Turkmenistan system which facilitates both internal and cross-border interconnections with neighbouring countries like Uzbekistan, Tajikistan, Iran, and Turkmenistan. The North East Power System (NEPS) is the largest. The NEPS currently supplies part of Kabul city over long 220 kV links from Tajikistan and, separately, Uzbekistan. The pictorial representation of Afghanistan's transmission system is as follows:

Figure 14: Afghanistan Transmission grid system[27] (as on December 2017)

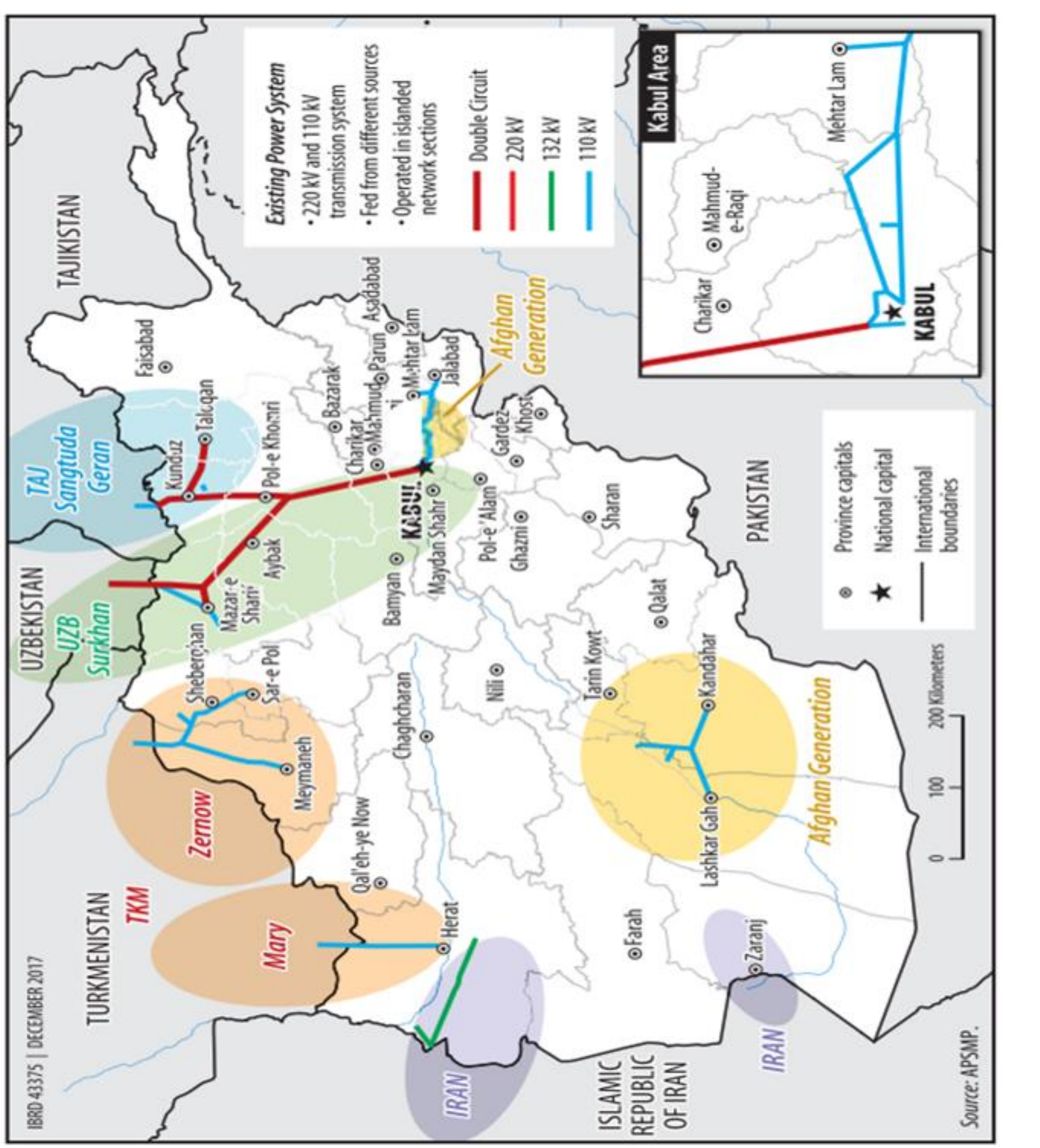


Table 4: Energy generated by type of fuel

Fuel	**Energy Generated in GWh (%)** (During FY 2017-18**)**	**Installed Capacity in MW (%)** (During FY 2017-18)
Hydro	1,098 (19.23%)	307 (19.43%)
Thermal (Fuel Diesel/HFO)		273 (17.28%)
Power Import	4,611 (80.77%)	1,000 (63.29%)

Fuel	Energy Generated in GWh (%) (During FY 2017-18)	Installed Capacity in MW (%) (During FY 2017-18)
Total	**5,709 (100%)**	**1,580 (100%)**

Table 5: Transmission line length (circuit kms)[28]

Transmission Line Type	Circuit km (as on 31.03.2018)
220 kV Transmission Line	751.00
132 kV Transmission Line	1275.00
Total Transmission Line	**2026.00**

Table 6: Transformation capacity (MVA)[29]

Sub-station Type	No of Sub-stations (as of March 2017)	Capacity (MVA) (as of March 2017)
110 kV to 220 kV	No info available	1,544

Table 7: Power Sector Snapshot of Afghanistan

Sr. No.	Prevailing status	Afghanistan
1	Does the Country have an Integrated power system?	No, the Afghanistan power system is comprised of four independent networks.
2	Transmission line loss levels (%)	No information available in public domain
3	Transmission interconnections along with voltage levels	Uzbekistan- 220kV AC Tajikistan-220kV AC Iran- 132kV AC Turkmenistan-110kV AC and 500kV AC[30]
4	Cross-border Import of Power (MW)	4,611 GWh during FY 2017-18 from Iran, Turkmenistan, Uzbekistan, and Tajikistan
5	Cross-border Export of Power (MW)	-

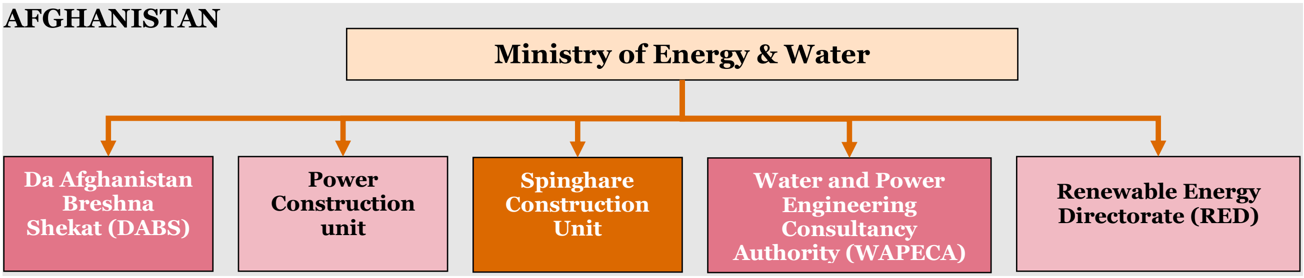
2.1.1.2. Legislative, policy, regulatory and other framework

Document type	Name of Document	Brief details
Apex Legal Document/ Act	The Afghanistan Electricity Law	The final version of the electricity law has been enacted by a presidential decree by President Ashraf Ghani on August 30th, 2015 (Electricity Law, 2015). The law stipulates that the citizens of Afghanistan should be provided access to electricity for a fair price and a "non-discriminatory access of the electric energy service providers to the market". The law also makes MEW the custodian and the prime implementing actor of the law and asks for the establishment of the Energy Regulatory Authority (ERA) under MEW's structure (Electricity Law, 2015).

Document type	Name of Document	Brief details
Energy Policy	National Integrated Energy Policy	The national energy policy outlines a broad scope for the energy sector in Afghanistan and makes MEW the prime custodian of the policy and mandates MEW implement the policy in the sector. Like the electricity law, the policy also underscores the provision of universal access to electricity to all Afghan citizens, the policy "ensures energy access to all in Afghanistan in an economically viable, reliable, socially equitable and environmentally sustainable manner".
Grid Code	-	No details found in public domain.

2.1.1.3. Institutions / stakeholders

Figure 15: Prevailing Institutional Structure of Afghanistan's electricity sector



The Ministry of Energy and Water (MEW) is the policy making body in the electricity sector in the country. At present, the policy and regulatory framework governing the electricity sector in Afghanistan is still evolving. DABS, wholly owned by the Government of Afghanistan, operates, and manages the entire electricity infrastructure in Afghanistan including generation, imports, and transmission and distribution activities. Currently, there is no private participation in the value chain of the power sector. MEW is responsible for policy and strategy development for the electricity sector. The Renewable Energy Directorate (RED) was created in 2009 and is the technical body concerned with the development of renewable energy projects at MEW[31]. Currently, DABS is responsible for ensuring grid discipline and grid reliability.

2.1.2. Bangladesh

2.1.2.1. Snapshot of the power sector

In Bangladesh, Power Division under the Ministry of Power, Energy and Mineral Resources (MoPEMR) manages the electricity business. Under its control, power is generated by the Bangladesh Power Development Board (BPDB), power plants that are departments and subsidiaries of BPDB, IPPs, and private power generation companies. Power is supplied through power transmission facilities of Power Grid Company of Bangladesh (PGCB) to customers in local cities by BPDB, in the metropolitan area by DPDC and DESCO, and in rural areas by PBS. A snapshot of Bangladesh's power sector is as follows:

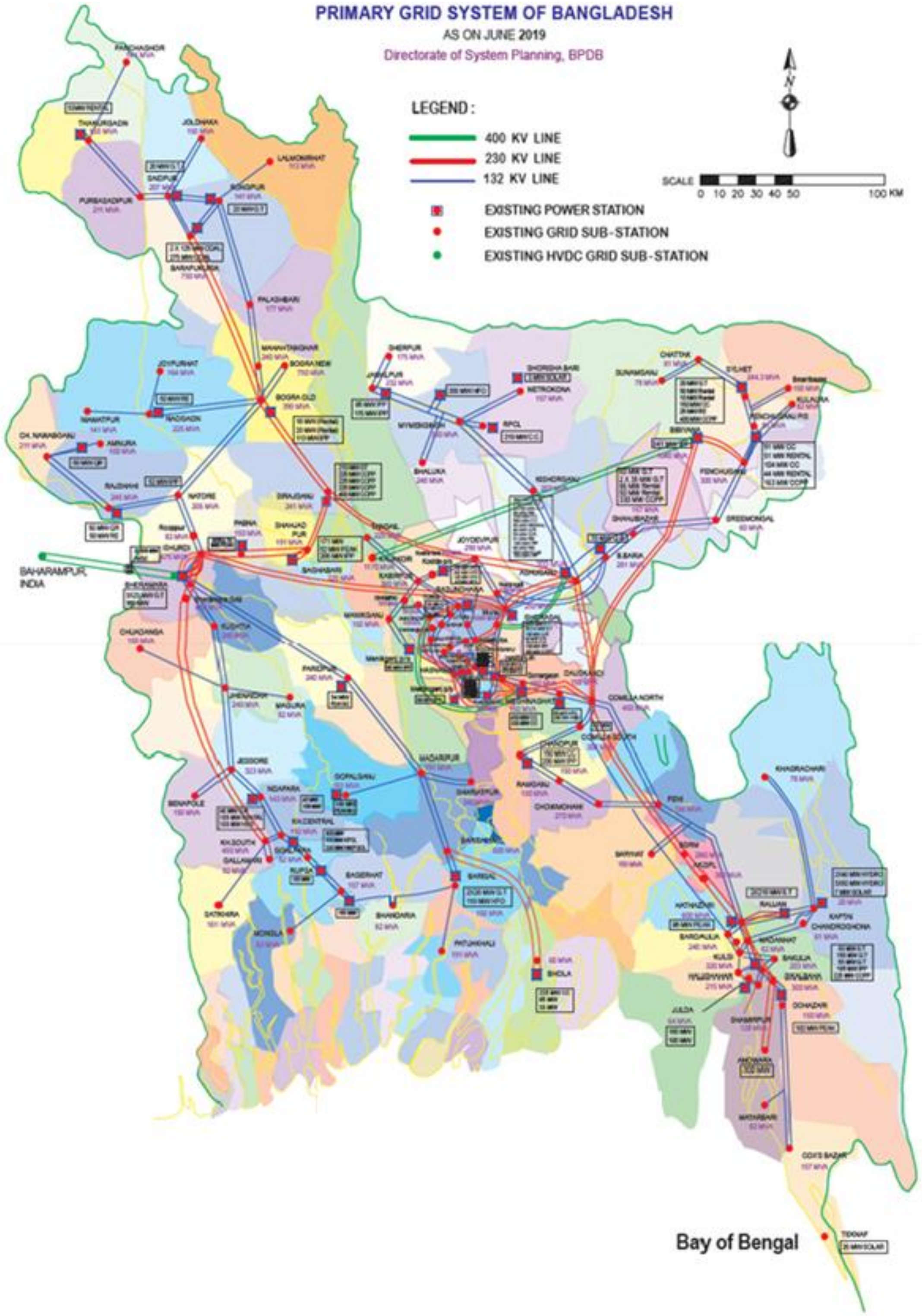


Figure 16: Bangladesh National Grid Plan[32]

Table 8: Energy generated by type of fuel[33]

Fuel	**Energy Generated in GWh (%)** (as on 30.06.2019)	**Installed Capacity in MW (%)** (as on 30.06.2019)
Hydro	725 (1.03%)	230 (1.21%)

Fuel	Energy Generated in GWh (%) (as on 30.06.2019)	Installed Capacity in MW (%) (as on 30.06.2019)
Natural Gas	48,306 (68.49%)	10,877 (57.37%)
Furnace Oil	11426 (16.20%)	4,770 (25.16%)
Diesel	2,022 (2.87%)	1,370 (7.23%)
Coal	1,230 (1.74%)	524 (2.76%)
Solar/ Renewable Energy	39 (0.05%)	30 (0.16%)
Power Import	6,786 (9.62%)	1,160 (6.12%)
Total	**70,533 (100%)**	**18,961 (100%)**

Table 9: Transmission line length (circuit kms)[34]

Transmission Line Type	Circuit kms (as on 30.06.2019)
400 kV Transmission Line	697.76
230 kV Transmission Line	3,406.69
132 kV Transmission Line	7,545.50
Total Transmission Line	**11,649.95**

Table 10: Transformation capacity (MVA)[35]

Sub-station Type	No. of Sub-stations (as on 30.06.2019)	Capacity (MVA) (as on 30.06.2019)
400 kV HVDC	1	1,111
400/230 kV	4	3,770
400/132 kV	1	650
230/132 kV	24	12,475
132/33 kV	135	23,640
Total	**165**	**41,646**

Table 11: Power Sector Snapshot of Bangladesh

Sr. No.	Prevailing status	Bangladesh
1	Does the Country have an Integrated power system?	Yes
2	Transmission line loss levels (%)	2.75%
3	Transmission interconnections along with voltage levels	• Baharampur (India) to Bheramara (Bangladesh)- 400kV DC • Surajmaninagar (Tripura-India) to Comilla (Bangladesh)- 132kV AC • Baharampur (India) - Bheramara (Bangladesh) 400kV D/C 2nd line and 400kV operation of Surajmaninagar (Tripura) -- North Comilla (Bangladesh) cross-border link along with

Sr. No.	Prevailing status	Bangladesh
		500MW HVDC Back-to-Back terminal at North Comilla is under implementation • Another high-capacity India-Bangladesh interconnection, viz., Katihar (India) - Parbotipur (Bangladesh) - Bornagar (India) line is under discussion
4	Cross-border Import of Power (MW)	1,160 MW (6,786 GWh) from India during FY 2018-19
5	Cross-border Export of Power (MW)	-

2.1.2.2. Legislative, policy, regulatory and other framework

Document type	Name of Document	Brief details
Apex Legal Document/ Act	Electricity Act, 2018	It is the apex law relating to the supply and use of electrical energy which have provision related to Licensing, works and supply of electricity.
Regulatory Commission	Bangladesh Energy Regulatory Commission Act, 2003 (Amended in 2005, 2010 & 2020)	It has provisions for the establishment of an independent and impartial regulatory commission to create an atmosphere conducive to private investment in the generation of electricity, transmission, transportation and marketing of gas resources and petroleum products, to ensure transparency in the management, operation, and tariff determination in these sectors; to protect consumers' interest and to promote the creation of a competitive market.
Grid Code	Electricity Grid Code, 2019	The Grid Code encompasses following areas: 1. Transmission system planning (Section 4) 2. Connection conditions (Section 5) 3. Outage planning (Section 6) 4. Schedule & despatch (Section 7) 5. Frequency & voltage management (Section 8) 6. Contingency planning (Section 9) 7. Cross boundary safety (Section 10) 8. Operational event/ accident reporting (Section 11) 9. Protection (Section 12) 10. Metering, communication, and data acquisition (Section 13) 11. Testing (Section 14) 12. Performance standards for transmission (Section 17)
Licensing	License Regulations, 2006 (Amended 2016)	The Regulation is published in local language and therefore not readable in English.

2.1.2.3. Institution's structure and role of stakeholders in ensuring grid discipline and reliability

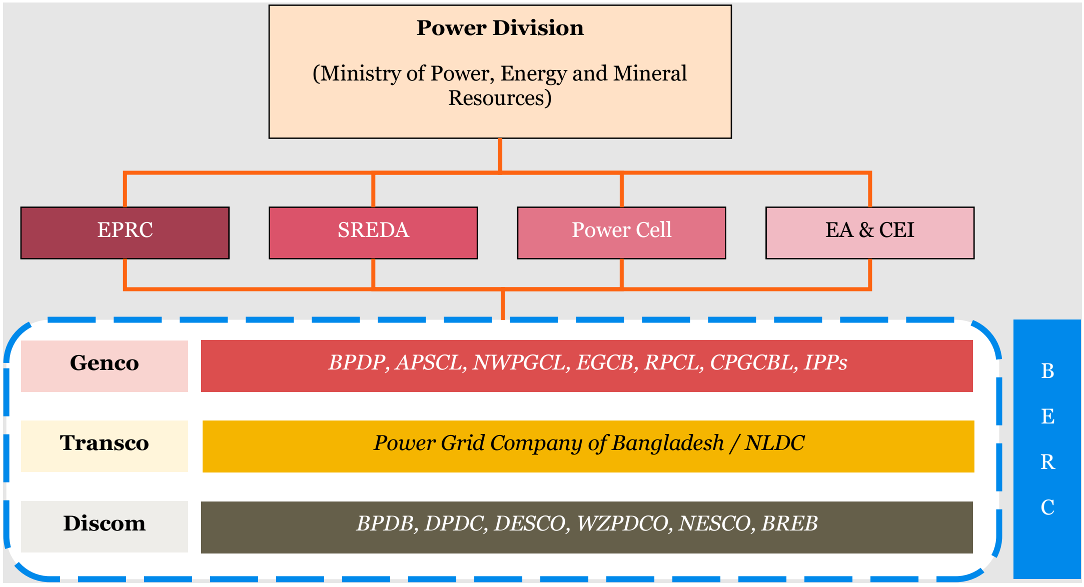


Figure 17: Prevailing Institutional Structure of Bangladesh's electricity sector

The Bangladesh Energy Regulatory Commission (BERC) and the Power Division in the Ministry of Power, Energy and Mineral Resources (MoPEMR) are the licensing and nodal authorities in the country. The BERC regulates the electricity, gas and petroleum products and their pricing in Bangladesh. Power Grid Company of Bangladesh (PGCB) was established in 1996 in the course of reorganization of the electricity sector of Bangladesh. PGCB is responsible for the operation and expansion of all power grid networks throughout the country. The National Load Despatch Centre (NLDC) functions as an arm of PGCB and carryout the function of scheduling and dispatch of power and real-time grid operations in Bangladesh. BERC is involved in formulating regulations related to grid discipline and grid reliability.

2.1.3. Bhutan

2.1.3.1. Snapshot of the power sector

Bhutan has one of the largest repositories of hydropower in Asia with a theoretical potential of 30 GW, out of which 23.8 GW is said to be techno-economically feasible for development.[36] The existing transmission voltage level in the country is 400kV, 220kV, 132kV and 66kV. The entire 220kV and 400kV transmission system networks were largely developed as Associated Transmission Systems for Chhukha hydropower plant, Tala hydropower plant and Mangdechhu Hydropower Project Authority. Bhutan's transmission network is connected with Indian grid with AC interconnections.

A snapshot of Bhutan's power sector is as follows:

Figure 18: Bhutan power system geographic map[37]

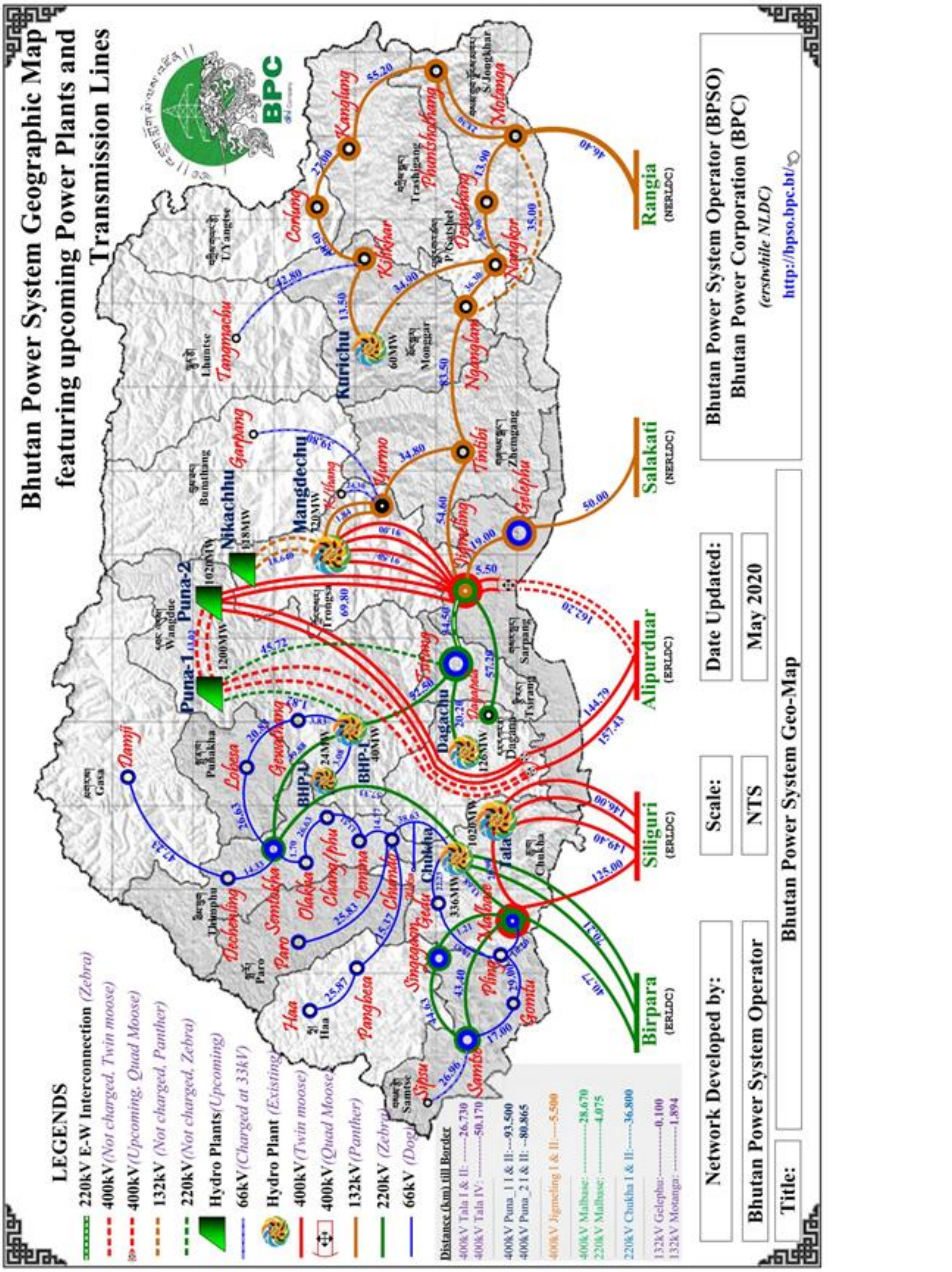


Figure 19: Bhutan Power System Transmission Network[38] (as of May 2020)

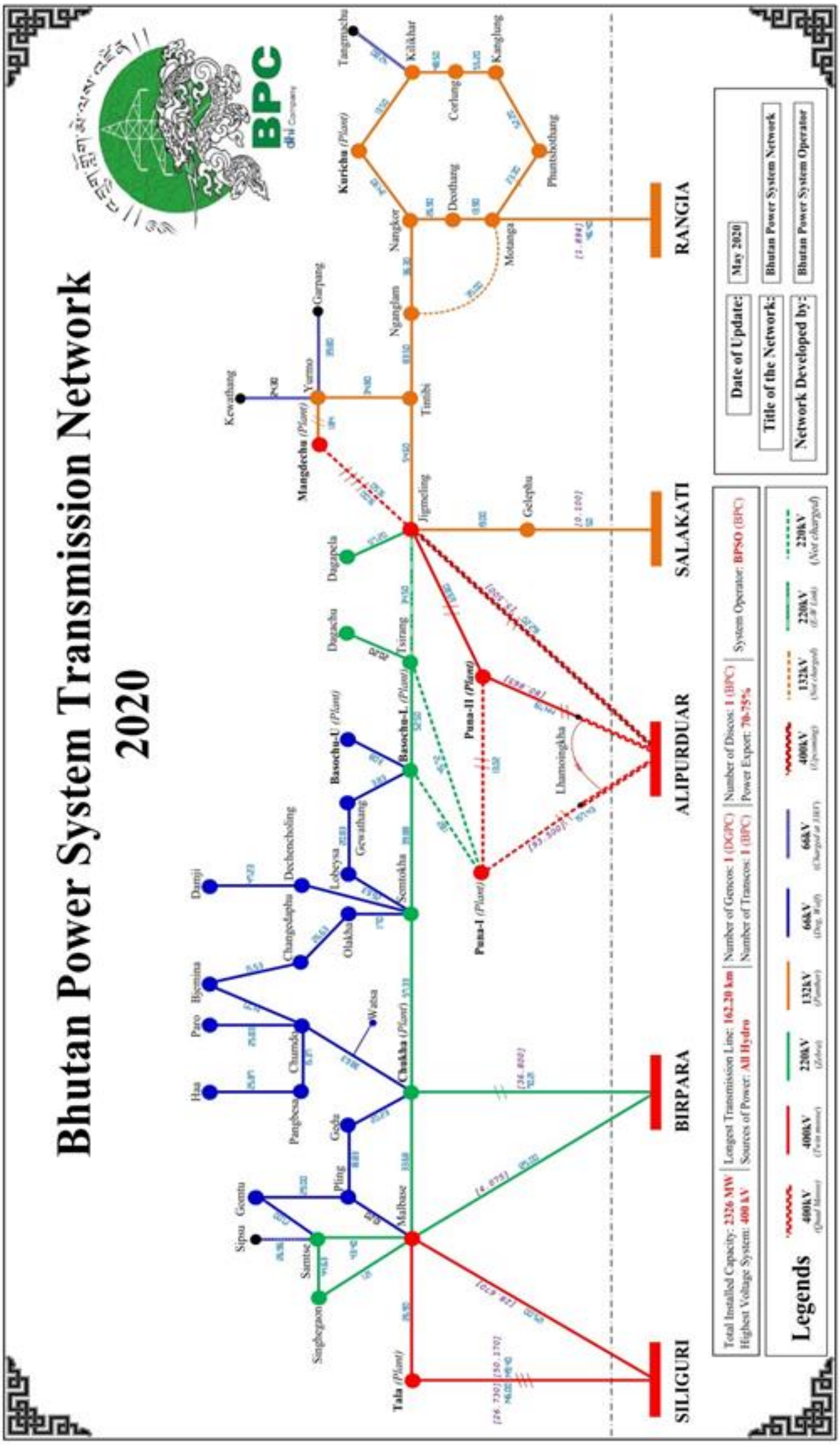


Table 12:Energy generated by type of fuel[39]

Fuel	Energy Generated in GWh (as on December 2019)	Generating Capacity in MW (as on December 2019)
Hydro	8,856.92 (99.79%)	2326 (99.34%)
Mini and Micro Hydel	17.79 (0.2%)	8.1 (0.346%)
Diesel generators	0.01 (0.001%)	6.78 (0.289%)
Wind Power	1.15 (0.013%)	0.6 (0.026%)
Total	**8,875.87 (100%)**	**2,341.48 (100%)**

Table 13: Transmission line length (circuit kms)[40]

Transmission Line Type	Circuit kms (as on December 2019)
400 kV Transmission Line	394.45
220 kV Transmission Line	325.05
132 kV Transmission Line	472.39
66 kV Transmission Line	360.14
Total Transmission Line	**1552.03**

Table 14: Transformation capacity (MVA)[41]

Sub-station Type	No of Sub-station (as of June 2018)	Capacity (MVA) (as of June 2018)
400/220 kV	2	700
220/132 kV	1	160
220/66 kV	5	682
132/66 kV	1	50
132/33 kV	8	97
66/33 kV	12	121
33/11 kV	10	137
Total	**39**	**1,947**

Table 15: Power Sector Snapshot of Bhutan

Sr. No.	Prevailing status	Bhutan
1	Does the Country have an Integrated power system?	Yes, the eastern and western grids of Bhutan are interconnected through a 220 kV interconnection.
2	Transmission line loss levels (%)	2.77%[42]
3	Transmission interconnections along with voltage levels	• Tala HEP to India- 400kV AC • Chhukha HEP to India- 220kV AC • Kurichhu HEP to India- 132kV AC •

Sr. No.	Prevailing status	Bhutan
4	Cross-border Import of Power (MW)	280.7 MW from India during CY 2019[43]
5	Cross-border Export of Power (MW)	1854 MW to India during CY 2019[44]

2.1.3.2. Legislative, policy, regulatory and other framework

Table 16: Overarching framework - Bhutan

Document type	Name of Document	Brief details
Apex Legal Document/ Act	Bhutan Electricity Act, 2001	The Electricity Act enables the restructuring of the power supply industry and the possible participation of the private sector, by providing mechanisms for licensing and regulating the operations of power companies. The establishment of the Bhutan Electricity Authority as an autonomous body ensures a transparent regulatory regime; the Authority also has the role of laying down the standards, codes, and specifications of the Electricity Supply Industry. By this means the Electricity Act will define the roles and responsibilities of suppliers and protects the interests of the general public.
Grid Code	Grid Code Regulation, 2008	The Grid Code encompasses following areas: 1. Role and Responsibilities of associated entities (Section 3) 2. Planning Code (Section 4) 3. Connection Conditions (Section 5) 4. Operations and Operation Planning (Section 6) 5. Scheduling & Dispatch Code (Section 7) 6. Management of Grid Code Regulation (Section 8)
Renewable Energy Promotion	Alternative Renewable Energy Policy, 2013 (AREP)	The AREP 2013 aims to promote the clean RE technologies and covers the following areas of RE interventions: a) Stand-alone systems b) Decentralized Distributed Generation (DDG) systems c) Grid-connected RE systems d) Fossil fuel substitution through green energy sources
Distribution Code	Distribution Code 2020	Distribution Code includes the following: 1. Conditions of Supply 2. Asset Management 3. Distribution Operation Code 4. Embedded Generation 5. Guaranteed Service Levels 6. Information Exchange 7. Reporting of Incidents/ Accidents

Document type	Name of Document	Brief details
Licensing	Guidelines for Processing of Licenses	This Guidelines establishes the procedures and routines to be applied by the Bhutan Electricity Authority (BEA) in processing applications and granting licenses to any person or entity intending to carry out activities related to construction, generation, transmission, system operation, distribution, sale, supply, and export or import of electricity in Bhutan in accordance with the Electricity Act, 2001.
Safety	Safety Regulation, 2008	This Regulation makes provisions for the design, construction, operation and maintenance of electric power plant and equipment in a manner that is electrically safe. It broadly includes the following sections: 1. Responsibilities of Authorities and Licensees 2. Provision for Safety Audits 3. Safety rules 4. Investigation of Serious Safety Incidents 5. Safety Reporting 6. Awareness for Safety
	Safety Code, 2008	This Safety Code specifies the Authority's minimum electrical safety requirements for the design, construction, operation and maintenance of electric power plant and equipment under the control of Licensees. These minimum requirements shall be incorporated by Licensees into the Safety Rules and Safety Management Systems developed by Licensees in accordance with the requirements of the Safety Regulation. This Code is concerned only with electrical safety and does not impose requirements on Licensees in respect of non-electrical safety risks arising from the design, construction, operation and maintenance of electric power plant and equipment under the control of Licensees. Licensees are expected to manage non-electrical safety risk in accordance with good industry practice and the requirements of relevant laws of Bhutan.

2.1.3.3. Institutions / stakeholders

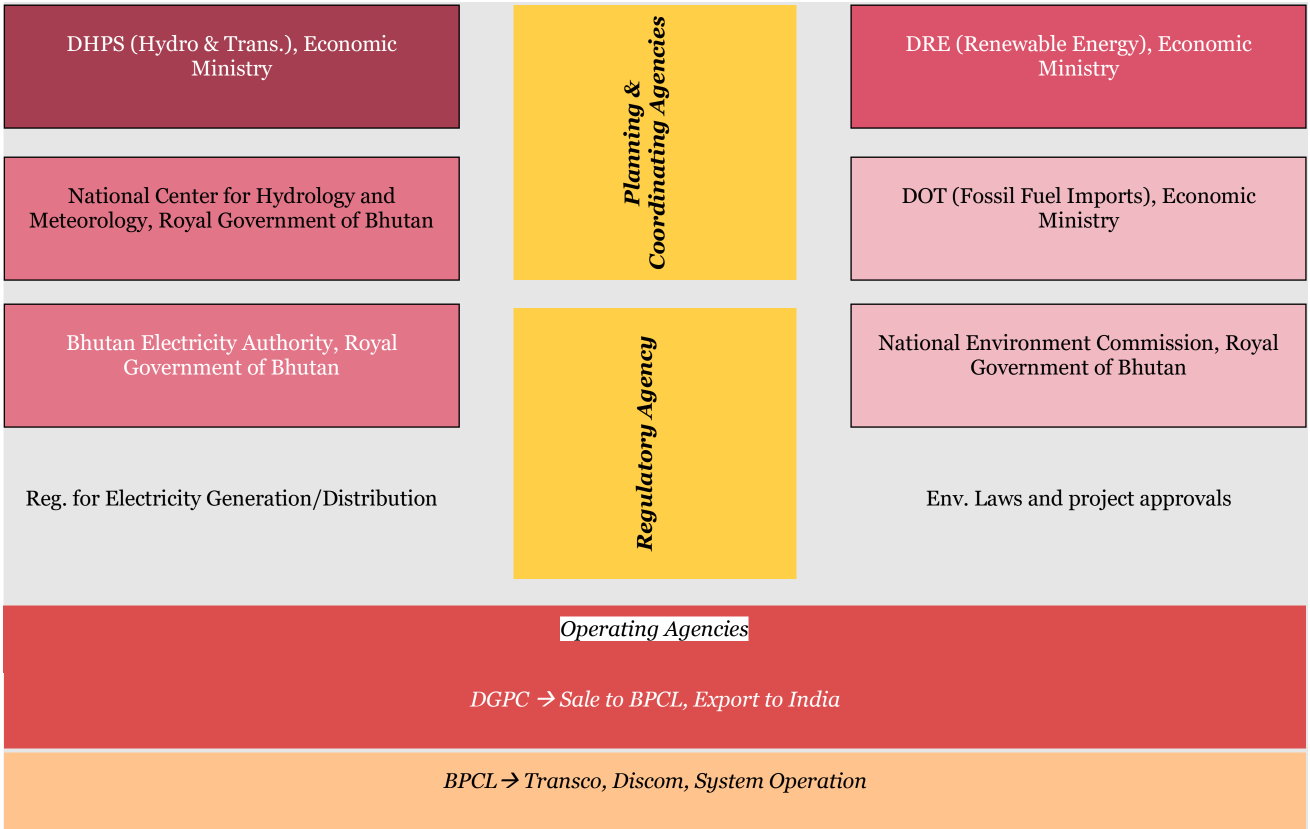


Figure 20: Prevailing Institutional Structure of Bhutan's electricity sector

The Department of Power (DoP) under the erstwhile Ministry of Trade and Industry was responsible for all activities related to the power sector in Bhutan till June 2002. The establishment of the Electricity Act in July 2001 enabled major restructuring of the power sector. The Bhutan Electricity Authority (BEA) is responsible for setting tariffs; establishing and enforcing technical, safety, and operational standards; issuing licenses; and monitoring other regulatory functions. Bhutan Power System Operator (BPSO) is entrusted to coordinate and regulate power system operation and outages and manage/monitor export and import of power in an optimal manner for overall reliability and security of electricity supply system of the nation. BPSO as of now has the main control centre (MCC) at Thimphu and the backup control centre at Malbase (also known as the Western Load Dispatch Centre, WLDC), Phuentsholing. Eastern Load Dispatch Centre (ELDC) is based in Tintibi. Power system network in Bhutan is divided into two regions: Eastern Region and Western Region[45]. Bhutan Power Corporation Limited is entrusted with the responsibility of transmission and distribution. BEA formulates regulations related to grid discipline and grid reliability and monitors compliance.

2.1.4. India

2.1.4.1. Snapshot of the power sector

The Indian power system for planning and operational purposes is divided into five regional grids. The integration of regional grids, and thereby establishment of national grid, was conceptualized in early nineties. The integration of regional grids which began with asynchronous HVDC back-to-back inter-regional links facilitating limited exchange of regulated power was subsequently graduated to high-capacity synchronous links between the regions. synchronisation of all regional grids has helped in optimal utilization of scarce natural resources by transfer of power from resource centric regions to load centric regions. Currently, India has a gigantic transmission network, spread over length and breadth of the country, and is consistently maintained at an availability of over 99%.

A snapshot of India's power sector is as follows:

Table 17: Energy generated by type of fuel

Fuel	***Energy Generated in Billion Units*** (for FY 2019-20)[46]	***Installed Capacity in MW*** (as on 31.03.2020)[47]
Total Thermal	1,044.445 (77.06%)	2,30,600 (62.32%)
Coal		1,98,525
Lignite		6,610
Gas		24,937
Diesel		510
Hydro (Renewable)	155.970(11.51%)	45,699 (12.35%)
Nuclear	46.381 (3.42%)	6,780 (1.83%)
Renewable Energy Sources	108.530 (8.01%)	87,028 (23.5%)
Total	**1355.326 (100%)**	**370,106 (100%)**

Table 18: Transmission line length (circuit kms)[48]

Transmission Line Type	**Circuit kms** (as on July 2020)
800 kV HVDC	6,124
500 kV HVDC	9,432
765 kV	44,855
400 kV	185,702
220 kV	181,297
Total Transmission Line	**427,410**

Table 19: Transformation capacity (MVA)

Sub-station Type	**Substations**	**Capacity in MVA** (as of July 2020)[49]
800 kV HVDC	Consolidated Data for number of substations is not available	12,000
500 kV HVDC		13,500
765 kV		234,900
400 kV		340,472
220 kV		318,191
Total		**979,063**

Figure 21: India National Grid Plan[50]

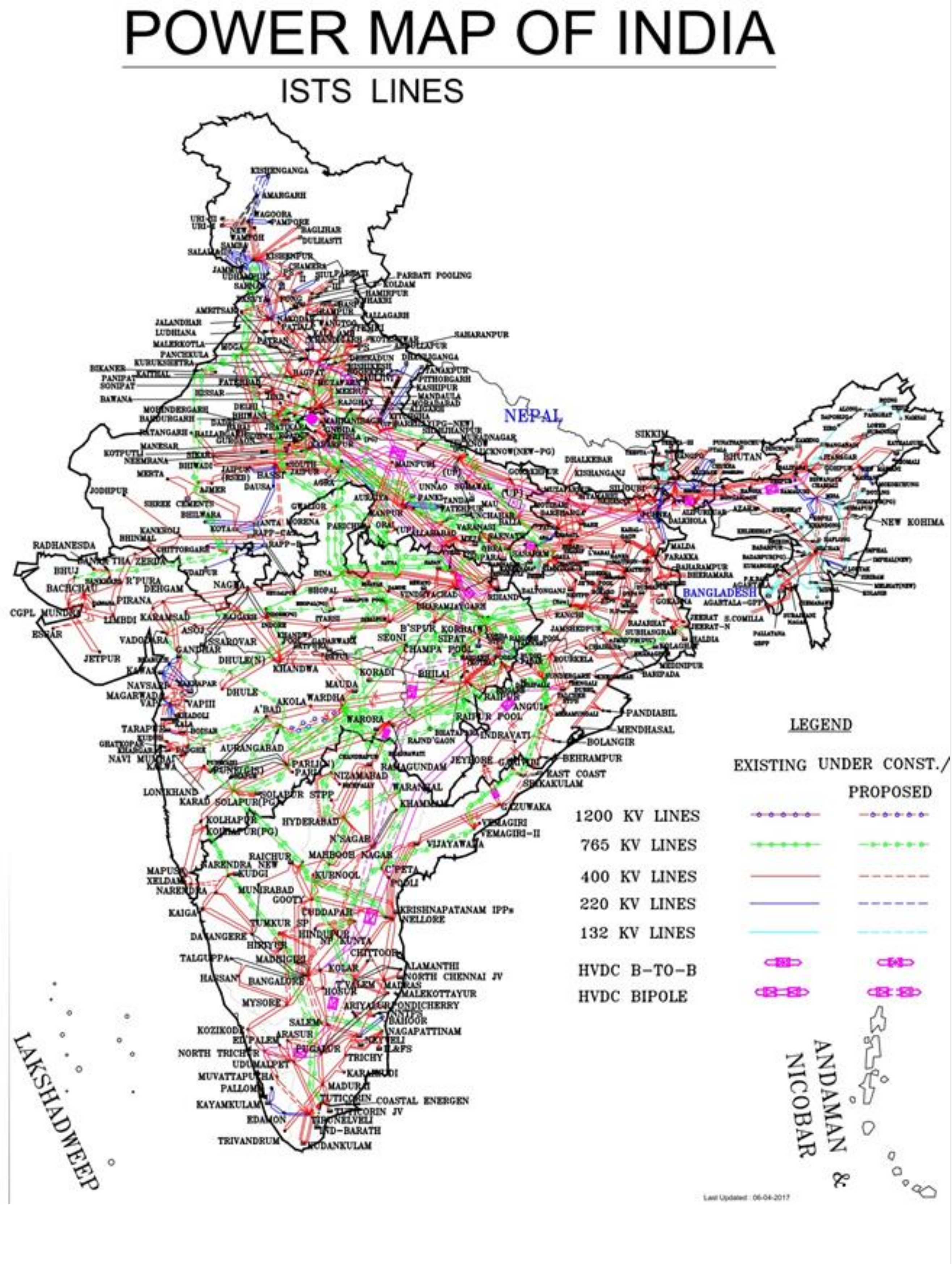


Table 20: Power Sector Snapshot of India

Sr. No.	Prevailing status	India
1	Does the Country have an Integrated power system?	Yes
2	Transmission line loss levels (%)	3.44%[51]
3	Transmission interconnections along with voltage levels	• BSEB(Kataiyain Bihar) to Kusaha/Duhabi in Nepal- 132kV • BSEB(Ramnagar in Bihar) to Gandak/Surajpura in Nepal- 132kV • BSEB(Sitamarhi in Bihar) to Jaleshwer in Nepal- 33kV • BSEB(Raxaul in Bihar) to Birganj in Nepal- 33kV • BSEB(Jainnagar in Bihar) to Siraha in Nepal- 33kV • BSEB(Kataiya in Bihar) to Rajbiraj in Nepal- 33kV • BSEB(Kataiya in Bihar) to Inarwa/Biratnagar(Rupni) in Nepal- 33kV • UPCL (Lohiyahead in Uttaranchal) to - Gaddachowki/Mahendranagar in Nepal- 33kV • UPCL (Pithoragarh in Uttaranchal) to Baitadi in Nepal- 11kV • UPCL (Dharchula in Uttaranchal) to - Jaljibe in Nepal- 11kV • UPCL (Dharchula in Uttaranchal) to - Pipli in Nepal- 11kV • Dhalkebar (Nepal) to Muzaffarpur (India)- 400kV AC • Baharampur (India) to Bheramara (Bangladesh)- 400kV DC • Surajmaninagar (Tripura-India) to Comilla (Bangladesh)- 132kV AC • Baharampur (India) - Bheramara (Bangladesh) 400kV D/C 2ndline • Tala HEP to India- 400kV AC (400 kV Tala-Alipurduar D/C line • 400kV Tala-Malbase-Pugli line • 400 kV Jigmeling-Alipurduar D/C line • Chhukha HEP to India- 220kV AC • Kurichhu HEP to India- 132kV AC • Moreh (Manipur) to Tamu (Myanmar)[52]- 11 kV
4	Cross-border Import of Power (MW)	1,500 MW (5,000 MU) from Bhutan during FY 2018-2019[53]
5	Cross-border Export of Power (MW)	6,168 MUs to Bangladesh[54] 1,839 MUs to Nepal[55] 7 MUs to Myanmar[56]

2.1.4.2. Legislative, policy, regulatory and other framework

Document type	Name of Document	Brief details
Apex Legal Document/ Act	The Electricity Act, 2003	An Act to consolidate the laws relating to generation, transmission, distribution, trading and use of electricity and generally for taking measures conducive to development of electricity industry, promoting competition therein, protecting interest of consumers and supply of electricity to all areas, rationalisation of electricity tariff, ensuring transparent policies regarding subsidies, promotion of efficient and environmentally benign policies constitution of Central Electricity Authority, Regulatory Commissions and establishment of Appellate Tribunal and for matters connected therewith or incidental thereto.
Grid Code and Regulations	Central Electricity Regulatory Commission (Indian Electricity Grid Code) Regulations, 2010 and 6 subsequent amendments	CERC Grid Code includes the following: a. Role of various Organizations and their linkages b. Planning Code for inter-State transmission c. Connection Code d. Operating Code e. Scheduling and Despatch Code
	CERC Planning, Coordination and Development of Economic and Efficient Inter-State Transmission System by Central Transmission Utility and other related matters Regulation, 2018.	This regulation lays down the broad principles, procedures, and processes to be followed for planning and development of an efficient, co-ordinated, reliable, and economical system of inter-State transmission system (ISTS) for smooth flow of electricity from generating stations to the load centres. It includes the following: a. Roles and Responsibilities of various Organizations b. Criteria for augmentation of the transmission system c. Process of Transmission Planning d. Manpower Deployment in Transmission Planning
Technical Standards	CEA (Grid Standards) Regulations, 2010	The Regulations cover the following standards to be complied by all entities, appropriate LDCs and RPCs: 1) Standards for Operation and Maintenance of Transmission Lines 2) Operation Planning 3) Maintenance Planning 4) Coordination in Operations 5) Operating Instructions

Document type	Name of Document	Brief details
		6) Instructions by Regional Load Despatch Centres and State Load Despatch Centres to be recorded 7) Islanding Schemes 8) Categorisation of grid incidents and grid disturbance based on severity of tripping 9) Reporting of events affecting grid operation 10) Reporting of grid disturbance 11) Restoration of grid following grid incident and grid disturbance 12) Operational Data during normal operation and during grid incidents and grid disturbances 13) Operational Data Records 14) Communication facilities and Safety Procedure 15) Maintenance of Tools and Equipment 16) Maintenance Procedures & Hot Line Methods 17) Emergency Restoration System 18) Inspection and Patrolling 19) Maintenance schedules, Maintenance records, etc.
	CEA (Technical Standards for Communication System in Power System Operation) Regulations, 2020	This prescribes technical standards for communication systems in power system operation for aspects such as: 1) Wideband network 2) Fibre optic communication 3) Power line carrier communication 4) Cellular and radio frequency communication etc.
	CEA (Installation and Operation of meters) Regulations, 2006 with 3 subsequent amendments in 2010, 2014 and 2019	This prescribes the technical standards for installation and operation of interface meters, consumer meters and energy accounting & audit meters
	• CEA (Technical Standards for Connectivity to the Grid) Regulations, 2007 with 2 subsequent amendments in 2012 and 2019 • CEA (Technical Standards for Connectivity of the	These regulations prescribe technical standards for grid integration of new generating units, existing generating units, transmission lines and sub-stations, distribution systems & bulk consumers and distribution generation resources so that grid reliability is maintained during interconnections

Document type	Name of Document	Brief details
	Distributed Energy Resources) Regulations, 2013 with an amendment in 2019	
Grant of Connection	CERC (Grant of Connectivity, Long-term Access and Medium-term Open Access in inter-state Transmission and related matters) Regulations, 2009 and 7 subsequent amendments	The Regulations cover the following: 1) Nodal Agency, process for filing the application, fee, and timeframe for processing the application 2) Grant of Connectivity 3) Long-term and medium-term open access - Conditions and procedure 4) Information System
Renewable Energy Integration	Central Electricity Regulatory Commission (Terms and Conditions for Recognition and Issuance of Renewable Energy Certificate for Renewable Energy Generation) Regulations, 2010	The Regulations cover the following: 1) Central Agency and its functions 2) Categories of Certificates, Eligibility and Registration for Certificates, Revocation of Registration, Denomination, and issuance of Certificates, Dealing in the certificates, Pricing of Certificate, etc.
Licensing	The Electricity Act, 2003	Part IV of the Act covers licensing conditions for transmission, distribution, and trading of electricity
Market Operation	Central Electricity Regulatory Commission (Power Market) Regulations, 2010 and 2 subsequent Amendments	These Regulations govern the rules for operation of Day Ahead Market and Real Time Market in India
Ancillary Services	Central Electricity Regulatory Commission (Ancillary Services Operations) Regulations, 2015	This covers the rules tertiary frequency control through Reserves Regulation Ancillary Services, i.e., Ancillary Services that consist of either Regulation Down Service or Regulation Up Service
Commercial penalty mechanism for deviation from normal frequency range	Central Electricity Regulatory Commission (Deviation Settlement Mechanism and related matters) Regulations, 2014 and 4 subsequent amendments	These Regulations lay out the rules for frequency linked deviation settlement charges for under-drawl and over-drawl of electricity
Cross-border Trade of Electricity	Central Electricity Regulatory Commission (Cross-border	Applicable to the Participating Entities in India and the neighbouring countries which are engaged in cross-border trade of electricity

Document type	Name of Document	Brief details
	Trade of Electricity) Regulations, 2019	with India and covers the following: - Institutional Framework - Transmission planning, connectivity, and access - System Operation - Payment of charges and payment security mechanism

2.1.4.3. Institutions / stakeholders

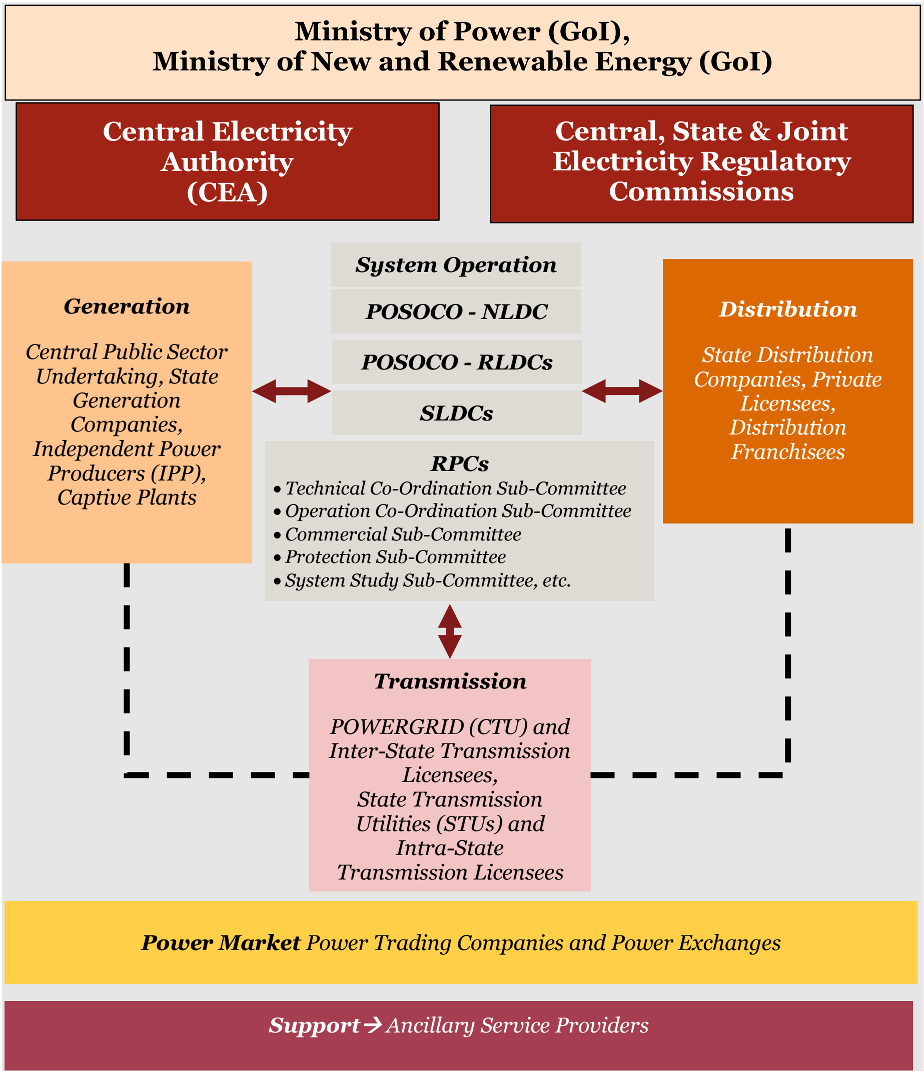


Figure 22: Prevailing Institutional Structure of India's electricity sector

Electricity is a concurrent subject as per Entry 38 in List III of the Seventh Schedule of the Constitution of India. That is both the Central Government and the State Governments in India have division of powers to make laws and to issue directions in the matter of Electricity at Central and State level respectively. The Ministry of Power (MoP), Government of India started functioning independently with effect from 2nd July 1992 and is primarily responsible for development of electrical energy in the country. Ministry of New and Renewable Energy (MNRE) is the nodal Ministry of the Government of India for all matters relating to new and renewable energy.

Power System Operation Corporation Limited (POSOCO) is responsible to ensure the integrated operation of the grid in a reliable, efficient, and secure manner. It consists of five Regional Load Despatch Centres and a National Load Despatch Centre (NLDC). It coordinates the functioning of NLDC and all the RLDCs, it provides advice and assists state level Load Despatch Centres, including conducting specialized trainings etc.

National Load Despatch Centre (NLDC) has been constituted as per MoP notification, dated 2nd March 2005 and is the apex body to ensure integrated operation of the national power system. It monitors the operations and grid security of the national grid. It supervises and controls the inter-regional links as may be required for ensuring stability of the power system under its control. It provides information relating to operations of transmission system in accordance with directions or regulations issued by the Central Electricity Regulatory Commission (CERC) and the Central Government from time to time.

Regional Load Despatch Centres (RLDC) are responsible for optimum scheduling and despatch of electricity within the region, in accordance with the contracts entered into with the licensees or the generating companies operating in the region. They are responsible for carrying out real time operations for grid control and despatch of electricity within the region through secure and economic operation of the regional grid in accordance with the grid standards and the grid code.

Government of India, under the provision of Section 2, Subsection 55 of the Electricity Act 2003 created Regional Power Committees (RPCs) with a function to undertake regional level operation analysis for improving grid performance. Key objectives of RPCs are to maintain archive of data and information pertaining to operating parameters, protection system and communication system of the regional power system. They undertake planning for maintaining proper voltages through review of reactive compensation requirement through system study committee and monitoring of installed capacitors. RPCs also coordinate planning of scheduled maintenance of generating machines of various generating companies in their region including those of inter-state generating companies supplying electricity to the region on annual basis and also to undertake review of maintenance programme on monthly basis.

Ministry of Power, Government of India vide notification[57] No. 14/1/2017-Trans-Pt(1) dated 26 November 2019 nominated NTPC Vidyut Vyapar Nigam Ltd. (NVVN) as Settlement Nodal Agency (SNA) for settlement of grid operation related charges with neighbouring countries, namely, Bangladesh, Bhutan, Nepal and Myanmar as per clause 8.8 of Guidelines for Import/Export (Cross Border) of Electricity 2018.

2.1.5. Maldives

2.1.5.1. Snapshot of the power sector

Maldives comprises a number of small, isolated island-based grid systems. Three vertically integrated state-owned utilities STELCO, FENAKA, and MWSC operate a total of 186 powerhouses on inhabited and industrial islands. There is no transmission grid in Maldives. Plans to connect Maldives to India or Sri Lanka through sub-sea cable are at planning stage. Further, plans to construct undersea cable when the proposed 200 MW power station at Thilafushi industrial island is commissioned is also under process.

A snapshot of Maldives' power sector is as follows:

Table 21: Energy generated by type of fuel[58]

Fuel	Energy Generated in GWh (in 2017)	Installed Generation capacity in MW (in 2017)
Diesel	704	438

Table 22: Power Sector Snapshot of Maldives

Sr. No.	Prevailing status	Maldives
1	Does the Country have an Integrated power system?	No, currently only distribution level grid is present in Maldives and no integrated grid is erected.
2	Transmission line loss levels (%)	Not Applicable as there is no transmission grid in Maldives.
3	Transmission interconnections along with voltage levels	
4	Cross-border Import of Power (MW)	
5	Cross-border Export of Power (MW)	

2.1.5.2. Legislative, policy, regulatory and other framework

Document type	Name of Document	Brief details
Apex Legal Document/ Act	Law 4/ 96 (Provision of Utility Services)	The Law is in local language and therefore not readable in English.
	Electricity Regulation of Maldives	The Regulation is in local language and therefore not readable in English.
Grid Code	-	Maldives does not have a transmission grid. Therefore, the grid code is not available.
Generation and Distribution Licensing Regulations	Generation, Distribution and Supply Licensing Regulation (Regulation No.: 2015/ R-243)	The Regulation is in local language and therefore not readable in English.
Distribution grid standards	Installation Standards Regulations	Includes following: 1) Standards for LV Electrical Installations (Outdoor areas and public areas) 2) Standards for LV Electrical Installations (In-house areas) 3) Standards for MV Electrical Installations (Outdoor and public areas and private areas) 4) Standards for Generating Stations 5) Inspection and verification

Document type	Name of Document	Brief details
Power System Approval Guideline	Guideline for Power Systems Approval	The Guideline endeavours to capture following: 1) Details of generation system, 2) Generator control panel and distribution panel details, 3) Details about fuel system, 4) Distribution system details, 5) Details about electric cables, 6) Details about firefighting system and lightning protection, 7) Environmental Impact Assessment of the generation facility, 8) Tariff, and 9)Rules and regulation of powerhouse for consumers

2.1.5.3. Institutions / stakeholders

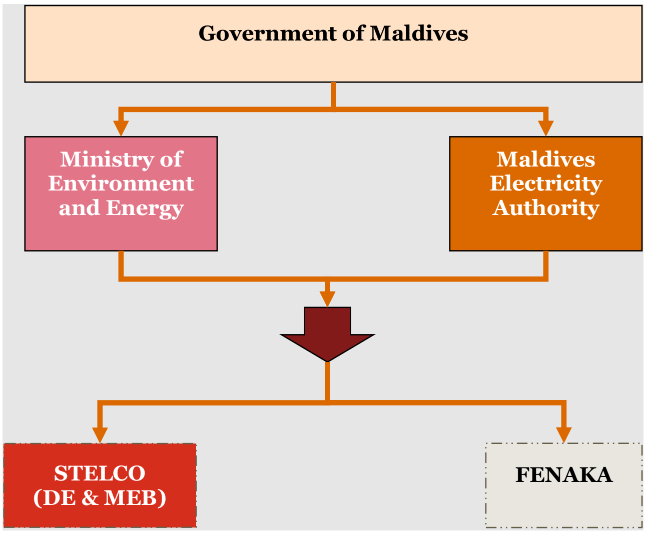


Figure 23: Prevailing Institutional Structure of Maldives' electricity sector

Since the introduction of electricity in 1949; the Government Department of Maldives under different names like "Department of Electricity" and "Maldives Electricity Board" managed the electricity sector in the country until 1997, when State Electric Company Limited (STELCO), was formed. STELCO, is wholly owned by the Government. Its core business includes power generation, distribution, and retail. It operates 28 power systems in 33 islands, providing electricity to 60% of the population of the country.

The Maldives Electricity Bureau (MEB) is responsible for regulating generation, distribution, and utilization including tariff setting. While the MEB has established the electricity standards by adopting the Singapore standards, it lacks the resources to implement them.

The Maldives Energy Authority (MEA) is an independent regulatory organization affiliated to the Ministry of Environment and Energy. It operates under the guidance of a governing board and is mandated to regulate the energy sector through the implementation of the relevant regulations. Since there is no transmission grid in Maldives currently, there are is no grid code and regulations governing grid discipline and grid reliability.

2.1.6. Nepal

2.1.6.1. Snapshot of the power sector

The Government of Nepal (GoN) established Rastriya Prasaran Grid Company Limited (RPGCL) in July 2015 to plan, construct and operate the transmission grid of Nepal. The majority of high voltage transmission line in Nepal is 132kV. With increase in the installed power and load demand, new lines of 220kV and 400kV have been introduced. Multiple cross-border transmission lines are under operation or at planning stage. The power grid of Nepal is divided into five[59] zones from West to East, with at least one interconnection point with India and China. A snapshot of Nepal's power sector is as follows:

Table 23: Energy generated by Source[60]

Source	***Energy Generated in GWh***(for FY 2019-20)
Own Generation of Nepal Electricity Authority	3,021
Independent Power Producers	2,991
Total	**6,012**

Table 24: Source-wise installed capacity[61]

Source	***Installed Capacity in MW(as of May 2020)***
Hydro (<1MW)	6.317
Hydro (>1MW)	1236.269
Thermal	53.410
Solar	1.680
Total	**1297.680**

Table 25: Transmission line length (circuit kms) and Substation Capacity (MVA)[62]

Transmission Line Type	**Circuit kms** (as on Aug 2020)
400 kV	78
220 kV	437
132 kV	3240
66 kV	514
Total Transmission Line	**4269.7**
Total Substation Capacity	**4299.7 MVA**

Table 26: Power Sector Snapshot of Nepal[63]

Sr. No.	**Prevailing status**	**Nepal**
1	Does the Country have an Integrated power system?	Yes

Sr. No.	Prevailing status	Nepal
2	Transmission line loss levels (%)	4.51% in FY 2019-20
3	Transmission interconnections along with voltage levels	• BSEB(Kataiyain Bihar) to Kusaha/Duhabi in Nepal- 132kV • BSEB(Ramnagar in Bihar) to Gandak/Surajpura in Nepal- 132kV • BSEB(Sitamarhi in Bihar) to Jaleshwer in Nepal- 33kV • BSEB(Raxaul in Bihar) to Birganj in Nepal- 33kV • BSEB(Jainnagar in Bihar) to Siraha in Nepal- 33kV • BSEB(Kataiya in Bihar) to Rajbiraj in Nepal- 33kV • BSEB(Kataiya in Bihar) to Inarwa/Biratnagar(Rupni) in Nepal- 33kV • UPCL (Lohiyahead in Uttaranchal) to - Gaddachowki/Mahendranagar in Nepal- 33kV • UPCL (Pithoragarh in Uttaranchal) to Baitadi in Nepal- 11kV • UPCL (Dharchula in Uttaranchal) to - Jaljibe in Nepal- 11kV • UPCL (Dharchula in Uttaranchal) to - Pipli in Nepal- 11kV • Dhalkebar (Nepal) to Muzaffarpur (India)- 400kV AC
4	Cross-border Import of Power	1729 GWh for FY 2019-20 from India
5	Cross-border Export of Power	107 GWh to India during FY 2019-20

Table 27: Integrated Nepal Power system[64]

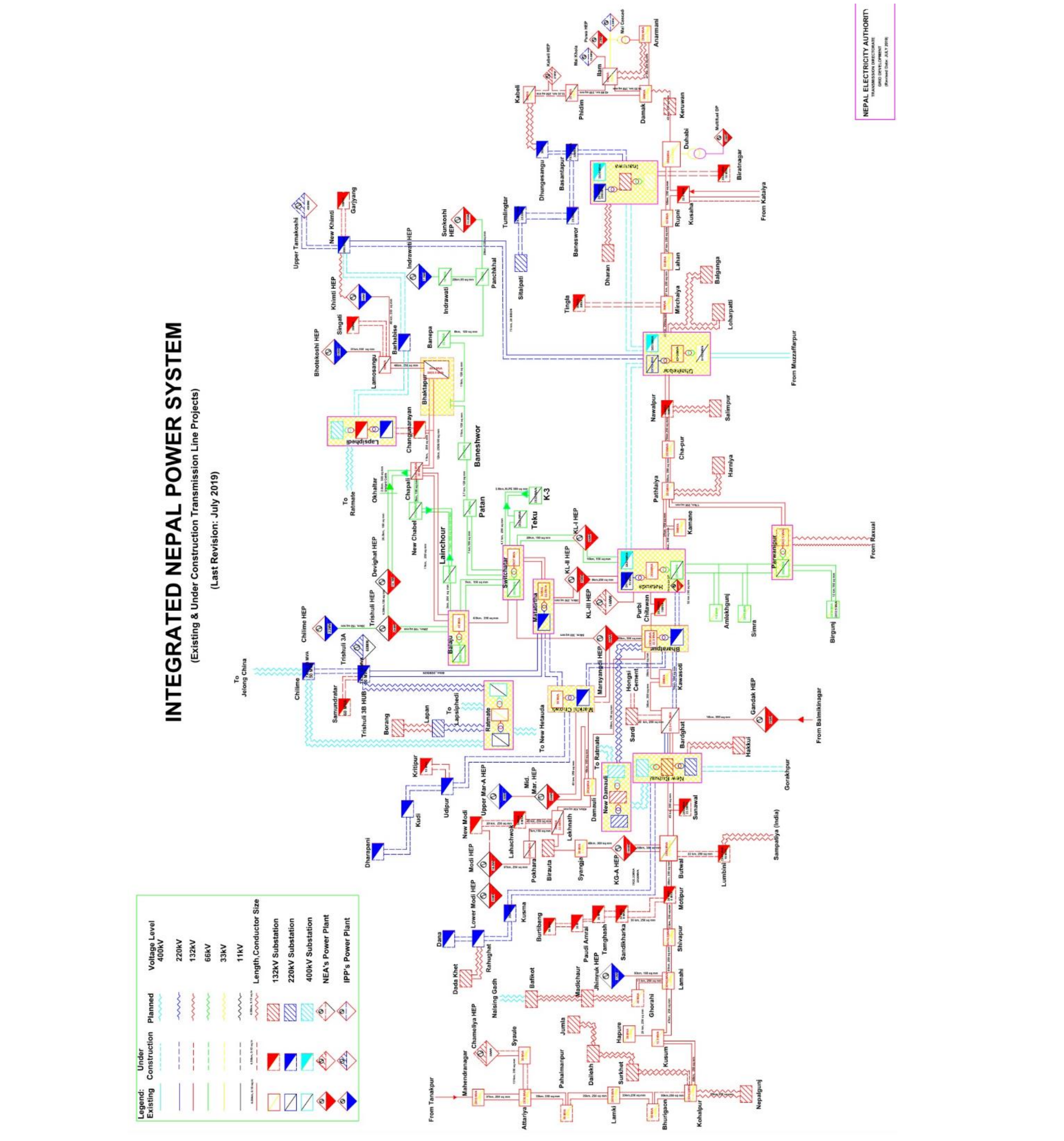
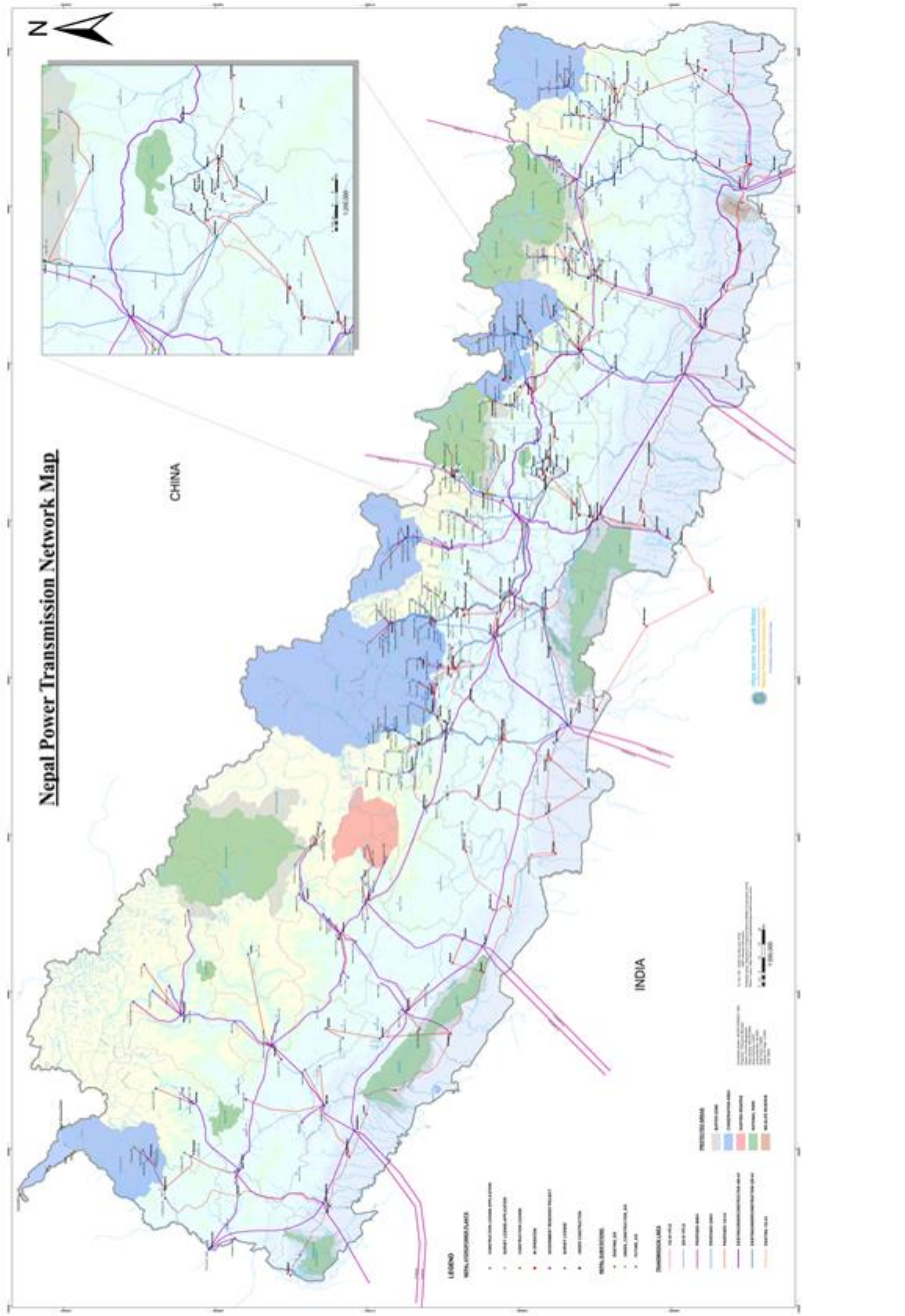


Figure 24: Transmission Network Map of Nepal[65] (as of January 2018)



2.1.6.2. Legislative, policy, regulatory and other framework

Document type	Name of Document	Brief details
Apex Legal Document/ Act	Electricity Act, 2049 (1992)	This legislature along with Electricity Regulation, 2050 (1993) shapes the overarching legal framework of Nepal's electricity sector. The objective of this Act is to develop electric power by regulating the survey, generation, transmission, and distribution of electricity and to standardize operating procedures and define safety standards for electricity services. In addition, it enables a person or a corporate body to involve in commercial Generation, Transmission and Distribution of electricity with projects of capacity more than 100 kW. It also specifies the survey and generation license period of a project.
Other Major Legislation in Electricity Sector	Nepal Electricity Authority Act, 2041 (1984)	The objective of the enactment of Nepal Electricity Authority Act, 2041 (1984) was to establish and manage Nepal Electricity Authority and to make arrangements for power supply by generating, transmitting and distributing electricity in an efficient reliable and convenient manner.
Constitution of Electricity Regulatory Commission its functions and duties	Electricity Regulatory Commission Act, 2074 (2017)	The Act covers following: 1) Establishment of the Commission 2) Formation of Commission, its Chairman and Members 3) Functions, duties, and authority of the Commission 4) Functions regarding management of technicalities 5) Functions to enhance organizational capacity of licensees 6) Functions to make policy suggestions to Govt. of Nepal 7) Functions to Investigate and Inspect licensees 8) Functions to impose fine, 9) Functions to Conduct Public Hearing, etc. 10) Determination of Tariff and Regulation of Electricity Purchase and Sale 11) Functions regarding maintaining competition and protection of consumer interests 12) Authority to inspect, resolve disputes, impose fines, collect charges, and organize public hearings 13) Provisions regarding employees of the Commission 14) Funding of the Commission, and other miscellaneous provisions
Grid Code	NEA Grid Code, 2005	The Grid Code encompasses following areas: 1) General Conditions (Chapter 1) 2) Grid Code Management (Chapter 2) 3) Grid Planning (Chapter 3)

Document type	Name of Document	Brief details
		4) Performance Standards for grid (Chapter 4) 5) Grid Connection requirement (Chapter 5) 6) Grid Operation management (Chapter 6) 7) Scheduling and Dispatch (Chapter 7) 8) System Test (Chapter 8) 9) Grid metering (Chapter 9) 10) Exemptions and Transitory Provisions (Chapter 10) 11) Reports (Chapter 11)

2.1.6.3. Institutions / stakeholders

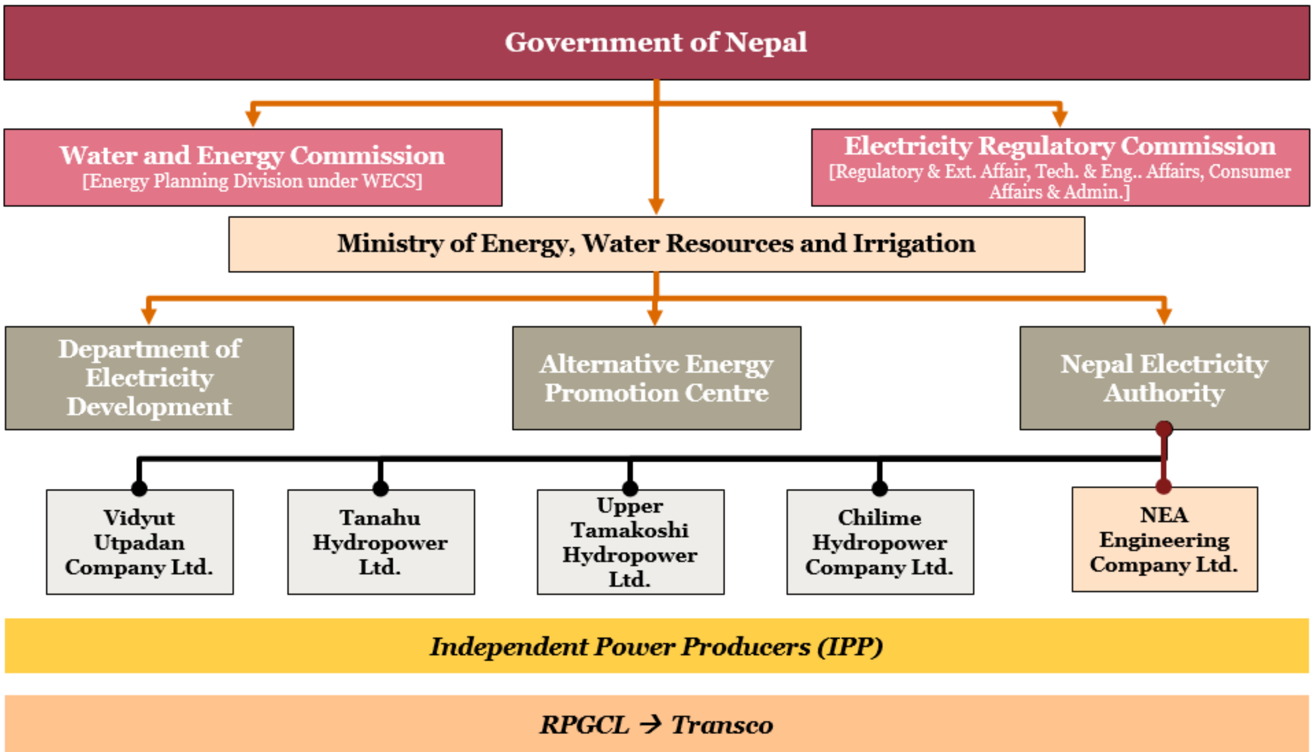


Figure 25: Prevailing Institutional Structure of Nepal's electricity sector

The Nepal Electricity Authority (NEA), a wholly Government of Nepal undertaking, was established in August 1985 under NEA Act 1984 and is responsible for generation, transmission, and distribution of electricity throughout Nepal. The key roles of NEA are project execution, power purchase, operation & maintenance of national grid and scheduling and dispatching.

The Rastriya Prasaran Grid Company Limited (RPGCL) was established by the Government of Nepal on 12 July 2015 to transmit and evacuate the power for the development and operation of the hydropower sector. Its key objective is development of transmission infrastructures to facilitate the electricity market for the management of transmission grid to supply the reliable electricity. The departments of power trading and transmission & system operation of NEA are responsible for CBET.

2.1.7. Pakistan

2.1.7.1. Snapshot of the power sector

The transmission and distribution networks of Pakistan are operated under the Ministry of Energy through various government entities. NTDC maintains and operates the transmission network whereas distribution operations are run by ten distribution companies (commonly known as DISCOs). K-Electric, the only vertically integrated power utility, operates only in the metropolitan area of Karachi. A snapshot of Pakistan's power sector is as follows:

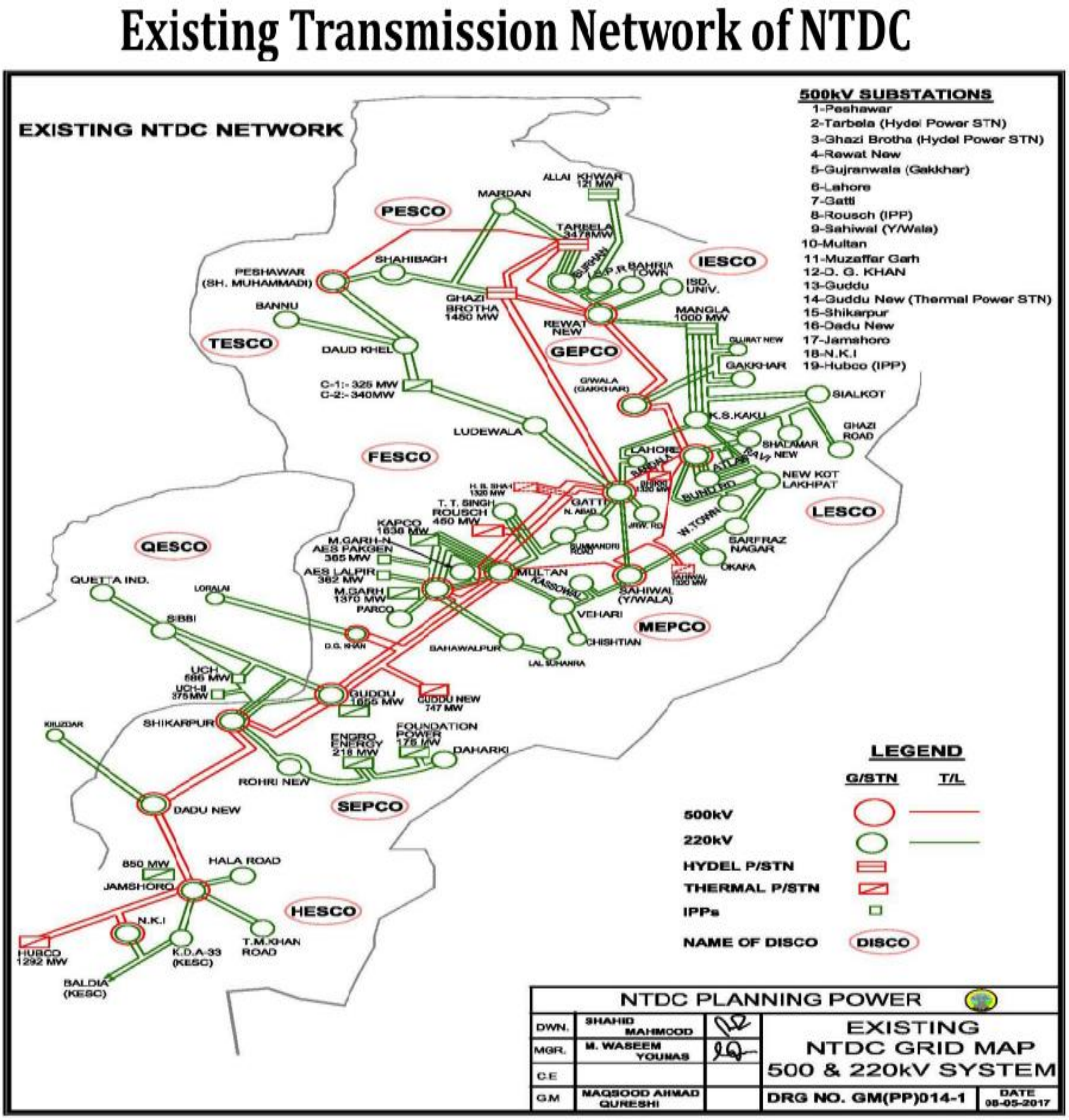


Figure 26: Pakistan National Grid Plan (as of May 2017)

Table 28: Energy generated by type of fuel[66]

Source	***Energy Generated in GWh (FY 2018-19)***	***Installed generation capacity in MW (FY 2018-19)***
Thermal	24,317 (34.13%)	7,792 (37.15%)
Nuclear	9,168 (12.87%)	1,415 (6.75%)
Hydel	32,577(45.69%)	9,769 (46.57%)
Solar	665 (0.93%)	400 (1.91%)
Wind	3,167 (4.44%)	1,235 (5.89%)
Bagasse	890 (1.25%)	364 (1.74%)
Import from Iran	486 (0.68%)	NA
Total	**71,250(100%)**	**20,975 (100%)**

Table 29: Transmission line length (circuit kms)[67]

Transmission Line Type	**Circuit km (FY 2019-20)**
500 kV	6290.00
220 kV	10928.00
132 kV	837.00
Total Transmission Line	**18055.00**

Table 30:Transformation capacity (MVA)[68]

Sub-station Type	**No. of Sub-station**(as of March 2020)	**Capacity (MVA)**(as of March 2020)
500 kV	16	22,950
220 kV	45	30,970
132 kV	722	50,278
66 kV	79	1,561
33 kV	40	216
Total	**902**	**1,05,975**

Table 31: Power Sector Snapshot of Pakistan[69]

Sr. No.	**Prevailing status**	**Pakistan (as of June 2020)**
1	Does the Country have an Integrated power system?	Yes
2	Transmission line loss levels (%)	2.57%
3	Transmission interconnections along with voltage levels	Iran to Pakistan - 132kV Iran to Pakistan -20kV Polan (Iran) to Gwadar (Pakistan) - 220 kV
4	Cross-border Import of Power	513.74 GWh from Iran during FY 2019-20

Sr. No.	Prevailing status	Pakistan (as of June 2020)
5	Cross-border Export of Power (MW)	No information available in public domain

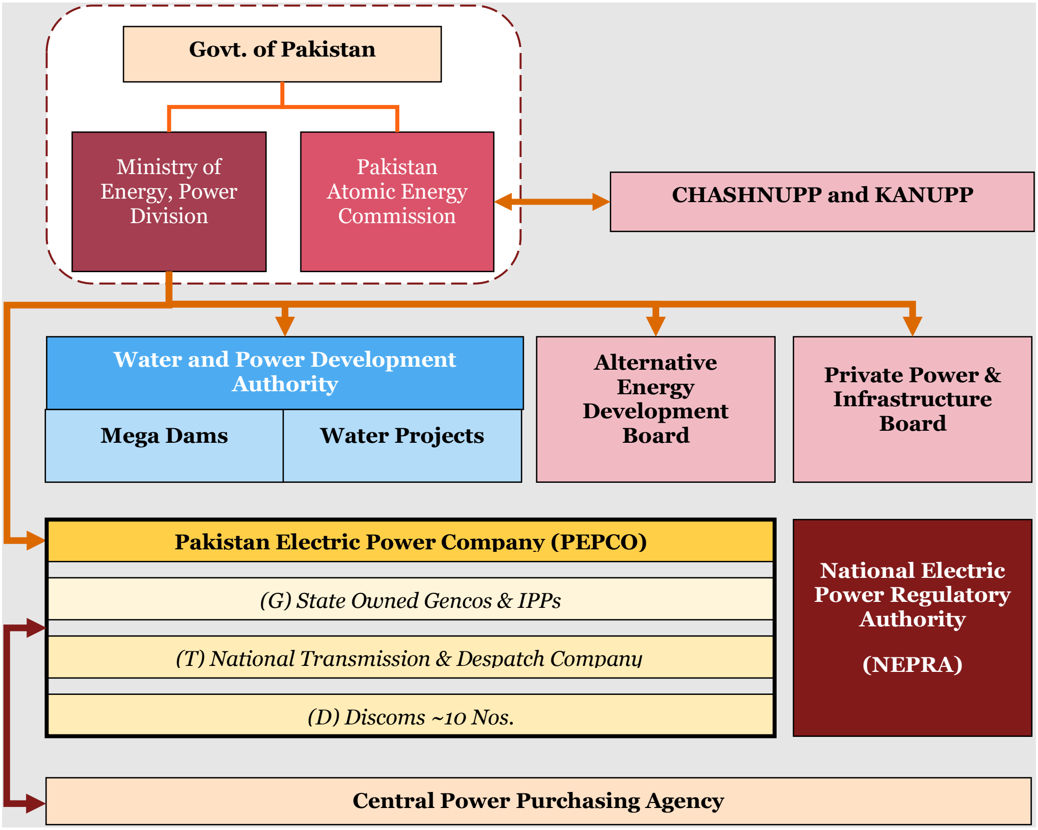
2.1.7.2. Legislative, policy, regulatory and other framework

Document type	Name of Document	Brief details
Apex Legal Document/ Act	Regulation of Generation, Transmission and Distribution of Electric Power Act, 1997 (Amended in 2012 & 2018)	Act provides for the regulation of generation, transmission, and distribution of electric power.
Grid Code	NTDC The Grid Code June, 2005	Code includes the following: 1. Operational parameters 2. Connection criterion 3. Planning Parameters 4. Protection and Metering standards 5. Scheduling and Despatch Code
Distribution Code	Distribution Code, 2005	The Code encompasses following areas: 1. Distribution Operation Code 2. Distribution Planning Criterion 3. Connection parameters 4. System performance, reliability, and consumer service requirement 5. System Maintenance and Testing
Safety	Power Safety Code for Transmission & Distribution Licensees 2015	The purpose of this safety code is to ensure that the license's network is planned, developed, operated, and maintained in an efficient & safe way without compromising on safety of any kind related to the systems, personnel & others.
Licensing	NEPRA Licensing (Application and Modification Procedure) Regulations, 1999	The regulation focus on provide procedure for licensing to Generation, Transmission and Distribution business
Market Operation	Commercial Code 2015 of CPPA-G	This commercial code shall be applicable on the existing market structure, i.e., the single buyer model as well as current practices being carried out by CPPA of NTDC. It provides the following rules:- 1. Market Participation & Termination conditions 2. Functions and responsibilities of CPPA-G 3. System for Commercial Metering

Document type	Name of Document	Brief details
		4. Commercial Transactions and Transfer Pricing 5. Settlement & Billing 6. Payment Mechanism 7. Reporting of Information

2.1.7.3. Institutions / stakeholders

Figure 27: Prevailing Institutional Structure of Pakistan's electricity sector



The National Electric Power Regulatory Authority (NEPRA) was established pursuant to the Regulation 3 of generation, transmission, distribution, grid discipline and cross-border electricity trade. National Transmission & Despatch Company Limited (NTDC) ensures transmission system reliability & safety and is committed to being a Transmission Network Operator (TNO). NTDC is also the System Operator (SO) with an objective to arrange non-discriminatory, non-preferential economic despatch ensuring safe, secure, and reliable supply. It also looks after system operation & despatch and transmission planning.

Central Power Purchasing Agency (CPPA-G) was incorporated in 1984 and is wholly owned by Government of Pakistan and presently functioning as the market operator in accordance with NEPRA Market Rules, 2015. Being the market operator, it facilitates the power market transition from the current single buyer to competitive market.

2.1.8. Sri Lanka

2.1.8.1. Snapshot of the power sector

The transmission division of Ceylon Electricity Board plans, develops, operates, and maintains all transmission assets of CEB, while maintaining high reliability of electricity supply in Sri Lanka. The division operates 220kV and 132kV grids, embracing all power stations and dispatches all electricity supplied to the grid through its System Control Centre. A snapshot of Sri Lanka's power sector is as follows:

Figure 28: Sri Lanka National Grid Plan[70]

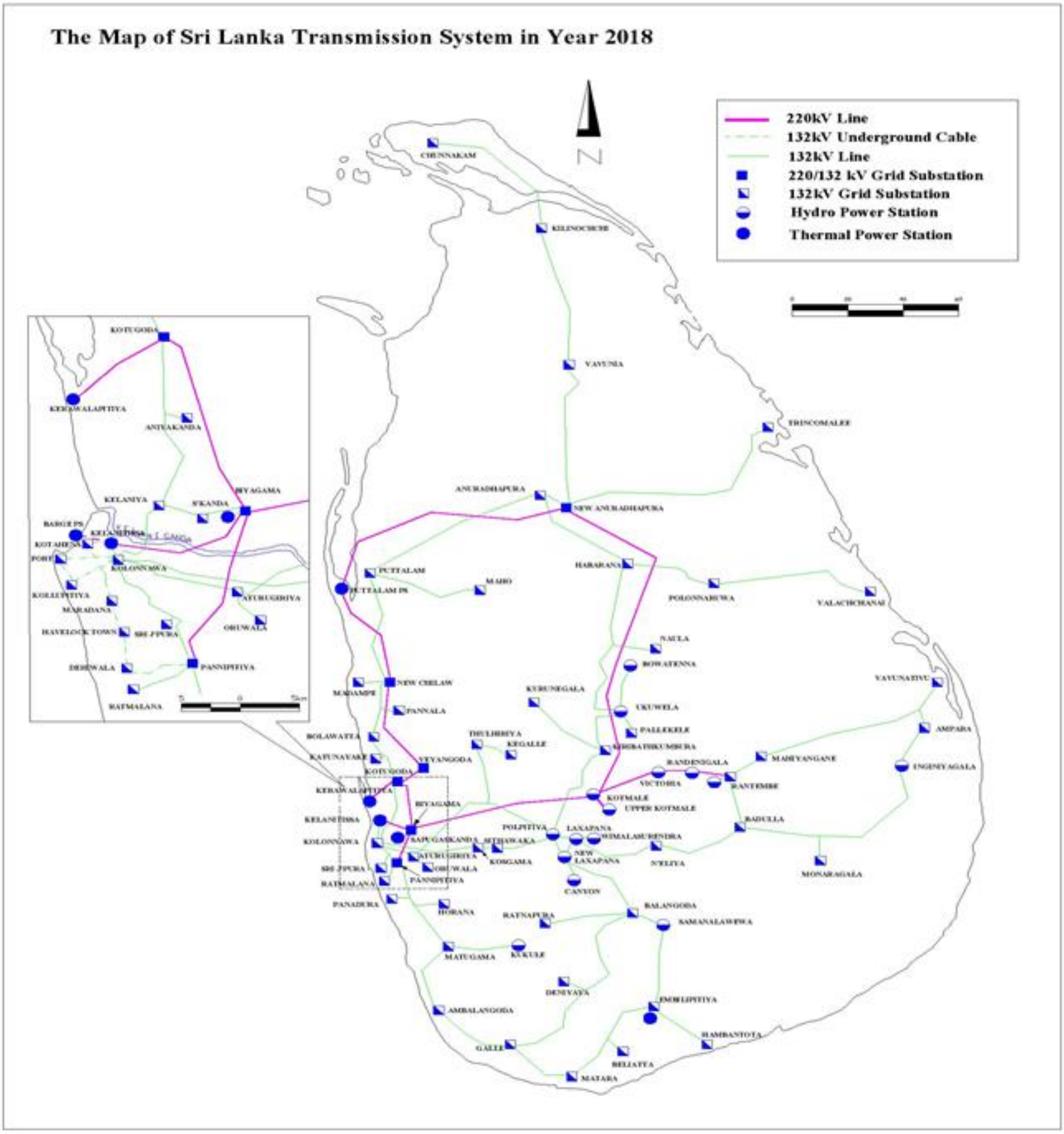


Table 32:Energy generated by type of fuel[71]

Fuel	***Energy Generated in GWh** (during CY 2018)*	***Installed Generation capacity in MW**(during CY 2018)*
Major Hydro	5,149 (33.49%)	1,399 (34.58%)
Mini Hydro	1,232 (8.01%)	394 (9.74%)
Thermal (Oil)	3,629(23.60%)	1,137 (28.10%)
Thermal (Coal)	4,764 (30.99%)	900 (22.24%)
RE (Except Mini Hydro)	600 (3.90%)	217 (5.36%)
Total	**15,374 (100%)**	**4,046 (100%)**

Table 33: Transmission line length (circuit kms)[72]

Transmission Line Type	**Circuit km (as in 2018)**
220 kV	601.00
132 kV	2338.00
Total Transmission Line	**2939.00**

Table 34: Transformation capacity (MVA)[73]

Sub-station Type	**No of Sub-station (as in 2018)**	**Capacity (MVA) (as in 2018)**
220/132 kV	4	1,510
220/132/33 kV	4	1,600
220/33 kV	1	75
132/33 kV	56	4,474
132/11 kV	5	369
33/11 kV	129	1,587
Total	**199**	**9,615**

Table 35: Power Sector Snapshot of Sri Lanka[74]

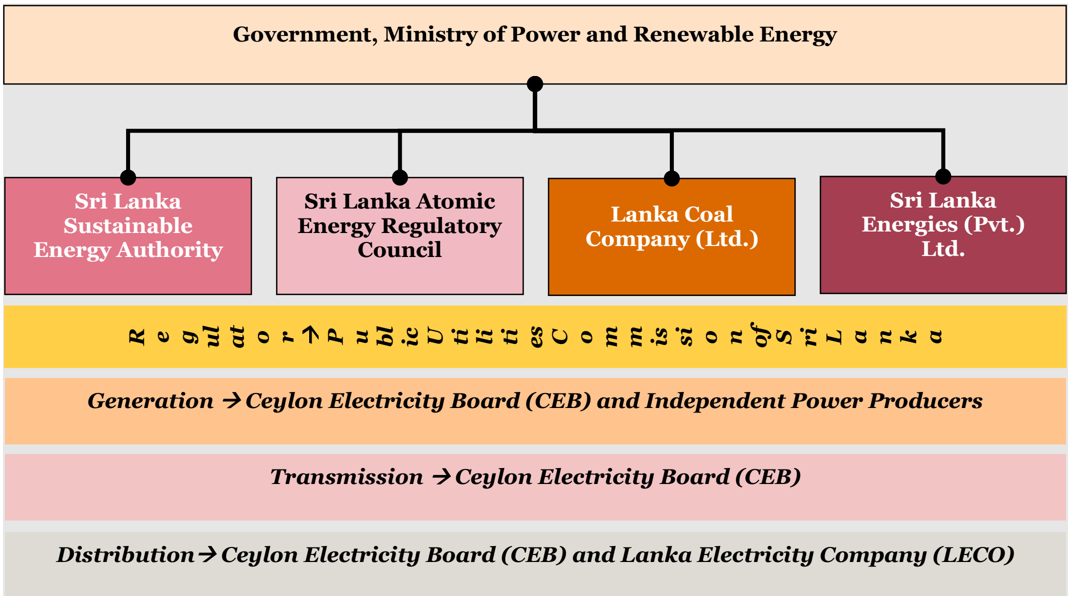
Sr. No.	**Prevailing status**	**Sri Lanka**
1	Does the Country have an Integrated power system?	Yes
	Transmission line loss levels (%)	8.34% is provisional data of Transmission & Distribution Losses (On net generation) as in 2018. Separate data for Transmission losses is not available.
3	Transmission interconnections along with voltage levels	Currently there is no interconnection with any other country. An interconnection from Madurai (India) to New Habarana (Sri Lanka) is under discussion.
4	Cross-border Import of Power (MW)	Not Applicable as Sri Lanka has no Transmission line connection with neighboring countries.
5	Cross-border Export of Power (MW)	

2.1.8.2. Legislative, policy, regulatory and other framework

Document type	Name of Document	Brief details
Apex Legal Document/ Act	Sri Lanka Electricity Act 2009	This regulation is for generation, transmission, distribution, supply and use of electricity in Sri Lanka. This act repeals the Electricity Reform of 2002.
	National Energy Policy & Strategies of Sri Lanka, 2008	National Energy Policy & Strategies of Sri Lanka 2008 spells out the implementing strategies, specific targets, and milestones through which the Government of Sri Lanka and its people would endeavour to develop and manage the energy sector in coming years in order to facilitate achieving its millennium development goals. Specific new initiatives are included in this policy to expand the delivery of affordable energy services to a larger share of the population, to improve energy sector planning, management, and regulation, and to revitalise biomass as a significant resource of commercial energy.
Grid Code	Grid Code of Sri Lanka, 2014	The Code encompasses following areas: 1. Planning code 2. Connection code 3. Operational parameters 4. Generation despatch code 5. Metering code 6. Planning and operational parameters 7. Information and data exchange
Planning Code	Transmission Planning Code, 2011	Planning code lays the foundation and methodology for transmission planning, it covers the following criterion: 1. Transmission plan boundaries 2. Planning period, frequency of updates and date of submission 3. Parameters for system modelling
Distribution Code	Distribution code of Sri Lanka, 2012	The Code encompasses following areas: 1. Distribution planning 2. Granting of connection 3. Operational parameters 4. Metering code 5. Planning and operation standards code 6. Information and data exchange
Licensing	Regulations for Electricity Applications for Licenses, Extensions of Licenses and Exemptions, 2009	It lays down the foundation of licensing generation, transmission, and distribution.

2.1.8.3. Institutions / stakeholders

Figure 29: Prevailing Institutional Structure of Sri Lanka's electricity sector



The Public Utilities Commission of Sri Lanka (PUCSL) regulates the energy sector, while larger policy decisions are undertaken by the Ministry of Power and Energy. The Ceylon Electricity Board (CEB), which is a vertically integrated utility (partially unbundled sector) acts as the single buyer, procuring power from all generating stations, for supply to distribution utilities. Lanka Electricity Company Private Limited (LECO) is a Company incorporated in 1983 for the purpose of electricity distribution in some parts of Colombo.

The system control centre of the transmission division plans and carries out the operation of generation and transmission systems in order to achieve reliability, quality, and operational economy. Archiving the generation and transmission data and the preparation of regular management information is also carried out by the division.

2.2. Step-2(a): Identify key indicators defining grid discipline and grid reliability

2.2.1. Frequency Variation

Power frequency reflects the load-generation balance in the grid at a particular instant. Frequency is one of the most important parameters for assessment of the security of power system and the quality of power supply in any grid. Frequency being a critical indicator for grid discipline and grid reliability, it does have impact on generator voltage and passive transmission network elements.

In present day most of generating stations are interconnected for optimum utilisation. Due to imbalance in generation and load resulting in variation in grid frequency, this change in frequency impacts reactive power capabilities of the generators. Passive elements of transmission network like transformers, capacitors, reactors, line etc. are basically combination of resistance, reactance, and capacitance. The impedance value of the passive network elements could be changed with respect to frequency because they have a linear correlation.

In order to ensure that all the electrical equipment perform safely and efficiently, the grid frequency is to be maintained within the specified range.

Frequency Variation is measured by the percentage of times the frequency breaches the given limits[75]. Provisions pertaining to frequency variation present in the regulations, rules, codes and standards in each of the SAR country are covered in sub-section 2.3.1.4of this chapter.

2.2.2. Voltage Variation

Voltage Variation can occur due to multiple reasons in the power system such as inadequate supply of reactive power, mismatched transformer taps and impedances, blown capacitor fuses, open-delta regulators, or open-delta transformers, overloaded/underloaded circuits, etc. These may lead to malfunctioning of equipment, like in transformers, voltage variation could result in saturation of magnetic core thereby increasing the magnetizing current and losses. Continued operation in over excited region can result in failure of unit, unwanted tripping due to mal operation of relays results in loss of load, failure of rotating machines by damaging their insulations, breakdown of the network from weakest points etc.

Voltage Variation is measured by the percentage of times the voltage breaches the normal operating limits and contingency limits. Provisions pertaining voltage variation present in the regulations, rules, codes and standards in each of the SAR country are covered in sub-section 2.3.1.5of this chapter.

2.2.3. Planning Reserve Margin

Planning reserve margin is designed to measure the amount of generation capacity available to meet expected demand in planning horizon.[76]

Reserve Margin (%) = (Capacity - Load) / Load x 100

The percentage provides an indication of the additional capacity available to meet unforeseen increases in demand, unforeseen outages of existing capacity, and trends which will identify whether capacity additions are keeping up with load growth. As this is a capacity-based metric, it does not provide an accurate assessment of performance in energy limited systems, e.g., hydro capacity with limited water resources. Approaches adopted for reserve margin are captured individually for each SAR country under sub-section 2.3.5.1 (ancillary services mechanism/ market for frequency control) of this chapter.

2.2.4. Frequency Response characteristics of the grid

Frequency Response is a measure of an interconnection's ability to stabilize frequency immediately following sudden loss of generation or load. It is defined as sum of the change in demand, plus the change in generation, divided by the change in frequency, expressed in megawatts per Hertz (MW/Hz).[77]

It is a critical component to the reliable operation of the bulk power system, particularly during disturbances and restoration. Strategies adopted for modulating frequency response are captured individually for each SAR country under sub-section 2.3.5.1 (ancillary services mechanism/ market for frequency control) of this chapter.

2.2.5. Partial or Complete Grid Disturbance

Transmission outages can occur either due to tripping of an equipment due to an actual fault, when the protection system has autocorrected, due to failed protection system equipment, due to improper maintenance of equipment or due to human error. The normalized count provides an indication of the relative protection system equipment performance or the human factor performance, specifically the AC transmission element outage rate for momentary and sustained outages initiated by either failed protection system equipment or human error.

These are measured in number of outages and the duration of outages. Further, details regarding partial or complete grid disturbances also helps keep repository of information regarding factors contributing to the disturbance. Provisions pertaining to partial or complete grid disturbance present in the regulations, rules, codes and standards in each of the SAR country are covered in sub-section 2.3.5.6 of this chapter.

2.2.6. Tripping per line and Tripping duration per line

Tripping means the interruption in electricity supply. An electric line is tripped if it starts carrying the fault current or gets overloaded or it gets broken or due to several other reasons like improper maintenance or false tripping due to protection system not operating properly. Tripping per line is the count of interruption over a period of time (daily / weekly/ monthly/ yearly). Tripping duration is the interval of time for how much duration an electric line is tripped.

The frequency and duration of tripping over a period of time provides an indication of performance measured at a balancing area level or interconnection level. As historical data is gathered, trends in future reports will provide an indication of either decreasing or increasing adequacy in the electric supply system. The metriccan also provide the amount of unserved energy due to tripping.

Unserved energy = Firm load interruption (MW) x duration (hour)

Provisions pertaining to tripping per line and tripping duration per line are present in the regulations, rules, codes and standards in each of the SAR country are covered in sub-section 2.3.5.8 of this chapter.

2.2.7. Angular Stability

A Phasor Measurement Unit (PMU) measures voltage and current signals and estimates a time-synchronized phasor representation (magnitude and phase angle) of these electrical quantities. These voltage and current phasors are referred to as synchro phasors.

> PMU phase angle differences are a useful quantity to monitor immediately following an unplanned and/or unstudied forced outage event. Phase angle difference is a means to measure angular stability. The real-time angle difference between nodes sampled from widely dispersed locations in the power system network and synchronized from the common time source of a Global Positioning System (GPS) radio clock provides the system operator with an immediate awareness of system strength and stress. Provisions pertaining to phase angle difference present in the regulations, rules, codes, and standards2.3.5.9 of this chapter.

2.2.8. System Adequacy

System adequacy is the ability of the electricity system to supply the aggregate electrical demand and energy requirements of the end-use customers at all times, considering scheduled and reasonably expected unscheduled outages of system elements. For system adequacy system operators can and should take controlled actions or procedures to maintain a continual balance between supply and demand within its control area by public appeals and interruptible demand (i.e., customer demand in accordance with contractual arrangements, can be interrupted by direct control of the system operator or by action of the customer at the direct request of the system operator).

Provision related to demand estimation or load forecasting for maintaining power system tolerability are captured under sub-section assessing level of implementation and compliance of identified measures for system operation (in chapter 3) foreach of the individual countries in SAR separately.

2.2.9. Total Harmonic Distortion (THD)

Voltage and current harmonic distortion can be quantified by Total Harmonic Distortion or THD. Current harmonics in the system are produced by nonlinear loads and causes power pollution akin to air pollution caused by automobile emission. On the other hand, voltage harmonic is a sinusoidal component of a periodic voltage waveform having a frequency that is an integral multiple of the fundamental frequency. It is the deviation from the original or pure voltage sine waveform. Generally, at the source point, the Voltage harmonics is absent. Provisions pertaining to harmonics present in the regulations, rules, codes, and standards in each of the SAR country are covered in sub-section 2.3.5.10 of this chapter.

2.3. Step-2(b): Identify key measures to achieve grid discipline and grid reliability

On the basis of the Step-1 and Step-2(a), we have designed a framework to identify key measures to achieve grid discipline and grid reliability. This will form the basis for comparison for the SAR.

We have categorized various measures required to be taken to achieve grid discipline and reliability in to the following eight groups:

1. *System planning*
2. *System construction and safety*
3. *Grid connection*
4. *System protection, testing and commissioning*
5. *System operation*
6. *Scheduling and despatch*
7. *Information and communications technology*
8. *Monitoring and compliance*

2.3.1. System planning

Power system is an essential and critical infrastructure upon which other strategic infrastructure services of our society depends. Components of the bulk electric system - which comprises of generating stations (i.e., power plants) and extra-high voltage transmission lines - have a typical life span averaging 40-60 years. Since the current decisions have long-term effects, system planning is important in maintaining the necessary flexibility required for a reliable and robust transmission system. Therefore, the objective of system planning is to make the best network design decisions today after considering all the possible future needs and expansion scenarios of the generation resources. System planning document shall cover the planning philosophy, the information required from various entities, permissible limits, reliability criteria, broad scope of system studies, modelling and analysis, and it should provide guidelines for transmission planning.

2.3.1.1. Contingency Criteria

Due to unplanned loss of generation or load in the power system, the entire system may face an outage. In order to avoid such circumstances, the power system is planned considering N-1 or N-2 contingency criteria wherein the power system can work efficiently even with loss of one/two elements respectively.

Country	Provision for Contingencies (n-1, n-2 etc.) at Planning Stage
Afghanistan	No information available in public domain
Bangladesh	• Single outage contingencies of facilities (N-1) were considered under clause 9.1.2 Planning Criteria of Power System Master Plan 2010 with following technical parameters:

Country	Provision for Contingencies (n-1, n-2 etc.) at Planning Stage
	- Facilities loading < 100% - Steady-state voltage range: +/- 10% - Transiently stable to 3-phase to ground fault with normal clearing • Section 9 of the Bangladesh Electricity Grid Code Regulations, 2019 specifies the strategy for contingency planning.
CBET (India-Bangladesh)	For international interconnect N-1 contingency has been considered at project feasibility stage. But limitation of N-1 contingency is also observed, interconnect study also highlights transmission constraints hinder transfer of additional capacity due to present N-1 contingency. [Source: Conclusion of Report on the feasibility of Additional Interconnection between India and Bangladesh, https://www.cea.nic.in/reports/committee/scm/ner/agenda_note/annex3.pdf]
Bhutan	• System requirements have been evolved considering (n-1) contingency as per references found in Clause 5.1 Planning Approach and Conclusion of National Transmission Grid Master Plan 2018. • Clause 4.5.3 (ii) of the Bhutan Grid Code Regulations 2008 states that the Transmission licensee shall conduct Grid planning study assessing the behaviour of Transmission System during normal and outage-contingency conditions.
India	• Clause 3.3.4 Criteria for steady-state and transient-state behaviour of National Electricity Plan 2019 have considered the following criterion: 1. Criteria for single contingency ('N-1') including Steady-state and Transient-state 2. Criteria for second contingency ('N-1-1') • The Indian Electricity Grid Code (IEGC) 2010 considers the contingency as a planning criterion • Clause 6 of the Manual on Transmission Planning Criteria published by CEA provides the reliability criteria and defines criteria for system with on contingency ('N-0'), criteria for single contingency ('N-1') and criteria for second contingency ('N-1-1') and criteria for generation radially connected with the grid.
Maldives	• Currently Maldives does not have transmission grid
Nepal	• Clause 3.6 "Planning Studies" of NEA Grid code mandates for N-1 contingency criteria for radial lines that supply more than 50 MW load. Where a second circuit can be added to existing towers, a minimum of 35 MW load is required for justification of (N-1) supply on radial circuits. Transformer installations shall comply with (N-1) criteria either through installation of excess capacity in the order of the largest transformer unit in the same region or transformer spares shall be shared in the same region. • Clause 6.1 "N-1 contingency" of RPGCLs Transmission System Development Plan have specified about N-1 and Considered Transmission Line N-1 contingency • Outage of one of the two circuits of the major transmission lines at 220kV or 400kV levels is considered, assuming that all major transmission lines have a double circuit design. • Transmission System Development Plan of Nepal (July 2018) specifies outage of one of the two circuits of the major transmission lines at 220kV or 400kV levels assuming that all major transmission lines have a double circuit design as N-1 contingency. For such contingencies, the acceptable post-fault condition of the network should be such that the power flow in the other circuit should be within 120% of its thermal rating, i.e., their

Country	Provision for Contingencies (n-1, n-2 etc.) at Planning Stage
	emergency loading limit, whereas other functioning transmission lines should be operating within 100% of their thermal rating without load shedding or rescheduling of generation. Further, Tower contingency is specified as to occur when both circuits of a double circuit transmission system suffer outage at the same time. For such contingencies, the acceptable post-fault condition of the network should be such that other functioning transmission lines should be operating within 120% of their thermal rating, i.e., their emergency loading limit.
Pakistan	Clause PC 2.1 Contingency Conditions of the Grid Code suggests that planning is based on N-0 and N-1 contingencies and the same is considered for National Power System Expansion Plan 2011 - 2030.
Sri Lanka	As per Chapter 4 Transmission System Analysis clause 4.1 of Long -Term Transmission Development Plan 2013-2022, N-1 contingency level for planning purposes is adopted in the plan.

2.3.1.2. System planning studies for addition of generation capacity from renewable energy sources

The world is gradually moving towards 100% clean energy, i.e., using only renewable energy sources for electricity generation. The RES such as solar and wind power are intermittent and variable in nature and that brings formidable challenges in the operation of power system. Hence, the system planning studies are to be carried out to understand and acquire the optimal generation mix and addition of generation capacities from renewable energy sources.

Country	System planning studies for addition of generation capacity from renewable energy sources
Afghanistan	No information available in public domain.
Bangladesh	• In the Power System Master Plan of 2016 renewable energy capacity addition had been considered by using the RE10 scenario increasing 10% Renewable energy and the RE20 scenario increasing 20% renewable energy. • As per Revisiting Power System Master Plan (PSMP) 2016 which was published in 2018 under clause 10.2.1 Renewable Targeted Generation Capacity defines renewable energy policy target 10%, as per plan the renewable based capacity will be 9,400 MW by 2041 and 2,800 MW by 2021.
Bhutan	• The Alternative Renewable Energy Policy, 2013 aims to develop RE Master Plan for each of the RE technologies by mapping capacity, generation potential and cost of generation by location across the Kingdom of Bhutan
India	• National Electricity Plan of 2019 considered the Renewable Energy Integration
Maldives	Currently Maldives does not have transmission grid
Nepal	• In Nepal, alternative energy like solar and wind are used as distributed sources and are mostly used in rural electrification. RPGCL's Transmission System Development Plan for Nepal report considered Solar generation of 0.6 MW for 2018

Country	System planning studies for addition of generation capacity from renewable energy sources
	• As per the information available on website of Department of Electricity Development, as of July 15, 2020, just over a 100 MW of solar plant have received generation license from Nepal Government while other projects with 375.62 MW capacity have received survey license and are currently under study. 9 MW renewable energy projects, which include wind and cogeneration have also received generation license while different projects with total capacity 18 MW are being studied. All these plants are being studied or are studied with intention of being connected to the Integrated Nepal Power System.
Pakistan	• Under clause 6.7.3 Other Generation Options of National Power System Expansion Plan 2011-30 scope for Power Import, Wind Energy Generation and Other Renewable Energy Resources like Biomass, Solar and Geothermal are also explored. Both National Electric Power Regulatory Authority (NEPRA) and National Transmission and Despatch Company (NTDC) understood the integration challenges of RE, therefore in August 2017 an amendment in Grid code was done for Wind Power Plants (Grid Code Addendum No.1 (Revision-1) for Grid Integration of Wind Power Plants).
Sri Lanka	• Prevailing Transmission Plan 2013-22 has considered addition of Renewable integration during the course of time.

2.3.1.3. System planning studies for CBET (cross-border electricity trade) growth

Cross-border Electricity Trade is increasing in the SA Region in the past years. CBET brings multiple challenges such as lack of harmonization of regulations between countries, varying generation mix of countries, mismatch in load curves (peak, off-peak), lack of adequate transmission interconnections between countries, etc. Hence, system planning studies for CBET growth are to be carried out by countries to address these challenges and to maintain reliability of the system.

Country	System planning studies for CBET
Afghanistan	No information available in public domain.
Bangladesh	Currently there is CBET with India. In March 2018, Bangladesh agreed[78] for trilateral CBET with Myanmar and China along with India as transit.
CBET (India-Bangladesh	Based on the location of interconnect, system studies outlining load flow considerations based on two scenarios. For instance, in Report on the feasibility of Additional Interconnection between India and Bangladesh two scenarios were considered one for high hydro and low hydro generation situations. Scenario based system studies done to ensure loading of related transmission lines remain in allowable limits. [Source: Conclusion of Report on the feasibility of Additional Interconnection between India and Bangladesh, https://www.cea.nic.in/reports/committee/scm/ner/agenda_note/annex3.pdf]
Bhutan	The National Transmission Grid Master plan 2018 considers CBET for system planning

Country	System planning studies for CBET
India	National Electricity Plan of 2019 considered the following scenarios: 1. CBTE Transactions (Page 243) 2. Energy Storage Systems (Clause 4.4) 3. Trade with Bangladesh, Bhutan, and Nepal.
Maldives	Currently Maldives does not have transmission grid
Nepal	As per Transmission System Development Plan of Nepal[79], Transmission System Master Plan and Nepal-India JTT have identified 6 locations for the cross-border power transmission with India. The Transmission System Development plan prepared by RPGCL has explored new cross-border transmission line with India.
Pakistan	Import from Iran and Tajikistan via Afghanistan has been envisaged (ongoing transaction).
Sri Lanka	Planning for India-Sri Lanka interconnector for transactions through overhead lines.[80]

2.3.1.4. Frequency variation limits

Every country follows different frequency variation limits to ensure and maintain grid discipline and reliability. Various measures are incorporated to maintain steady frequency. During interconnection of the countries, these variation limits need to be harmonized to ensure no harm is caused to equipment and the power system of either of the countries.

Country	Frequency variation limits
Afghanistan	No information available in public domain.
Bangladesh	Chapter 17 of Bangladesh Electricity Grid Code Regulations, 2018 lays down the performance standards for transmission and clause 17.2.2 states that the Transmission System frequency shall normally be 50.0 Hz and shall normally be controlled in the range 49.5 Hz. - 50.5 Hz. (50 Hz. ± 1%).
Bhutan	Clause 5.13.3 and 6.4.1 of Bhutan Grid Code regulations 2008 states that Rated frequency of the system shall be 50.0 Hz and shall normally be controlled within the following limits: - a) 49.5 Hz to 50.5 Hz in Normal State, b) 49.0 Hz to 51.0 Hz in Alert State and c) the transmission system shall be considered to be in Emergency state if there is a generation deficiency and frequency is below 49.0 Hz
India	As per IEGC 2010, the frequency variation limits are 49.9 Hz. - 50.05 Hz. The nominal frequency band has been narrowed to 49.95-50.05 Hz band in the Expert Group Report: Review of IEGC, January 2020.
Maldives	Currently Maldives does not have transmission grid
Nepal	Clause 4.3.2 “Frequency Variation” of NEA Grid code mandates System Operator shall ensure that the fundamental frequency in the System is maintained between 48.75 Hz and 51.25 i.e., +/- 2.5% of 50 Hz, which is the nominal value of fundamental frequency.

Country	Frequency variation limits
Pakistan	CC 5.4 of Grid Code 2005 mandates that the Frequency shall be nominally 50 Hz and shall be maintained within the limits of 49.8 Hz - 50.2 Hz unless exceptional circumstances prevail.
Sri Lanka	Section 3 of the Grid Code specifies the Frequency variation limits as follows: - Normal System Condition- 49.5 Hz - 50.5 Hz, Emergency Conditions- 50.5Hz - 52.0 Hz and 47.0 Hz - 49.5 Hz

2.3.1.5. Voltage variation limits

Voltage varies throughout the grid with transformers used to change voltages. Variation, fluctuations, and imbalance in voltage affects the power system and may result in in malfunction or damage to electrical devices. Therefore, the voltage is to be maintained within the specifies limits to ensure discipline and reliability in the system.

Country	Voltage variation limits
Afghanistan	No information available in public domain.
Bangladesh	Chapter 17 of Bangladesh Electricity Grid Code Regulations, 2018 lays down the performance standards for transmission and clause 17.2.3 states that the voltage variation limits as 95%-105% of nominal voltage at any connection point during normal conditions.
Bhutan	Clause 5.13.4 and 6.4.1 of Bhutan Grid Code regulations 2008 states that: a) The voltage at all connection points are within the limits of 0.95 times and 1.05 times of the nominal values in Normal state b) The voltage at connection points are outside the normal limit but within the limits of 0.9 times and 1.1 times of the nominal values in Alert state c) Transmission System voltage are outside the limit of 0.9 times and 1.1 times of nominal values in Emergency state
India	The IEGC 2010 and its amendments specifies the minimum design and technical criteria for grid connection and specifies the Voltage Variation limits as+/- 5% for 765 kV & 400 kV and +/- 8% to 11% for 220 kV & 132 kV.
Maldives	Currently Maldives does not have transmission grid
Nepal	• Regulation 42 of Electricity Regulation, 2050 (1993) specifies that the standard of the voltage in the high voltage transmission system shall be transmitted at 33 kV, 66 kV, 132 kV, 220 kV, 400 kV • Clause 4.3.1 "Voltage Variation" of the NEA Grid code specify that fluctuation shall not be allowed for more than ten percent (10%) of standard voltage.
Pakistan	CC 5.4 of Grid Code 2005 mandates that under normal operating conditions, the system operating voltage shall be maintained within the bandwidth of +8% to -5% of nominal system voltage. Under (N-1) contingency operating conditions, the Voltage variation shall be in the range of +/-10% of nominal system voltage.
Sri Lanka	Section 3.6.2 of the Grid Code specifies the Voltage variation limits as follows: - a) +/-6% for 11kV, 22kV and 33kV, b) +/-10% for 132kV, 220 kV and 400 kV

2.3.1.6. Estimation and declaration of transmission capabilities in advance

Estimation and Declaration of transmission capabilities in advance helps in planning for power evacuation and planning of power transfer from transmission corridors.

Country	Estimation and declaration of transmission capabilities in advance
Afghanistan	No information available in public domain.
Bangladesh	No clause is given for Estimation and Declaration of transmission capabilities in advance in the Grid code
Bhutan	As per Clause 7.5.2 of the Bhutan Grid Code regulations 2008, the total energy capability and anticipated hourly power capability that can be delivered to the Transmission System, on an Ex-Power Plant basis, shall be calculated after deducting the above local demands.
India	Regulation 5.3 (h) of IEGC 2010 states that in order to facilitate estimation of Total Transfer Capability /Available Transfer Capability on three months ahead basis, the SLDC shall furnish estimated demand and availability data to RLDCs. Central Electricity Authority Procedure for approval and facilitating Import/Export (Cross Border) of Electricity) by the Designated Authority notified on 26th February, 2021 has mandated that, Total Transfer Capability (TTC), Transmission Reliability Margins (TRM) and Available Transfer Capability (ATC) for the cross-border interconnection shall be assessed and exchanged by the System Operators of the participating countries. Accordingly, POSOCO has assessed the cross border TTC/ ATC with grids of neighbouring countries.
Maldives	Currently Maldives does not have transmission grid
Nepal	Clause 3.6.1 "General Planning Criteria (T-3)" of the NEA Grid code states that studies related to Maximum transfer capability of transmission lines shall be carried out periodically and prior to authorizing any new connection point or modifying in the existing connection point.
Pakistan	CC 4.5 of Grid Code 2005 states that the augmentation or the required extensions of the affected transmission networks to provide appropriate transfer capabilities to other Code Participants with the new connection in place shall be carried out by NTDC;
Sri Lanka	No clause is given for Estimation and Declaration of transmission capabilities in advance in the Grid code

2.3.2. System construction and safety

2.3.2.1. General safety requirements pertaining to construction, installation, protection, operation and maintenance of electric lines

Country	General safety requirements
Afghanistan	No information available in public domain.
Bangladesh	Clause 17.5.1 of Bangladesh Electricity Grid Code Regulations, 2019 states that the Electricity Rules 1937 and revisions thereof govern the safety requirements for electrical installation, operation, and maintenance which covers electrical equipment and associated work practices employed by the electric utility.

Country	General safety requirements
Bhutan	• Clause 3.3.1 and 6.4.1 of Bhutan Grid Code regulations 2008 states that the BEA is responsible for developing regulation standards, codes, principles, and procedures for minimum technical and safety requirements for construction operation and maintenance of generation, transmission, and distribution facilities. • BEA Safety Regulation 2008 makes provisions for the design, construction, operation and maintenance of electric power plant and equipment in a manner that is Electrically Safe. • BEA Safety Code 2008 specifies the Authority's minimum electrical safety requirements for the design, construction, operation and maintenance of electric power plant and equipment under the control of Licensees
India	• Clause 2.6.1.-(1)-(ii) of the IEGC 2010 and its amendments states that CEA specifies the safety requirements for construction, operation and maintenance of electrical plants and electric lines • CTU/STU and the concerned Users shall be responsible for safety in accordance with CEA Regulation 2007 & 2008 and CERC Regulation 2009.
Maldives	No information available in public domain.
Nepal	• Section 4.5 of the NEA Grid Code mandates that The Grid Owner shall operate and maintain the Grid in a safe manner in accordance with the provisions in the Electricity Regulation 2050 (1993) and any amendments thereof. Other provisions not covered by the regulation shall be in accordance with the Best Industry Practice. • Chapter 5 and 6 of Electricity Regulation, 2050 (1993) specifies the safety measures regarding electric devices and safety provisions relating to electrical works respectively • Clause 6.11.1.1 of the NEA Grid Code specifies that the Grid Owner and User(s) shall each develop and adopt safety rules and safety instructions for implementation of safety precautions on their HV Line/Equipment.
Pakistan	• 'Guidelines for Power Safety Code for Transmission & Distribution Licensees 2015' is published by NEPRA is available in the public domain • In this Power Safety Code, Guidelines/ Instructions have been provided in each section with sufficient details. • On the basis of this Safety Code, a Safety Manual is to be prepared by each licensee depending upon its own requirements, and the same has to be approved by NEPRA • Similarly, a safety manual is to be prepared by other users of the transmission and distribution system and approved by Licensee when carrying out works or tests at the operational interface with the licensee.
Sri Lanka	Clause 4.18.1 of Grid Code mandates the Transmission Licensee to abide by the existing CEB Safety Manual (the "Safety Manual") applicable to the Transmission System.

2.3.3. Grid connection

2.3.3.1. Detailed procedure for grid connections including RE Generating Companies - Time Frame of processing of application, Standard formats for applicants and model connection agreement

With increasing demand of electricity and addition of renewable generation sources, the connections to the grid have been growing. The existing transmission system should not be adversely affected due to addition of a new generators and consumers. To ensure that the system remains stable as the system complexity increases, certain connectivity and operational criteria are to be developed as well. Detailed procedure for grid connections including RE generating companies, time frame for processing of applications, and standard format/ form and model connection agreement are made to standardized connection to the grid and to bring in certainty in the system. These will help maintain grid reliability.

Country	Detailed procedure for grid connections
Afghanistan	No information available in public domain.
Bangladesh	• Detailed procedures and requirements for interconnection are laid down for various users like the generators (new/existing power station), Distribution utility, Bulk Power consumers, etc. in Bangladesh Electricity Grid Code Regulations, 2019. • As per clause 5.7.1 of the Grid Code, the User seeking to establish or modify connection shall submit an application in standard format. • Connection agreements are signed with submission of site responsibility schedule mentioning the ownership and responsibility of equipment. • Section 5.11 of the Grid Code gives procedure for international and inter-regional connections and states that the execution of agreement shall be done by the Licensee in consultation with BPDP (single buyer) and line ministry.
Bhutan	• Detailed procedure for users seeking interconnection is given in the Bhutan Electricity Authority Grid Code Regulation 2008. • Clause 5.4 and 5.5 of BEA Grid Code Regulations 2008 specifies that, application is to be submitted by the user in standard format to the transmission licensee and a connection agreement is signed between the user and the transmission licensee.
India	• The Connection Code of the Indian Electricity Grid Code (IEGC) 2010 gives the detailed guidelines and procedures for CTU, STU and all Users connected to or seeking connection to the Inter State Transmission System (ISTS). • Any User seeking a new connection or modification of an existing connection or for use of ISTS shall submit an application in standard format to CTU in accordance with the CERC (Grant of Connectivity, Long-term Access and Medium-term Open Access in inter-state Transmission and related matters) Regulations, 2009. • A connection agreement is signed by the consumer. • The procedure for international Connection to ISTS and the execution of agreement for the same shall be determined by CTU in consultation with CEA and Ministry of Power (MOP).
Maldives	Currently Maldives does not have transmission grid.
Nepal	• Detailed procedure is in place for users seeking interconnection in chapter 5 “Grid Connection Requirement” of NEA Grid Code 2005. • Application is to be submitted in standard format to the Grid Owner and an agreement has to be signed between the consumer and the licensee. • Application are sent to Grid Operation Department to provide connection facilities to IPPs and bulk consumers at different voltage levels by accomplishing connection agreement as per NEA grid code.
Pakistan	• The Connection Code (CC 1) of the Grid Code,2005 states that NTDC shall negotiate a Connection Agreement with the entity requesting a connection agreement with the

Country	Detailed procedure for grid connections
	NTDC transmission system in accordance with the provisions of NTDC transmission licensee. • CC 4.1 of the Grid Code, 2005 states that Generators, Distribution Companies, BPCs and SPTL shall submit the Connection application to NTDC if connecting directly to NTDC's Transmission System. Whereas the application shall be submitted to the respective Distribution Companies and NTDC simultaneously if connecting indirectly.
Sri Lanka	• Appendix C of the Grid Code states that Any User seeking a new connection or modification of an existing connection shall submit a formal application to the Transmission Licensee. • A connection agreement is signed between the consumer and the licensee.

2.3.3.2. Details of test required for conventional and non-conventional energy sources prior to trial run for declaration of commercial operation

System tests involve simulating conditions or the controlled application of unusual or extreme conditions that may have an impact on the grid or the user system. A number of tests are considered while connecting the conventional and non-conventional energy sources to the transmission grid to ensure grid discipline and reliability.

Country	Details of test required for conventional and non-conventional energy sources
Afghanistan	No information available in public domain.

Bangladesh	• Section 14.5 of Bangladesh Electricity Grid Code Regulations, 2019 lays down the test procedures for conventional generators. These are as follows:
	  • Declared Available Capacity Testing
	  • Schedule and Dispatch Instruction Testing
	  • Reactive Power Testing
	  • Automatic Frequency Sensitive Testing
	  • Fast Start Capability Testing
	  • Black Start Testing
	  • Synchronization Time and Ramp Rate
	• Section 14.6 of Bangladesh Electricity Grid Code Regulations, 2019 lays down the test procedures for VRE generators. These are as follows:
	  • Reactive power test
	  • Active power control test
	  • Voltage Control test
	  • Frequency withstands capability tests
	  • Low Voltage Ride Through and performance under disturbances capability tests

Bhutan	• Section 5.13 of Bhutan Grid Code regulations 2008 lays down the conditions for connection to the transmission system. These include Reactive power capability limits, Frequency, and voltage variation limits, etc.
India	The CEA (Technical Standards for Connectivity to the Grid) Regulations, 2007 states that the requester shall complete all inspections and tests finalised in consultation with the

Country	Details of test required for conventional and non-conventional energy sources
	Appropriate Transmission Utility or licensee or generating station to which its equipment is connected before grid connectivity
Maldives	Currently Maldives does not have transmission grid.
Nepal	• Chapter 8 "System Test" of the NEA Grid Code specifies the details of system tests conducted. These are as follows: • Declared Availability Capacity Testing • Schedule and Dispatch Instruction Testing • Reactive Power Testing • Primary Response Testing • Fast Start Capability Testing • Black Start Capability Testing • Isolation Mode Operation

Pakistan	• OC 12 of Grid Code 2005 lays down the following tests:
	  • Reactive capability
	  • Governor system testing
	  • Fast start capability test
	  • Black start capability test
	  • Synchronization time
	  • Run-up and run-down rate testing

Sri Lanka	• Section 3.16 of the Grid Code lays down the following tests for conventional generators:
	  • Frequency Variation capability
	  • Voltage Variation capability
	  • Power factor Variation capability
	  • Unbalanced loading capability
	  • Load following capability
	  • Fault ride-through capability
	  • Black start capability
	  • Line charging capability
	  • Synchronizing
	• Section 3.17 of the Grid Code lays down the following tests for Intermittent Resource Based Generating Systems(IRBGS) generators:
	  • Power factor variation capability
	  • Reactive power capability
	  • Current distortion limits
	  • Emission limits of fluctuating loads

2.3.4. System protection, testing and commissioning

2.3.4.1. Protection philosophy

Protection philosophy shall be designed with an objective to maintain dynamic stability, prevent, or minimize equipment damage , minimize system outage area, reduce system voltage disturbance and to allow continuous flow of power within the emergency rating of equipment on the system.

Country	Protection philosophy
Afghanistan	No information available in public domain.
Bangladesh	No information available in public domain.

Bhutan	• Section 5.5. of Bhutan Grid Code regulations 2008 states that the connection agreement shall include general philosophy and guidelines on protection
	• Clause 4.6.1 of Bhutan Grid Code regulations 2008 states that the transmission planning criteria shall be based on the security philosophy envisaged in the planning of the transmission system.
	• The National Transmission Grid Master Plan 2012 specified following norms to be generally followed in order to carry out transmission planning exercise:
	  • Planning for development of integrated National transmission grid in Bhutan.
	  • (n-1) contingency including tower outage in hilly terrain.
	  • Powertransmissionat400kV,220kV,132kVand66kVACvoltageand ±800kV for HVDC Transmission.
	  • Twin Moose ACSR conductor in hilly terrain and quad moose and/or twin moose conductor at plain for power transmission at 400kV with in Bhutan border.
	  • 0.5 % auxiliary consumption at hydro stations.
	• Subsequently, the National Transmission Grid Master Plan 2018 specified following norms to be generally followed in order to carry out transmission planning exercise:
	  • Planning for development of integrated transmission grid;
	  • (n-1) contingency including tower outage in hilly terrain;
	  • Power transmission at 400kV, 220kV, 132kV and 66kV AC voltage
	  • 0.5% auxiliary consumption at hydropower stations.

India	• There is protection philosophy prepared and adopted by each RPC in coordination with stakeholders in concerned region in accordance with the objectives, design criteria and other details provided below. However, protection design in any particular system may vary depending on the judgment and experience in the broad contours of the System Protection Scheme (SPS) philosophy[81]. Consideration must also be given to the type of equipment to be protected as well as the importance of this equipment to the system. Further, protection must not be defeated by the failure of a single component. • The basic objectives of any protection schemes should be to: (i)Mitigatetheeffectofshortcircuitandotherabnormalconditionsinminimum possible time and area. (ii) Indicate the location and type of fault and (iii)Provide effective tools to analyze the fault and decide remedial measures. • To accomplish the above objectives, the four design criteria for protection that should be considered are: (i) fault clearing time; (ii) selectivity; (iii) sensitivity and (iv) reliability (dependability and security). • Philosophy of Line Protection: Transmission circuit Main protection is required to provide primary protection for the lineandclearalltypeoffaultsonitwithinshortestpossibletimewithreliability, selectivityandsensitivity.Transmissioncircuitback-upprotectionshallcaterfor failure of any main protection system to clear any fault that it is expected to clear. A protectionfunctionthatoffersback-upformostfaultsmayalsoprovidemain protectionforsomefaultconditions.Combinationsofmainandback-upprotection systems should be used to address the main and application specific requirements for transmission circuits.

Country	Protection philosophy
Maldives	Currently Maldives does not have transmission grid.
Nepal	• Chapter 5 "Grid Connection Requirement" and schedule 10 "Protection Scheme" of NEA Grid code mandates for implementation of minimum protection scheme for transmission line, distribution lines. • Clause 6.2 "Grid Security" specify to implement primary and back-up protection schemes in the transmission grid for all time. Nepal Electricity Authority has expressed its intention to install Special Protection Scheme, communication and SCADA system within the Nepalese power system for synchronous operation of the Nepal grid and Indian grid. For the same, Joint NEA and Indian team had already visited different substations within Nepal. The study suggested that synchronization of two grids shall be achieved with installation of SPS system at existing Dhalkebar, Chandranigahapur, Kamane, Bharatpur, Butwal, Hetauda, Bhaktapur and Lamahi substations and some strengthening on protection, communication system of present integrated Nepal power system. NEA has already requested to PGCIL for submission of techno-commercial proposal towards implementation of SPS and communication system.
Pakistan	No information available in public domain.
Sri Lanka	No information available in public domain.

2.3.4.2. Protection audit plans with scope of dependability, security and reliability index

Protection audit acts as a control mechanism and helps organizations to assess the actual implementation of the protection plans. The Scope of protection audit includes review of the implementation of protection schemes / philosophy and settings with reference to grid code or other relevant documents. Provisions regarding protection audit plans in the country grid code/ regulations of SAR countries is captured below:

Country	Protection audit plans with scope of dependability, security and reliability index
Afghanistan	No information available in public domain.
Bangladesh	No information available in public domain.
Bhutan	No information available in public domain.
India	National Load Dispatch Centre (NLDC) publishes a daily, weekly, and monthly report for monitoring of reliability standards named as "System Reliability Indices Report".
Maldives	Currently Maldives does not have transmission grid.
Nepal	No information available in public domain.
Pakistan	No information available in public domain.
Sri Lanka	No information available in public domain.

2.3.4.3. System / Special protection schemes

A protection scheme is designed to detect a particular system condition that is known to cause unusual stress to the power system and to take some predetermined action to counteract the observed condition in a controlled manner. In some cases, special protection schemes are designed to detect a system condition that is known to cause instability, overload, or voltage collapse. The provisions regarding system/ special protection schemes as per the regulations/ grid code of respective countries in SAR are covered below:

Country	System / Special protection schemes
Afghanistan	No information available in public domain.
Bangladesh	• Section 12.7 of Bangladesh Electricity Grid Code Regulations, 2019 states that requirement of reactive power compensation devices shall be considered as per system study and appropriate protection scheme shall be incorporated accordingly. • Anti-islanding protection scheme is to be considered while planning for VRE generation.
Bhutan	Clause 6.7.3.3. of Bhutan Grid Code regulations 2008 states that the transmission licensee shall facilitate identification, installations, and commissioning of system protection schemes (including inter-tripping and runback) in the power system to protect against situations such as voltage collapse and cascading.
India	• The IEGC 2010 and its amendments specifies in the planning criterion that suitable System Protection Schemes may be planned by NLDC/RLDC in consultation with CEA, CTU, RPC and the Regional Entities, either for enhancing transfer capability or to take care of contingencies • Section 5.2 of the IEGC 2010 mandates that all Users, STU/SLDC, CTU/RLDC and NLDC, shall also facilitate identification, installation, and commissioning of System Protection Schemes (SPS) (including inter-tripping and run-back) in the power system to operate the transmission system closer to their limits and to protect against situations such as voltage collapse and cascade tripping, tripping of important corridors/flow-gates, etc.
Maldives	Currently Maldives does not have transmission grid.
Nepal	Clause 5.7 “Requirement of Protection”of the NEA Grid Code specifies the minimum protection scheme for transmission lines, distribution lines.
Pakistan	PMC 3.1 of Grid Code 2005 mandates that a primary protection scheme and a back-up protection scheme shall be provided for each User/Code Participant's System.
Sri Lanka	• Section 2.12.5 of the Grid Code specifies that the Transmission Licensee shall ensure that all protection schemes in the Transmission System are capable of clearing electrical faults within acceptable time durations. • It is the responsibility of the Transmission Licensee to develop and expand protection schemes in the Transmission System, and include plans for such development and expansions, in the Long-term Transmission Development Plan. • Section 3.10 state that protection schemes employed in the Transmission System and User’s systems shall have appropriate backup protection schemes and breaker fail schemes.

2.3.4.4. Testing and commissioning guidelines

Country	Frequency variation limits
Afghanistan	No information available in public domain.
Bangladesh	Section 14.1 of Chapter 14 of Bangladesh Electricity Grid Code Regulations, 2019 specifies the responsibilities and procedures for arranging and carrying out tests which have (or may have) an effect on the transmission system or the generation or distribution systems.
Bhutan	A Standard Procedure, in line with the Grid Code 2008, for integration of new network elements into the grid is published by BPSO. A certificate is issued by Bhutan Power System Operator (BPSO) for successful operation with existing power system elements after conducting test charging of the elements[82].
India	Prior to energization the transmission line/substation needs to get clearance from Chief Electrical Inspectorate (CEI) Division of CEA. Therefore, an application for statutory inspection of the electrical installations under Regulations 43 & 32 of the Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations, 2010 for approval of the electrical inspector for energization is required. Later, the CEI division of CEA publishes information related to the inspections done on a monthly basis. [CEA CEI Format - http://www.cea.nic.in/cei_forms.html]
Maldives	Currently Maldives does not have transmission grid.
Nepal	Chapter 5 "Grid Connection Requirement" of the NEA Grid Code specifies procedures for processing a grid connection request, which include conducting grid impact studies and testing the equipment prior to energizing the connection.
Pakistan	OC 12 of Grid Code 2005 specifies the procedure to be followed by the system operator for testing.
Sri Lanka	Clause 6.5.4 of the Grid Code specifies the Transmission Licensee will test meters and equipment in accordance with the accepted international practices.

2.3.5. System operation

The foremost function of a System Operator is to match the generation of electricity with the constantly changing demand/ load in real time and do so while maintaining the reliability of grid. Though there are some forms of storage such as pumped hydro storage and utility scale battery storage systems emerging around the world, a vast majority of supply and demand is matched at real time. Furthermore, with the rise of Variable Renewable Energy (VRE), the nature of challenges with load following are growing ever more complex. In order to deal with these challenges, a System Operator employs various tools to perform its functions such as ancillary services, automatic load shedding, islanding schemes, curtailment of Renewable Energy sources etc. The key parameters in this regard and the as-is scenario in various SAR countries are discussed in the subsequent section.

2.3.5.1. Ancillary services mechanism/ market for frequency control (primary/ secondary/ tertiary response)

Frequency control i.e., maintaining system frequency within accepted limits is essential for grid stability. The system frequency is maintained to ensure that there is no mismatch between supply and demand of electricity at all times i.e., the power being injected into the network matches the power being drawn from the network. The balancing is predominantly achieved on three timescales:

- **Primary response-** typically achieved through autonomous governor response from conventional generators and response time may range from few seconds to 5 minutes
- **Secondary response-** while primary response ensures that a sudden drop in frequency is arrested, secondary response ensures that the frequency is brought back closer to the nominal value. This is achieved through Automatic Generation Control (AGC) and response time may range from 30 seconds to 15 minutes
- **Tertiary response-** manually maintained through system operator despatch and response time may range from 5-30 minutes for fast tertiary response and 15-60 minutes for slow tertiary response

Comparison of this aspect in various SAR countries is discussed in the following table:

Country	Ancillary services mechanism/ market for frequency control (primary/ secondary/ tertiary response)
Afghanistan	No information available in public domain.
Bangladesh	• As per section 8.3 of Bangladesh Energy Regulatory Commission Electricity Grid Code, 2019: ○ Primary Frequency Control: Generators running on Free Governor Mode of Operation (FGMO) are to be available within 10 seconds and be sustainable for 30 seconds. ○ Secondary Frequency Control: Select generators with AGC capabilities to be available within 30 seconds and be available for at least 30 minutes. ○ Tertiary Frequency Control: Kicks in via security constrained economic dispatch if secondary control is insufficient. [Source: http://berc.portal.gov.bd/sites/default/files/files/berc.portal.gov.bd/notices/82138506_08a5_4f09_a28a_b0c57ca9b367/Grid%20Code%202018%20-%2011.11.2018%20-%20Corrected%20Version.pdf]
Bhutan	• As per clause 6.4.2 of Bhutan Electricity Authority Grid Code Regulation, 2008 frequency control is achieved through Frequency Regulating Reserve (assistance through governor action) and Contingency Reserve (additional generating capacity that is intended to take care of the loss of the largest synchronized generating unit), • No market mechanism for providing ancillary services, • No explicit distinction between primary, secondary, and tertiary control. [Source: http://www.bea.gov.bt/wp-content/uploads/2013/12/Grid-Code-Regulation.pdf]

Country	Ancillary services mechanism/ market for frequency control (primary/ secondary/ tertiary response)
India	• As per clause 5.2 (f) of Central Electricity Regulatory Commission (Indian Electricity Grid Code) Regulations, 2010: • Primary Frequency Control ○ Generating stations are mandated through IEGC to maintain reserves for system security, ○ Being implemented partially through restricted governor mode of operation (RGMO). • Secondary Frequency Control ○ Under administered mechanism and pilot project is under implementation at NTPC Dadri - Achieved through generating units operating in AGC, • Tertiary Frequency Control ○ Procurement through administered mechanism or through wholesale markets, ○ Despatch based on Merit Order Despatch (MOD), ○ Mostly limited to thermal power stations, even with ramping limitations. • As per para 6.3 of CERC Discussion Paper on "Re-designing Ancillary Services Mechanism in India" (September 2018), CERC has issued orders for Pilot projects to harness hydro projects (fast tertiary response). [Source 1: http://www.cercind.gov.in/Regulations/Signed-IEGC.pdf Source 2: http://www.cercind.gov.in/2018/draft_reg/DP.pdf]
Maldives	Currently Maldives does not have transmission grid.
Nepal	• As per clause 6.5 "System Frequency Management" of the Nepal Electricity Authority Grid Code, 2005: ○ Managed through frequency regulating reserve (primary and secondary response) and contingency reserve, ○ Primary response time of generators operating in free-governor mode should not exceed 5 seconds, ○ Secondary response through AGC or manual adjustment of power output with specific dispatch instructions from the System Operator should not exceed 25 seconds, ○ Generating units which do not participate in the load frequency control are set to run independent of the grid frequency, ○ Contingency reserve is comprised of spinning reserve (generating units providing spinning reserve are synchronized with the grid) and backup reserve (generating units providing backup reserve need not be synchronized with the grid but need to have fast start capability, and ○ No market mechanism for providing ancillary services.
Pakistan	• As per clause OC 4.8 of the Grid code, all thermal generators above 100 MW and reservoir-based hydro are mandated to provide free AGC for maintenance within prescribed limits of frequency • Automatic load shedding below 49.4 Hz, • In case of 'instantaneous frequency excursions' - tolerance band within 5 mins and sensitive mode within 10 mins - if outside contingency band, contingency band within 60 seconds through load shedding, tolerance band within 5 minutes and sensitive mode within 30 minutes, • No market mechanism for providing ancillary services. [Source: https://nepra.org.pk/Legislation/6-Codes/6.2%20NTDC%20The%20Grid%20Code%20June%202005%20with%20Grid%20Code%20Addendum%20No.%20I%20&%20II/Grid%20Code%202005.pdf]

Country	Ancillary services mechanism/ market for frequency control (primary/ secondary/ tertiary response)
Sri Lanka	• As per clause 3.16.10 of The Grid Code of the Transmission Licensee, Ceylon Electricity Board (2015): ○ Primary Control achieved with fast-acting prime mover speed Governor, ○ Primarily managed through load shedding as spinning reserve maintained is not sufficient for frequency control, ○ Grid Code mandates reserve requirements but no explicit distinction between primary, secondary, and tertiary control, ○ No market mechanism for providing ancillary services. [Source: https://ceb.lk/front_img/img_reports/1532500179Grid_Code_of_Transmission_Division.pdf]

2.3.5.2. Commercial mechanisms such as frequency-linked Unscheduled Interchange (UI) or Deviation Settlement Mechanism (DSM) for grid discipline and frequency control

A System Operator's (SO) foremost function is to match the generation of electricity with the constantly changing demand/ load in real time and do so while maintaining the reliability of grid. A SO must maintain the target grid frequency within a predetermined error margin. A commercial incentive/ penalty mechanism helps a SO maintain the grid frequency minimize the control error by penalizing the generators that deviate from target frequency.

Country	Commercial mechanisms such as frequency-linked Unscheduled Interchange (UI) or Deviation Settlement Mechanism (DSM) for grid discipline and frequency control
Afghanistan	No information available in public domain.
Bangladesh	No commercial penalty/ incentive mechanism for frequency management.
Bhutan	
India	• As per clause 7 of Central Electricity Regulatory Commission (Deviation Settlement Mechanism and related matters) Regulations, 2014, frequency linked deviation settlement charges under-drawl and over-drawl of electricity governed by Central Electricity Regulatory Commission (Deviation Settlement Mechanism and related matters) Regulations (CERC DSM Regulations), 2014 and its five subsequent amendments. • As per clause 4 of Central Electricity Regulatory Commission (Deviation Settlement Mechanism and related matters) (Fourth Amendment) Regulations, 2018 frequency band is restricted from 49.85 Hz. to 50.05 Hz. • As per clause 2 and 3 of Central Electricity Regulatory Commission (Deviation Settlement Mechanism and related matters) (Fifth Amendment) Regulations, 2019, DSM penalties are linked to clearing prices in Day Ahead Market. [Source 1: http://www.cercind.gov.in/2014/regulation/noti132.pdf Source 2: http://www.cercind.gov.in/2018/regulation/dsm_fourth_amendment11-22-2018.pdf Source 3: http://www.cercind.gov.in/2019/regulation/DSM(5th%20Amendment)149.pdf]

Country	Commercial mechanisms such as frequency-linked Unscheduled Interchange (UI) or Deviation Settlement Mechanism (DSM) for grid discipline and frequency control
Maldives	Currently Maldives does not have transmission grid.
Nepal	No commercial penalty/ incentive mechanism for frequency management.
Pakistan	
Sri Lanka	

2.3.5.3. System Security - Islanding Schemes, Automatic Voltage Regulators(AVR)/ Power System Stabilizers for Gencos, Maximum Continuous Rating

A system operator/ grid operator should utilize various tools in their arsenal to ensure grid reliability. Some common methods are:

- **Islanding schemes**– It is isolation of a part of power system during external widespread grid disturbance. This isolated part of Grid is called Island. Such a disturbance may lead to black out. Islanding scheme in power system is designed in such a way that, in case of major grid disturbance as sensed by the protection element, a portion of power system is isolated by tripping/ disconnecting the pre-defined element. Thus, isolating the part of system from the remaining grid. Thus, the effect of grid disturbance is eliminated.

- **Automatic Voltage Regulators (AVR)-** These are installed at various points of the power system to regulate the voltage. Voltage variations may lead to equipment damage in the power system and typically caused due to the variation in load on the supply system

- **Power System Stabilizers (PSS)-** PSS control provides a positive contribution by damping generator rotor angle swings, which are in a broad range of frequencies in the power system. These range from low frequency intertie modes (typically 0.1 Hz - 1.0 Hz), to local modes (typically 1 Hz – 2Hz), to intra-plant modes (about 2 Hz -3 Hz). The low frequency modes, commonly called intertie or interarea modes, are caused by coherent groups of generators swinging against other groups in the interconnected system. These modes are present in all interconnected systems and the damping is a function of tie line strength and unit loading factors. Weak ties due to line outages and heavy system loads can lead to poorly damped intertie modes. PSS control can generally provide significant improvements in intertie mode damping, by applying stabilizers to most units that participate in power swing modes.

Country	System Security - Islanding Schemes, Automatic Voltage Regulators/ Power System Stabilizers for Gencos, Maximum Continuous Rating
Afghanistan	No information available in public domain
Bangladesh	• As per clause 9.4 of Bangladesh Energy Regulatory Commission Electricity Grid Code, 2019:

Country	System Security - Islanding Schemes, Automatic Voltage Regulators/ Power System Stabilizers for Gencos, Maximum Continuous Rating
	○ System Operator coordinates with generation and distribution utilities to form discrete islands, ○ Islanded system is required to operate within the system frequency range when in islanded mode, ○ Each discrete power island should contain at least one black start generator capable of running on Isochronous Mode, ○ All generating units are required to have their AVRs in operation. [Source: http://berc.portal.gov.bd/sites/default/files/files/berc.portal.gov.bd/notices/82138506_08a5_4f09_a28a_b0c57ca9b367/Grid%20Code%202018%20-%2011.11.2018%20-%20Corrected%20Version.pdf]
Bhutan	• As per clause 6.4.2 of the Bhutan Electricity Authority Grid Code Regulation, 2008 transmission system are separated into several self-sufficient island grids if an incident makes it impossible to avoid island grid operation (usually in extreme state when the corrective measures undertaken by the system operator during an emergency state fails to maintain system security), • Further, all generating units are required to have their AVRs in operation. [Source: http://www.bea.gov.bt/wp-content/uploads/2013/12/Grid-Code-Regulation.pdf]
India	• Islanding schemes are part of the grid restoration/ recovery plans. • The list of islanding schemes in each region of India can be found on the respective Regional Power Committee (RPC) websites. • All generating units are required to have their AVRs in operation. • Power System Stabilizers (PSS) in AVRs of generating units (wherever provided), are required to be properly tuned by the respective generating unit owner as per a plan prepared for the purpose by the CTU/RPC from time to time. CTU/RPC will be allowed to carry out checking of PSS and further tuning it, wherever considered necessary. [**Source 1:**Central Electricity Regulatory Commission (Indian Electricity Grid Code) Regulations, 2010 - Clause 5.2 - http://www.cercind.gov.in/Regulations/Signed-IEGC.pdf **Source 2:** Southern Regional Power Committee (http://www.srpc.kar.nic.in/html/xml-search/protection.html **Source 3:** Operating Procedure for Northern Region 2017-18, Northern Regional Power Committee (https://nrpc.gov.in/wp-content/uploads/2017/12/Operating-Procedure-of-Northern-Region-2017-18.pdf) **Source 4:** Western Regional Power Committee (http://www.wrpc.gov.in/Islanding%20Scheme.pdf) **Source 5:** Eastern Regional Power Committee (http://erpc.gov.in/islanding-schemes/)]
Maldives	Currently Maldives does not have transmission grid.
Nepal	• Clause 6.7.5 "Operational Requirements for Large Generators" of NEA Grid code specify that generating stations shall have the capability to operate in Island mode and operate in Islanding mode as and when instructed by the System Operator. • Clause 7.9.2.3 "System Recovery from Total Grid Blackout" of NEA Grid code prescribe that after total grid blackout formation of discrete power islands for restoration of national grid. Furthermore, System Operator is made responsible for maintaining normal frequency in power islands during

Country	System Security - Islanding Schemes, Automatic Voltage Regulators/ Power System Stabilizers for Gencos, Maximum Continuous Rating
	resynchronization (Clause 6.3.1 “Operational Responsibilities of System Operator” of NEA Grid code).
Pakistan	• As per OC 8.3 of the Grid Code, the system operator, operators of power plants, and the local distribution companies are required to agree on procedures for islanding, • NTDC responsible for re-synchronisation of the islanded network • All generating units are required to have their AVRs in operation.
Sri Lanka	• As per clause 3.16.10 of The Grid Code of the Transmission Licensee, Ceylon Electricity Board (2015) creation of small independent systems (islands) with identified generation and loads is part of the system restoration plan, • Islanded system is required to operate within the system frequency range when in islanded mode, • All generating units are required to have their AVRs in operation. [Source: https://ceb.lk/front_img/img_reports/1532500179Grid_Code_of_Transmission_Division.pdf]

2.3.5.4. Demand Management - Under Frequency Management / Load Shedding

When the supply of power significantly lags behind the demand and the System Operator (SO) is unable maintain grid frequency in desired range, demand management tools such as targeted load shedding, though undesired in ideal scenarios, become crucial in maintaining grid security.

Country	Demand Management
Afghanistan	No information available in public domain
Bangladesh	• As per clause 8.4.2 of the Bangladesh Energy Regulatory Commission Electricity Grid Code, 2018, when frequency falls below 49.3 Hz, the system operator issues instructions to distribution utilities to reduce load demand by appropriate manual and/ or automatic load shedding, • When the frequency falls below 49.1 Hz, the system operator will impose SCADA operation to open the circuit breaker of outgoing feeders to the distribution utilities/ bulk consumers at connection points to stabilize the system frequency. [Source: http://berc.portal.gov.bd/sites/default/files/files/berc.portal.gov.bd/notices/82138506_08a5_4f09_a28a_b0c57ca9b367/Grid%20Code%202018%20-%2011.11.2018%20-%20Corrected%20Version.pdf]
Bhutan	As per clause 6.7.4 of the Bhutan Electricity Authority Grid Code Regulation, 2008, the system operator directs the distribution licensee to reduce their drawl when there is insufficient supply. If required by the system operator, distribution licensees are also required to provide automatic under-frequency load shedding facilities in their respective systems. [Source: http://www.bea.gov.bt/wp-content/uploads/2013/12/Grid-Code-Regulation.pdf]

Country	Demand Management
India	• As per clause 5.4 of Central Electricity Regulatory Commission (Indian Electricity Grid Code) Regulations, 2010, the SLDC/ SEB/ distribution licensee and bulk consumer are responsible to ensure that requisite load shedding is carried out in its control area so that there is no over drawal, • Each User/ SLDC/ STU is also responsible for formulating contingency procedure under normal and/ or contingent conditions. The Grid Code includes a provision for regular update of these procedures as required though there is no fixed timeline provided for doing so, • The Grid Code also puts the onus on SEBs/ distribution licensees to formulate and implement state-of-the-art demand management schemes for automatic demand management like rotational load shedding, demand response (which may include lower tariff for interruptible loads) etc. Progress in implementation to be periodically reviewed by concerned SLDCs, • SLDCs are responsible for monitoring the action taken by the concerned entity and ensure the reduction of drawl from the grid as directed by RLDC, • The procedure for application of measures to relieve congestion in real time as well as provisions of withdrawal of congestion are detailed in Central Electricity Regulatory Commission (Measures to relieve congestion in real time operation) Regulations, 2009 and its subsequent amendment in 2013. [Source: http://www.cercind.gov.in/Regulations/Signed-IEGC.pdf]
Maldives	Currently Maldives does not have transmission grid.
Nepal	• As per clause 6.5 of Nepal Electricity Authority Grid Code, 2005, if demand control is initiated by SO due to insufficient generation, the SO is required to issue a public notice seven days prior to the commencement of such demand control citing the reason and amount for demand reduction required, the locations and the dates, timings, and duration of demand control, • If demand control is initiated by grid user, the grid user is required to notify the SO the day before with details of the proposed location, date, time, and the duration of the disconnection along with the magnitude of the proposed demand reduction, • In case of severe generation deficiency, grid users often resort to Voluntary Load Curtailment (VLC) schemes wherein the customers are formed into weekday groups and each group voluntarily reduces their respective loads for a certain period of the day in each week fixed for the group.
Pakistan	As per clause OC 3 of the Grid Code, National Transmission and Despatch Company Ltd. (2005)Overseen by NTDC, procedures for the notification of demand management initiated by distribution companies, implementation of demand management on the instructions of NTDC, automatic low frequency demand disconnection and emergency manual disconnection provided in the grid code. [Source: https://nepra.org.pk/Legislation/6-Codes/6.2%20NTDC%20The%20Grid%20Code%20June%202005%20with%20Grid%20Code%20Addendum%20No.%20I%20&%20II/Grid%20Code%202005.pdf]
Sri Lanka	• As per clause 4.15.4 of The Grid Code of the Transmission Licensee, Ceylon Electricity Board (2015) demand control methods adopted are as follows: ○ **Automatic Load Shedding:** Implemented by the transmission licensee and the selection of the loads to be shed is based on the information provided by distribution licensees, ○ **Manual load shedding:** Transmission licensee issues warnings on manual load

Country	Demand Management
	shedding to the appropriate distribution licensees and to transmission customers, ○ **Demand side management initiatives and agreements:** The transmission licensee may enter into agreements with transmission customers to act on warnings issued by the transmission licensee a day ahead or at short notice, ○ **Demand response initiatives:** The transmission licensee has the option to resort to control the demand through other measures such as voltage reduction and instruct the distribution licensees also to act in the same manner. [Source: https://ceb.lk/front_img/img_reports/1532500179Grid_Code_of_Transmission_Division.pdf]

2.3.5.5. Outage Planning- Procedure for Planned, Forced and Emergency outages, Frequency of Outage Planning (Monthly/Quarterly/Yearly)

Outage Planning of power equipment is one of the most important activity for power system management. It is also an important measure to guarantee healthy operation of the network system. Utilities are focused on optimising maintenance schedule so as to minimize outage costs, taking into consideration various factors such as system security/reliability, system availability, and manpower utilization. Normally Grid code specifies the outage planning procedures, consisting of the process for preparation of outage schedules for generators and transmission lines at the national level subject to network security, network constraints and grid reliability.

Country	Outage Planning
Afghanistan	No information available in public domain.
Bangladesh	• As per clause 6.5 of Bangladesh Energy Regulatory Commission Electricity Grid Code, 2019: • Transmission licensee to submit annual transmission outage program, • Licensee, SO, single buyer and generators also form part of generator operating, committees that meet at least once a month to discuss, inter alia, outage coordination • Outage planning process and details regarding data requirements from grid users laid out in the Grid Code. [Source: http://berc.portal.gov.bd/sites/default/files/files/berc.portal.gov.bd/notices/82138506_08a5_4f09_a28a_b0c57ca9b367/Grid%20Code%202018%20-%2011.11.2018%20-%20Corrected%20Version.pdf]
Bhutan	• As per clause 6.11 of Bhutan Electricity Authority Grid Code Regulation, 2008: ○ System Operator responsible for finalization of outage plans submitted by all licensees, ○ The outage plan is submitted annually containing identification of each generating unit/line/interconnecting transformers (ICTs), the preferred date for each outage and its duration and where there is flexibility, the earliest start date and latest finishing date, ○ The outage plan is reviewed by the system operator on a quarterly and monthly basis in coordination with all concerned Licensees.

Country	Outage Planning
	[Source: http://www.bea.gov.bt/wp-content/uploads/2013/12/Grid-Code-Regulation.pdf]
India	• As per clause 5.7 of Central Electricity Regulatory Commission (Indian Electricity Grid Code) Regulations, 2010: ○ Annual outage plan shall be prepared in advance for the financial year by the RPC Secretariat in consultation with NLDC and RLDC and reviewed during the year on quarterly and Monthly basis, ○ Outage planning process laid out in detail in the Grid Code. [Source: http://www.cercind.gov.in/Regulations/Signed-IEGC.pdf]
Maldives	Currently Maldives does not have transmission grid.
Nepal	Clause 6.10.1 "Grid Outage Program" of NEA Grid Code, 2005: ○ Grid users are required to provide to the system operator in writing a three-year rolling annual Grid Outage Program; ○ Grid Owner shall prepare a three-year rolling provisional annual Grid Outage Program with focus on Grid Outage. Clause 6.10.2 "Generator Outage Program" of NEA Grid Code, 2005 mandates each Generator, including Embedded and non-Embedded Generating Plants, shall submit to the System Operator, in writing, a three- year rolling Generator Outage Program.
Pakistan	As per clause OC 4.3, 4.4 & 4.5 of the Grid Code, National Transmission and Despatch Company Ltd. (2005), annual generation and NTDC outage programmes are planned on short-term (year 0), medium-term (years 1-2) and long-term (years 3-5) basis. The planning procedures for the same is detailed in the Grid Code. [Source: https://nepra.org.pk/Legislation/6-Codes/6.2%20NTDC%20The%20Grid%20Code%20June%202005%20with%20Grid%20Code%20Addendum%20No.%20I%20&%20II/Grid%20Code%202005.pdf]
Sri Lanka	• As per clause 4.2 and 4.3 of the Grid Code of the Transmission Licensee, Ceylon Electricity Board (2015): ○ The system operator will prepare the annual transmission outage plan and the annual generation outage plan in coordination with distribution licensees and other grid users, ○ The procedures to be followed during outages under unforeseen situations/ emergencies and forced outages are laid out in the Grid Code. [Source: https://ceb.lk/front_img/img_reports/1532500179Grid_Code_of_Transmission_Division.pdf]

2.3.5.6. Grid recovery procedures - System restoration plans

In order to deal with contingencies like partial or total black out, plans for restoration and recovery of the bulk power system should be prepared. The procedure should deal with restoration strategies, general guidelines during restoration and description of restoration procedure in each sub-system. Provisions regarding grid recovery procedures and/ or system restoration plans in the relevant regulations/ grid code of SAR countries are captured in table below:

Country	Grid recovery procedures - System restoration plans
Afghanistan	No information available in public domain.
Bangladesh	• Section 9 of Bangladesh Energy Regulatory Commission Electricity Grid Code, 2019 describes the recovery process to be followed by the Licensee, the System Operator and all Users in the event of Transmission System total or partial blackouts. • It defines a general guideline of the recovery process and responsibilities of all Users to achieve the fastest recovery in the event of a partial or total system blackout, taking into account essential loads, Generating Units capabilities and system constraints.
Bhutan	• Clause 6.6.2 of Bhutan Grid Code 2008 states that the restoration process shall be supervised by the System Operator, as per operating procedures separately formulated. • Section 6.12 of Bhutan Grid Code 2008 gives the provisions for Recovery procedures. They are as follows: ○ Detailed plans and procedures for restoration of the Transmission System under partial or total blackout shall be developed by the System Operator in consultation with all Licensees and shall be reviewed and updated annually. ○ A list of generating stations with Black Start facility, Transmission System elements associated with export of power to neighbouring countries, synchronising points and essential loads to be restored on priority, shall be prepared and be available with the System Operator. ○ The System Operator is authorised during the restoration process following a black out, to operate with reduced security standards for voltage and frequency as necessary in order to achieve the fastest possible recovery of the Transmission System. ○ All communication channels required for restoration process shall be used for operational communication only, until Transmission System Normal State is restored.
India	Clause 5.8 of IEGC 2010 entails the recover procedures. They are as follows: • Detailed plans and procedures for restoration of the regional grid under partial/total blackout shall be developed by RLDC in consultation with NLDC, all Users, STU, SLDC, CTU and RPC Secretariat and shall be reviewed / updated annually. • Detailed plans and procedures for restoration after partial/total blackout of each User's/STU/CTU system within a Region, will be finalized by the concerned User's/STU/CTU in coordination with the RLDC. The procedure will be reviewed, confirmed and/or revised once every subsequent year. Mock trial runs of the procedure for different subsystems shall be carried out by the Users/CTU/STU at least once every six months under intimation to the RLDC. Diesel Generator sets for black start would be tested on weekly basis and test report shall be sent to RLDC on quarterly basis. • List of generating stations with black start facility, inter-State/interregional ties, synchronizing points and essential loads to be restored on priority, shall be prepared and be available with NLDC, RLDC and SLDC. • The RLDC is authorized during the restoration process following a black out, to operate with reduced security standards for voltage and frequency as necessary in order to achieve the fastest possible recovery of the grid. • All communication channels required for restoration process shall be • used for operational communication only, till grid normalcy is restored.

Country	Grid recovery procedures - System restoration plans
Maldives	Currently Maldives does not have transmission grid
Nepal	Clause 7.9.2 "System Recovery from Total Grid Blackout" and 7.9.3 "System Recovery from Partial Grid Blackout" of the NEA Grid Code 2005 lays down steps to be taken during such emergencies also it mandates system operator to determine a procedure for black start.
Pakistan	Operation Code 8 of Grid Code deals with the procedures for the restoration of power supplies following a Total Shutdown or a Partial Shutdown of the System and the re-synchronisation of specific parts of the System that have been Islanded. It applies to the System Operator, NTDC, distribution companies, Operators of power plants, and Users of the System. Contingency arrangements are required to be established by the System Operator with each Externally connected Party/Consumers.
Sri Lanka	Section 14,5.1 of Grid Code of the Transmission Licensee, Ceylon Electricity Board (2015) states that it is the responsibility of the Transmission Licensee to develop and maintain restoration plans to manage contingencies that arise in the Transmission System. These shall include the following: (a) Issuing instructions to Generators with Black start capability to start, energise the system and synchronise where possible (b) Issuing standing instructions to Users (c) Creation of small independent systems (islands) with identified generation and loads. (d) Listing the synchronising points for the islands (e) Step-by-step process of integration of the islanded parts forming larger islands (f) Completing the restoration

2.3.5.7. Partial or Complete grid disturbance

Details about chain of events leading to partial or complete grid disturbance provide useful information that can be used to help improve the grid reliability by preventing similar events from occurring in the future. Grid code/ regulations describes the procedure to record and report details of grid disturbances. Following table describes the provisions in regulations/ grid code of each of the SAR country regarding recording and reporting of grid disturbance related information.

Country	Partial or complete grid disturbance
Afghanistan	No information available in public domain.
Bangladesh	Under section 17.3.3 Inclusions and Exclusions of Interruption Events of grid code define grid incident type. A power Interruption shall include any Outage in the Grid which may be due to the tripping action of protective devices during faults or the failure of transmission lines and/or power transformers, and which results in the loss of service to a grid user or a group of users. Also, the Licensee and the System Operator shall submit every three (3) months the monthly interruption reports using the standard format prescribed by the Commission. [Source: http://berc.portal.gov.bd/sites/default/files/files/berc.portal.gov.bd/notices/82138506_08a5_4f09_a28a_b0c57ca9b367/Grid%20Code%202018%20-%2011.11.2018%20-%20Corrected%20Version.pdf]

Country	Partial or complete grid disturbance
Bhutan	Grid code define any event as an unscheduled or unplanned occurrence on the transmission system including disturbances, faults, incidents and breakdowns. In case of emergency in the system viz., loss of generation, break-down of transmission line affecting the system, Transmission System disturbance, system isolation, the System Operator may conduct studies again before clearance of the planned outage. The grid code defines major transmission system disturbance as total black out in the country. [Source: http://www.bea.gov.bt/wp-content/uploads/2013/12/Grid-Code-Regulation.pdf]
India	Section 2 (i & j) of CEA (Grid Standards) Regulation, 2010 defines grid related events into two categories i.e., Grid Incident and Grid Disturbance. ▪ A **Grid Incident** means tripping of one or more power system elements of the grid like a generator, transmission line, transformer, shunt reactor, series capacitor and Static VAR Compensator, which requires re-scheduling of generation or load, **without total loss of supply at a substation or loss of integrity of the grid** at 220 kV and above (132 kV in the case of North-Eastern Region). These grid incidents are categorized into two categories. # **GI-1:** Tripping of one or more power system elements of the grid like a generator, transmission line, transformer, shunt reactor, series capacitor and Static VAR Compensator, which requires rescheduling of generation or load, without total loss of supply at a substation or loss of integrity of the grid at 220 kV. # **GI-2**: Tripping of one or more power system elements of the grid like a generator, transmission line, transformer, shunt reactor, series capacitor and Static VAR Compensator, which requires rescheduling of generation or load, without total loss of supply at a substation or loss of integrity of the grid at 400 kV and above ▪ A **Grid Disturbance** means tripping of one or more power system elements of the grid like a generator, transmission line, transformer, shunt reactor, series capacitor and Static VAR Compensator, resulting **total failure of supply at a sub-station or loss of integrity of the grid**, at the level of transmission system at 220 kV and above. These grid disturbances are further classified into 5 categories. **GD-1:** When less than ten per cent. of the antecedent generation or load in a regional grid is lost. **GD-2:** When ten per cent. to less than twenty percent of the antecedent generation or load in a regional grid is lost. **GD-3:** When twenty per cent. to less than thirty per cent. of the antecedent generation or load in a regional grid is lost. **GD-4:** When thirty per cent. to less than forty per cent. of the antecedent generation or load in a regional grid is lost. **GD-5:** When forty per cent. or more of the antecedent generation or load in a regional grid is lost. [Source: http://www.cea.nic.in/reports/regulation/grid_standards_reg.pdf]
Maldives	No information available in public domain.
Nepal	The grid code defines events as total system blackout and partial system blackout: Total System Blackout: The condition when all generation in the Grid has ceased, the entire System has shut down, and the System Operator must implement a Black Start to restore the Grid to its Normal State.

Country	Partial or complete grid disturbance
	Partial System Blackout: The condition when a part of the Grid is isolated from the rest of the Grid and all generation in that part of the Grid has shut down or tripped off.
Pakistan	The grid code defines grid event as partial collapse and total collapse: **Partial Collapse:** Breakdown of the electrical system due to a failure or contingency that affects a particular area or region of the country and is limited to that area or region only. **Total Collapse:** Breakdown of the national interconnected electrical system due to a failure or severe contingency that causes the interruption of the electrical services of the entire system. [Source: https://nepra.org.pk/Legislation/6-Codes/6.2%20NTDC%20The%20Grid%20Code%20June%202005%20with%20Grid%20Code%20Addendum%20No.%20I%20&%20II/Grid%20Code%202005.pdf]
Sri Lanka	The grid code defines a Significant Incident as an event with a significant effect on either the Transmission System or a User's system, and usually entails one or more of the following operational effects: # Tripping of plant and/or apparatus manually or automatically # Voltage outside statutory limits # System frequency outside statutory limits # System instability # System overload Whether an event has a significant effect on a system is determined by the entity (Transmission Licensee or User) that owns that system. [Source: https://ceb.lk/front_img/img_reports/1532500179Grid_Code_of_Transmission_Division.pdf]

2.3.5.8. *Tripping per line and tripping duration per line*

Tripping means interruption in supply of electricity. An electric line is tripped if it starts carrying fault current or it gets broken leading to interruption of supply of electricity which may be due to several other reasons. The frequency and duration of tripping per line over a period of time acts as a system performance indicator that outlines various factors such as age of network assets, status of maintenance of those assets, effectiveness of preventive maintenance of the network assets, skilfulness of maintenance staff etc. The Grid code normally specifies that information regarding tripping per line and tripping duration per line shall be recorded and reported in a timely manner. Further, sometimes the grid code also specifies the fault clearance time for transmission system. The provisions related to tripping per line and tripping duration per line in the respective grid codes/ regulations of SAR countries are as follows:

Country	Tripping per line and tripping duration per line
Afghanistan	No information available in public domain
Bangladesh	Section 12.5 of grid code specifies fault clearance time for transmission system:

Country	Tripping per line and tripping duration per line
	400 kV and above: 80 milli second **230 kV:** 100 milli second **132 kV:** 120 milli second **33 kV:** 300 milli second
Bhutan	Section 16.5.2 of the BEA grid code regulations 2008 has provision related to reporting of tripping of any inter-connecting transformer (ICT), transmission line or capacitor bank, tripping of any generating units and sequence of tripping duration. Also, clause 6.6.10 of the BEA grid code regulations 2008 states that the licensee shall send data including disturbance recorder and sequential event recorder output to the system operator for purpose of analysis of any transmission system events. [Source: http://www.bea.gov.bt/wp-content/uploads/2013/12/Grid-Code-Regulation.pdf]
India	Section 3 (e) of CEA (Grid Standards) Regulation, 2010 laydown standards for operation and maintenance of transmission lines. These standards define fault clearance time for voltage systems. **765 kV and 400 kV:** Max. time shall be 100 milli second **220 kV and 132 kV**: Max. time shall be 160 milli second In the event of non-clearance of these faults by a circuit breaker within the time limit specified above, the breaker fail protection shall initiate tripping of all other breakers in the concerned bus-section to clear the fault in the next 200 milliseconds. Section 12 Reporting of events affecting grid operation of CEA (Grid Standards) Regulation, 2010 further states that any tripping of generating unit or transmission element, along with relay indications, shall be promptly reported by the respective Entity to the Appropriate Load Despatch Centre in the reporting formats as devised by the Appropriate Load Despatch Centre. [Source: http://www.cea.nic.in/reports/regulation/grid_standards_reg.pdf]
Maldives	No information available in public domain.
Nepal	Clause 11.8.3 "Significant Event Report" of NEA grid code specifies that after every major grid event like cascade tripping, power System black-outs and grid disturbance, the system operator needs to record and report such event. The grid code also provides formats to capture tripping details for generators and transmission lines.
Pakistan	The grid code has designated system operator under section CM10 to maintain necessary information about transmission system status. It also instructed it to install cross-tripping schemes in the eventuality of loss of a generator or transmission facility under PMC 3.2 of the Grid Code, 2005. Under clause OC 4.10 the grid code provided with clearing time of specific type of faults: # Permanent three-phase fault on any primary transmission element, shall be cleared by the associated circuit breaker action in 5 cycles. # Failure of a circuit breaker to clear a fault ("Stuck Breaker" condition) in 5 cycles, with back up clearing in 9 cycles after fault initiation. [Source: https://nepra.org.pk/Legislation/6-Codes/6.2%20NTDC%20The%20Grid%20Code%20June%202005%20with%20Grid%20Code%20Addendum%20No.%20I%20&%20II/Grid%20Code%202005.pdf]

Country	Tripping per line and tripping duration per line
Sri Lanka	Section 4.4.2 of the Grid code defines responsibility of transmission licensee's and system operator to report and analyse all transmission system failures for performance improvement. [Source: https://ceb.lk/front_img/img_reports/1532500179Grid_Code_of_Transmission_Division.pdf]

2.3.5.9. Phase angle difference

Synchro phasors/ Phasor measurements between two distant PMUs can indicate the relative stress across the grid, even if the PMUs are not directly connected to each other by a single transmission line. It provides visualisation of power system and are useful in monitoring safety and security of the grid in an effective manner. This would also enable better utilization of the power system without compromising on the reliability front.

Country	Phase angle difference
Afghanistan	No information available in public domain.
Bangladesh	Regulation 13.8.4 of the Grid Code 2019 states that for the SCADA and EMS system the Single Buyer shall be responsible for providing and installing the equipment including any Remote Terminal Units (RTUs)/ IEDs/PMUs/ Gateways within the Generator or Distribution Utility or Bulk Power Consumer sites.
Bhutan	No information available in public domain
India	Country already started implementing implementation of Phasor Measurement Unit (PMU) for dynamic monitoring of transmission network on real time basis. The journey started with implementing pilot under Unified Real Time Dynamic State Measurement (URTDSM) scheme. Also, National Electricity Plan for transmission also talks about PMU under adoption of new technologies in communication (section 4.2) and wide area measurement system (section 4.3) for larger use. Under phase-1 of URTDSM scheme more than 1,400 PMUs have been commissioned (pan India) which are reporting to the concerned LDCs. These are providing visibility to the LDCs by providing real time monitoring of power system parameters like oscillations, line parameter estimation, spectral analysis. Apart from this they are helping on conducting Post-Despatch analysis of events, Asset Management, Primary frequency Response assessment, Feedback to generators for poorly damped oscillations, Model Validation, SPS action validation and Fault Clearing time feedback, etc. Phase-2 of URTDSM is under progress. [Source: URTDSM Report http://www.cea.nic.in/reports/committee/scm/allindia/agenda_note/1st.pdf CEA NEP (Transmission) - http://www.cea.nic.in/reports/others/ps/pspa2/nep_transmission.pdf]
Maldives	No information available in public domain.
Nepal	No information available in public domain.

Country	Phase angle difference
Pakistan	No information available in public domain.
Sri Lanka	No information available in public domain.

2.3.5.10. Harmonics

Harmonics, one of the growing power quality issue, it is caused due to non-linearity of customer loads. Presence of harmonics in power system cause premature aging of insulation which result in deterioration of equipment's performance. In power transformers current harmonics flowing through windings result in over heating of winding and reduction in output. In measuring equipment like interface meters have problems related to invalid measurements because of error in equipment taking zero reference wave. There is also possibility of maloperation of protection relay / system due to harmonics.

Country	Harmonics
Afghanistan	No information available in public domain.
Bangladesh	Section 17.2.4 of grid code defines Total Harmonic Distortion (THD) as the ratio of the RMS value of the harmonic content to the RMS value of the fundamental quantity, expressed in percent and allowable limits at connection point are specified below. **400 kV:** THD 1.5% **132 kV to 220 kV:** THD 2.5% **66 kV:** THD 3% [Source: http://berc.portal.gov.bd/sites/default/files/files/berc.portal.gov.bd/notices/82138506_08a5_4f09_a28a_b0c57ca9b367/Grid%20Code%202018%20-%2011.11.2018%20-%20Corrected%20Version.pdf]
Bhutan	No information available in public domain.
India	Section 3 Standards for Operation and Maintenance of Transmission Lines of CEA grid standard regulation, 2010 specified standard harmonic distortion of different voltage levels as mentioned below. Method of harmonic measurement and other related matters shall be in accordance with the IEEE 519-2014 standards as specified under CEA Technical Standards for Connectivity to the Grid- Amendment Regulations, 2019. **765 kV:** THD 1.5% **400 kV:** THD 2% **220 kV:** THD 2.5% **33 kV to 132 kV:** THD 5% [Source: http://www.cea.nic.in/reports/regulation/grid_standards_reg.pdf and http://cea.nic.in/reports/others/god/gm/notified_regulations.pdf]
Maldives	No information available in public domain.

Country	Harmonics
Nepal	No information available in public domain.
Pakistan	Grid code section CC 5.4 Operational Obligation of Code Participants Power Quality specifies compliance for harmonic content as per IEEE 519-1992 standards. [Source: https://nepra.org.pk/Legislation/6-Codes/6.2%20NTDC%20The%20Grid%20Code%20June%202005%20with%20Grid%20Code%20Addendum%20No.%20I%20&%20II/Grid%20Code%202005.pdf]
Sri Lanka	Grid code section 3.1 (d) specifies adherence to IEC 6100 part 3 to 6 (Harmonics). The code also emphasizes transmission licensee to conduct harmonic studies. [Source: https://ceb.lk/front_img/img_reports/1532500179Grid_Code_of_Transmission_Division.pdf]

2.3.6. Scheduling and despatch

2.3.6.1. Detailed procedure and timelines for scheduling and despatch

Detailed procedure and timelines for scheduling and despatch is imperative to ensure economic Despatch of generating units to meet the demand and to maintain voltage and frequency within an acceptable range and to defines the responsibilities of the Transmission Licensee and contributions by Users to help achieve this goal. Since electricity is generated and consumed at the same time, it is important to forecast the demand in advance, provide generating schedule to the generating stations and ensure that electricity is dispatched as per the schedule. To make this process more efficient, scheduling and dispatching is done in time blocks.

Country	Detailed Procedure and Timelines for Scheduling and Despatch
Afghanistan	No information available in public domain.

Bangladesh	• Section 7.3 of Bangladesh Electricity Grid Code Regulations, 2018 lays down the Procedures for Generators, System operators and distribution utilities for scheduling & despatch.
	• The System Operator shall coordinate and prepare the following schedules:
	  ◦ yearly/ monthly and weekly load generation balance schedules and generation schedules
	  ◦ The year ahead schedule for monthly peak/off peak period demand
	  ◦ The month ahead schedule for daily peak/off peak period demand
	  ◦ The day ahead schedule for hourly demand
	• The generators shall promptly report the changes of generating unit availability or capability or any other changes to the System Operator. The System Operator shall advise the Users of any necessary rescheduling.
	• The generation is scheduled for 60-minute time blocks.
	• By 12PM every day, the station wise ex-power plant MW and MWh capabilities foreseen for the next day shall be estimated. The day-ahead generation schedules will be informed to the respective generators not less than 7 hours before the beginning of each day in Bangladesh.

Country	Detailed Procedure and Timelines for Scheduling and Despatch
	• Section 7.4 of Bangladesh Electricity Grid Code Regulations, 2018 states that - All Generators will be subject to despatch instructions and shall regulate generation according to these instructions • Despatch instructions shall be in standard format. These instructions will recognize declared availability, Merit Order and other parameters that have been made available by the Single Buyer and Generator to the System Operator.
Bhutan	• Clause 7.5 of Bhutan Grid Code regulations 2008 lays down the Scheduling and despatch procedure. • Generators are responsible to provide their capabilities for day-ahead schedules. The generation is scheduled for 60-minute time blocks. • By 9 AM every day, the station wise ex-power plant MW and MWh capabilities foreseen for the next day shall be estimated. • By 9.30 AM, all generating stations directly connected to the Transmission System shall advise the System Operator of the station-wise Ex- Power Plant demand and energy capabilities foreseen for the next day. • Until the East and West Grids are interconnected inside Bhutan, the day-ahead demand on the Eastern Grid and that of Western Grid shall be estimated by the System Operator separately on an hourly basis. • The System Operator by 1800 hours shall issue the hourly schedule of generation to each of the generators, excluding embedded and off-grid generators. • In the event of bottleneck in evacuation of power due to any constraint, outage, failure or limitation in the Transmission System, associated switchyard and substations owned by the Transmission Licensee, sudden demand change by the Distribution Licensees or Large Consumers, the System Operator shall revise the schedules and advise the NLDC in Bhutan.
India	• Part 6 of The IEGC 2010 and its amendments specifies the Scheduling and Despatch Code for India. • The Regional grids shall be operated as power pools with decentralized scheduling and despatch, in which the States shall have operational autonomy. • If regional entities deviate from the drawal schedule, within the limit specified by the CERC in DSM Regulations as long as such deviations do not cause system parameters to deteriorate beyond permissible limits and/or do not lead to unacceptable line loading. • Generators are responsible to provide their capability for the day ahead schedules. • Generation is scheduled for a 15-minute time block. • Clause 6.4 (14) of Indian Electricity Grid Code 2010 states that, any bilateral agreements between buyer and seller for scheduled interchanges on long-term, medium -term basis shall also specify the interchange schedule in accordance with CERC (Grant of Connectivity, Long-term Access and Medium-term Open Access in inter-state Transmission and related matters) Regulations 2009. • Clause 6.4 (16) of the IEGC 2010 and its amendments specifies that the ISGS shall make an advance declaration of ex-power plant MW and MWh capabilities foreseen for the next day, i.e., from 0000 hrs. to 2400 hrs. • During fuel shortage condition, in case of thermal stations, they may specify minimum MW, maximum MW, MWh capability and declaration of fuel shortage. The generating stations shall also declare the possible ramping up / ramping down in a block. In case of a gas turbine generating station or a combined cycle generating station, the generating station shall declare the capacity for units and modules on APM gas, RLNG and liquid fuel separately, and these shall be scheduled separately.

Country	Detailed Procedure and Timelines for Scheduling and Despatch
	• By 6 AM every day, the ISGS shall advise the concerned RLDC, the station-wise ex-power plant MW and MWh capabilities foreseen for the next day. The above information of the foreseen capabilities of the ISGS and the corresponding MW and MWh entitlements of each State, shall be compiled by the RLDC every day for the next day, and advised to all beneficiaries by 10 AM. The SLDCs shall review it vis-à-vis their foreseen load pattern and their own generating capability including bilateral exchanges, if any, and advise the RLDC by 3 PM their drawal schedule for each of the ISGS in which they have Shares, long-term and medium-term bilateral interchanges, approved short-term bilateral interchanges. The day-ahead generation schedules shall be informed to respective generators by 6 PM. • Scheduling of Collective Transactions: Provision for buyers and sellers of power to participate in power trade through a power exchange has been made only in the grid code of India. Regional entities in India can participate by availing in short-term open access to inter-control area transmission facilities. Other state utilities/intra-state entities shall obtain "Standing Clearance/ No Objection Certificate" from their respective SLDCs for participating through power exchange. NLDC shall, by 11 AM on the previous day, provide the power exchange a list interfaces/ control area/ regional transmission system on which unconstrained flows are required and the power exchange shall furnish the same by 1 PM along with the information of total withdrawal and injection in each of the regions. Based on the information furnished by the Power Exchanges, NLDC shall check for congestion and inform the same along with available limit for Scheduling Collective Transactions to the Power Exchange by 2 PM. After ensuring that the Scheduling Collective Transactions are within limits, power exchange shall submit the same to NLDC by 3 PM. NLDC shall send the details to different RLDCs for final checking and accommodating in their schedules. RLDCs shall confirm on the same by 5 PM and NLDC shall inform the Power Exchanges about the e=acceptance by 5.30 PM. RLDCs shall schedule the Collective Transaction at the respective periphery of the Regional Entities.
Maldives	Currently Maldives does not have Transmission grid.
Nepal	• Chapter 7 "Scheduling and Dispatch" of the NEA Grid Code specifies the Scheduling and Dispatch procedure for Nepal. • Monthly Availability Declaration: By the third day of every month, Generators shall submit to the System Operator an Availability Declaration Projection for the month ahead and following month ahead on a week-by-week basis. • Monthly Generation Schedule: By the 15th day of every month, the System Operator shall notify each Generator, in writing, of their approved monthly Projected Availability Declaration for the month ahead and following month ahead. • Weekly Availability Declaration: By every Wednesday, Generators shall provide the System Operator, in writing, the weekly Availability Declaration Projection for the week ahead and following week ahead on day-by-day basis. • Weekly Generation Schedule: The System Operator shall notify each Generator, in writing, of their approved weekly Projected Availability Declaration not later than 16:00 hours on Friday following submission. • Daily Availability Declaration: Not later than 12:00 hours every day, each Generator shall provide to the System Operator, in writing, the daily Output Usable for each Generating Unit and the order of dispatch of each Generating Unit for day ahead and following day ahead on hourly basis.

Country	Detailed Procedure and Timelines for Scheduling and Despatch
Pakistan	• Scheduling and despatch Code of Grid Code 2005 sets out the procedure to ensure minimum-cost generation despatch. • Generators are responsible to provide their capability for the day-ahead schedules. • Generation is scheduled for a 30-minute time block. • By 10 AM every day, the station wise ex-power plant MW and MWh capabilities foreseen for the next day shall be estimated. The day-ahead generation schedules will be informed to the respective generators by 5 PM in Pakistan.
Sri Lanka	• Generation despatch Code of Grid Code specifies the procedure to be adopted for the scheduling and economic Despatch of Generating Units. • Generators are responsible to provide their capability for the day-ahead schedules. • Generation is scheduled for a 60-minute time block. • By 12 PM every day, the station wise ex-power plant MW and MWh capabilities foreseen for the next day shall be estimated. The day-ahead generation schedules will be informed to the respective generators by 3 PM in Sri Lanka.

2.3.6.2. Declaration discipline

The Generating stations must declare their capabilities and availability in advance to help plan meeting the consumer's demand. Sometimes the generating stations may mis-declare a parameter in its availability declaration in order to make an undue commercial gain. For enforcing the discipline, the grid code/ regulation shall prescribe a punitive action/ penalty against any mis-declarations submitted by the Generating stations.

Country	Declaration discipline
Afghanistan	No information available in public domain.
Bangladesh	• Clause 7.3.2.2 of the Bangladesh Grid Code 2019 ensures that the generating stations must declare available capacity to the SO during each hour of the day. Section 14.5 of the Bangladesh Grid Code 2019states that the declared available capacity of conventional generator is tested if the SO has reasonable suspicion. The generating unit will pass the test if it can attain and maintain the load to the Declared Available Capacity for 2 hours. But no clause is given for mis-declaration in the grid code.
Bhutan	• Clause 7.4.8 of the Bhutan Grid Code ensures that the generating stations must declare the plant capabilities faithfully, i.e., according to their best assessment. But no clause for mis-declaration is given in the grid code.
India	• Clause 6.4 (20) of the IEGC 2010 and its amendments specifies that the quantum of penalty for the first mis-declaration for any duration/block in a day shall be the charges corresponding to two days fixed charges. For the second mis-declaration the penalty shall be equivalent to fixed charges for four days and for subsequent mis-declarations, the penalty shall be multiplied in the geometrical progression over a period of a month.
Maldives	Currently Maldives does not have Transmission grid.
Nepal	• Clause 7.5 "Availability declaration information required for scheduling" of the NEA Grid code have provision for availability declaration for monthly, weekly and daily declaration. It also has provision for to modify information related to declaration under the clause 7.5.6 "Change to information".

Country	Declaration discipline
Pakistan	• Clause CM 14 of Grid Code 2005 mandates that violation of grid code shall be subject to penalties as per NEPRA fees and fines rules 2002.
Sri Lanka	• No clause for mis-declaration in the grid code.

2.3.6.3. Short-term (up to three months) demand estimation and resource management

For continual energy availability in a rapidly developing economy, short-term (up to three months) demand forecasting is an essential step in the process of energy planning.

In case of deficiency in generation, the system has to manage the resources through demand control i.e., reduction in system demand carried out to maintain balance between generation and demand for the purpose of frequency control.

Country	Short-term demand estimation and resource management
Afghanistan	No information available in public domain.
Bangladesh	• Clause 6.3.1 of Bangladesh Electricity Grid Code Regulations, 2018 states that Demand estimation is necessary in the shorter time scale to assist with frequency control. • Clause 7.8 of Bangladesh Electricity Grid Code Regulations, 2018 specifies that the System Operator shall consider the probable shortfall in generation, if any, and apportion the available generation among the Entities by maintaining a definite principle approved by the Commission. • The Entities, in turn, manage the demand shortfall by imposing load shedding in a systematic and rational manner by maintaining a definite principle approved by the Commission. • The System Operator and Distribution Utilities shall always endeavour to restrict the net drawl at the Connection Point from the Grid within the drawl schedules, whenever the system frequency is within normal operating limits. The concerned Distribution Utilities/ User shall ensure that their automatic demand management scheme to ensure that there is no over drawl when frequency is 49.5 Hz or below. • Distribution Utilities shall establish their own SCADA system to impose automatic load management in 11 kV feeders in case of shortfall.
Bhutan	• Clause 6.8.1 of Bhutan Grid Code regulations 2008 states that the Distribution Licensee shall formulate a short-term demand forecast (MW, MVAR and MWh) from the historical data and demand estimation submitted by Large Consumers. • Section 6.9.2 of Bhutan Grid Code regulations 2008 specifies the methods of Demand control. Distribution Licensees should reduce their demand in the event of insufficient generating capacity, and transfers from external interconnections being not available to meet demand, or in the event of breakdown or operating problems (such as frequency, voltage levels or thermal overloads) on any part of the Transmission System. • In case of certain contingencies and/or threat to system security, the System Operator may direct the Distribution Licensees to decrease their drawal by a certain quantum.
India	• Clause 6.4 (8) of the IEGC 2010 and its amendments specifies that the SLDCs/STUs / Distribution Licensees shall regularly carry out the necessary exercises regarding short-

Country	Short-term demand estimation and resource management
	term demand estimation for their respective States/area, to enable them to plan in advance as to how they would meet their consumers' load without overdrawing from the grid. • Clause 6.4 (12) of the IEGC 2010 specifies that the RLDC may direct the SLDCs/ISGS/other regional entities to increase/decrease their drawal/generation in case of contingencies e.g., overloading of lines/transformers, abnormal voltages, threat to system security. • Based on this demand estimate and the estimated availability from different sources, SLDC shall plan demand management measures like load shedding, power cuts, etc. and shall ensure that the same is implemented by the SEB/distribution licensees
Maldives	Currently Maldives does not have Transmission grid.
Nepal	• Clause 3.4.2.1 "Demand Forecast Data" of NEA Grid code specifies that Distributors shall provide the Grid Owner, by the 15th day of the month of each Bhadra (end of August), annual energy and Demand Forecast for existing High Voltage Consumers at each Connection Point. • Clause 6.5.2.2.1 of the NEA Grid Code mentions that Demand control can be implemented for balancing deficiency in generation caused by non-availability of Generators or power transfer not being available from external connections or Grid break down. • Clause 7.7.1 of the NEA Grid Code states that based on the historical Demand forecast and the Demand forecast projected by the System Planning Department, the System Operator shall develop a cohesive Demand forecast on an hour-by-hour basis for every day. This Demand forecast shall be compared with the Demand Forecast submitted by Distributors and the higher of the two, after adjustment for system losses, shall be established as the final Demand Forecast. •
Pakistan	• OC 2.3 of the Grid Code 2005 specifies that each user connected to the NTDC Transmission system has to supply demand forecast data to NTDC for a period of4 week ahead of real time. • Grid Code 2005 specifies that demand management is used in case of deficiency in generation.
Sri Lanka	• No information available regarding short-term demand estimation. • Section 5.7of the Grid Code specifies that the System Operator may plan and instruct a Licensee to shed load if the daily despatch schedule or real time Despatch shows shortage of energy in the system as a whole or in one or more specific regions in the system, owing to insufficient generation or insufficient transmission capacity. All Licensees are obliged to comply with the curtailment schedules, load shedding plans and instructions of the System Operator. • In case of prolonged shortages, the Transmission Licensee shall prepare a rotational load shedding scheme in coordination with Distribution Licensees. The System Operator will determine the amount, timing and duration of load shedding to Licensees.

2.3.6.4. Ramping rate to be declared for scheduling

In order to balance the variable renewable energy, flexible generation is useful in which power plants can ramp up and down quickly and efficiently and run at low output levels. It has been observed that wind and solar generation can create the need for more flexibility as they lead to steeper ramps, deeper turn downs, and shorter peaks in system operations. Thus, ramping rate must be declared by the generators and considered during scheduling.

Country	Ramping rate to be declared for scheduling
Afghanistan	No information available in public domain.
Bangladesh	• Clause 14.5.7 of Bangladesh Electricity Grid Code Regulations, 2018 mentions that while preparing generation schedules, the concerned entity should consider the ramping up/ ramping down limits of the generators
Bhutan	• Clause 7.5.13 of Bhutan Grid Code regulations 2008 states that the generators are required to furnish the System Operator the typical ramping up/down rate capabilities of their machines and the same is considered while preparing generation schedules.
India	• Clause 6.4 (16) of the IEGC 2010 and its amendments specifies that the generating stations shall also declare the possible ramping up / ramping down in a block for consideration in generating schedules.
Maldives	Currently Maldives does not have Transmission grid.
Nepal	Clause 7.8.2 "Dispatch Instruction" of NEA Grid Code mentions that dispatch instruction shall be based on ramp rates wherever applicable.
Pakistan	• The Grid Code 2005 mentions that while preparing generation schedules, the concerned entity should consider the ramping up/ ramping down limits of the generators.
Sri Lanka	• Section 2.3.3.2 of the Grid Code Data (Appendix B) specifies that ramp rate of Wind and Solar Generating plants is to be submitted.

2.3.6.5. Scheduling of wind and solar generation

For Variable Renewable Energy (VRE) power plants (solar and wind), accurate forecasting of generation is not possible. Therefore, efforts are made to forecast generation as accurate as possible. Further, non-scheduling of VRE may result in wastage of clean energy generated, therefore, Normally VRE are classified under 'MUST RUN' status and are omitted from the Merit Order for despatch.

Country	Scheduling of wind and solar generation
Afghanistan	No information available in public domain.
Bangladesh	• 7.3.2.6. of Bangladesh Electricity Grid Code Regulations, 2019 states that hourly forecast of VRE generation is considered while preparing generation schedule and the System Operator shall produce a day ahead hourly generation schedule based on Merit Order of the Generating Units.
Bhutan	• No specific clause for scheduling of Wind and solar generation in the grid code.
India	• CERC has published the procedure for implementation of the framework on Forecasting, scheduling and imbalance handling for renewable energy generating stations including power parks based on wind and solar at inter-state level. This Procedure shall be followed by National Load Despatch Centre (NLDC), all Regional Load Despatch Centres (RLDCs), Regional Power Committees (RPCs), and State Load

Country	Scheduling of wind and solar generation
	Despatch Centres (SLDCs), regional entity Wind / solar generating stations including power parks, Principal Generators, Lead Generator. • Clause 6.2 of the Central Electricity Regulatory Commission (Indian Electricity Grid Code) (Third Amendment) Regulations, 2015 provides the methodology for re-scheduling of wind and solar energy generators which are regional entities, on one and half hourly basis and the methodology of handling deviations of such wind and solar energy generators. • Clause 6.4 (11) of the IEGC 2010 and its amendments specifies that Since variation of generation in run-of-river power stations shall lead to spillage, these shall be treated as must run stations. All renewable energy power plants, except for biomass power plants, and non-fossil fuel-based cogeneration plants whose tariff is determined by the CERC shall be treated as 'MUST RUN' power plants and shall not be subjected to 'merit order despatch' principles. • CERC (Deviation Settlement Mechanism and related matters) (Second Amendment) Regulations, 2015, is a Framework on Imbalance Handling for Variable Renewable Energy Sources (Wind and Solar). The regulation imposes deviation quantum-based slab and penalties applicable of RE generators. • CERC have also published procedure for forecasting, scheduling and imbalance handling for Renewable Energy generating stations including power parks based on wind and solar at inter-state level in 2017. It outlines applicability of these procedures, roles and responsibilities of different entities, process for connectivity and scheduling & despatch, metering for energy accounting and provision related to commercial settlement. • In Report of the expert group: Review of Indian Electricity Grid Code, 2020. It has defined roles and responsibilities of Qualified Coordinating Agency (QCA) for RE sources. Even CERC (Fees and Charges of Regional Load Despatch Centre and other related matters) Regulations, 2019 identify QCA as a user who use the inter-State transmission network or the associated facilities and services of National Load Despatch Centre and Regional Load Despatch Centres.
Maldives	Currently Maldives does not have Transmission grid.
Nepal	• No specific clause for Scheduling for Wind and solar generation is available in the grid code.
Pakistan	• SDC 1.4.3.3 of Grid Code 2005 lays down various factors considered for compiling the Final Generation schedule. No specific clause for Scheduling for Wind and solar generation is available in the grid code.
Sri Lanka	• Section 5.5.1 of the Grid Code specifies that all IRBGS of 5 MW or above shall submit a year-ahead Rolling Despatch Plan, updated monthly with forecast generation. The System Operator shall include this forecast generation in despatch planning.

2.3.6.6. Scheduling of inter-regional and cross-border transactions

With increasing cross-border electricity trade in the SA Region, regulations are desired for scheduling of cross-border transactions to ensure grid reliabilities for both the countries.

Country	Scheduling of inter-regional and cross-border transactions
Afghanistan	No information available in public domain.
Bangladesh	• The system operator is responsible for scheduling and despatch of electricity over inter-regional links in accordance with the grid code and for co-ordination of trans-national exchange of power.

Bhutan	• Clause 7.5.8, 7.5.9 and 7.5.10 of Bhutan Grid Code regulations 2008 states that:
	  ◦ By 1130 hours, the System Operator shall advise the ERLDC of the expected cross-border transfer at Salakati in India. The cross-border transfer at Salakati shall be arrived at subtracting the demand on the Eastern Grid and notional transmission loss from the ex-power plant energy available to the Eastern Grid
	  ◦ Similarly, by 1130 hours, the System Operator shall advise ERLDC of the expected cross-border transfer at Birpara and Binaguri in India. The cross-border transfer at Birpara and Binaguri shall be arrived at subtracting the demand on the Western Grid and notional transmission loss from the ex-power plant energy available to the Western Grid
	  ◦ By 1330 hours, the ERLDC shall inform the System Operator of any modifications required in the cross-border transfers arising from any anticipated transmission constraints. ERLDC, in finalizing the despatch schedule for its own system, shall reconfirm the same to the System Operator by 1730 hours (i.e.,1700 hours IST).
	• Clause 5.14 of the Bhutan Grid Code regulations 2008 states that the procedure for international connection to the Transmission System and the execution of agreement for the same shall be done by the agency who has been assigned this responsibility by the Ministry

India	• Clause 25 "Scheduling" of CERC (Cross border Trade of Electricity Regulations), 2019 lays down procedure to be followed for scheduling and despatch of cross border trade of electricity transactions between India and the respective neighbouring country. Scheduling shall be carried out for each 15-minute time block or such other duration as may be notified subsequently.
Maldives	Currently Maldives does not have Transmission grid.
Nepal	• The system operator is responsible for scheduling and dispatch of electricity over inter-regional links in accordance with the grid code and for co-ordination of trans-national exchange of power.
Pakistan	• The system operator is responsible for scheduling and despatch of electricity over inter-regional links in accordance with the grid code and for co-ordination of trans-national exchange of power.
Sri Lanka	• The system operator is responsible for scheduling and despatch of electricity over inter-regional links in accordance with the grid code and for co-ordination of trans-national exchange of power.

2.3.7. Information and communications technology including cyber security

2.3.7.1. Communication facilities for data and voice

Adequate, reliable, and efficient communication facilities for data and voice are required to facilitate necessary communication and data exchange, and supervision/control of the grid between all the users of the grid and the system operator. It also helps in data flow up to appropriate data collection points.

Country	Communication facilities for data and voice
Afghanistan	No information available in public domain.
Bangladesh	Section 13.7 of Bangladesh Electricity Grid Code Regulations, 2018 states that independent dedicated communication links such as microwave, PLC, optical fibre, etc. for voice communication, for written communication and for data acquisition shall be installed between all power stations, substations, other User's premises and the NLDC.
Bhutan	• Section 3.8 of Bhutan Grid Code regulations 2008 mandates that licensees and users shall appoint a representative to be responsible for all communications between them and that any communication media may be used. • Clause 6.6.9 of Bhutan Grid Code regulations 2008 states that each licensee shall provide an adequate and reliable communication facility internally and with the System Operator to ensure exchange of data information. Wherever possible, redundancy and alternate path shall be maintained for communication along important routes.
India	• Section 4.6.2 of the IEGC 2010 mandates all users, STUs, CTU and RLDCs to provide Reliable and efficient speech and data communication systems. • Central Electricity Regulatory Commission (Communication System for inter-State transmission of electricity) Regulations, 2017 provides guidelines for availability of reliable data and voice communication. • Central Electricity Authority (Technical Standards for Communication System in Power System Operations) Regulations, 2020 emphasise on providing reliable data and voice communication and tele-protection for power system at national level, regional level, inter-State level and intra-State level. It ensures that communication system shall be capable to provide integration with supervisory control and data acquisition system, wide area measurement system, video conferencing system, automatic meter reading, electronic private automatic branch exchange, voice over internet protocol and tele protection.
Maldives	Currently Maldives does not have transmission grid.
Nepal	Clause 6.9 "Communication Requirements" of the Nepal Electricity Authority Grid Code, 2005 specifies the Communication requirements for grid operations. It mandates use of telecommunication facilities between the system operator and NEA Load Dispatch Centre and Generators, Distributors, and other Users.
Pakistan	• CM 4 of Grid Code 2005 specifies the Communication requirements between NTDC and the users. It mandates that all operational instructions issues by NTDC shall be between the NTDC control engineer and user responsible engineer through dedicated telephone network. All non-operational communication shall be in writing.

Country	Communication facilities for data and voice
	• OC 6.3 of Grid Code 2005 states that NTDC shall provide at least dual high-speed network-wide communication system, to provide for the communications facilities, installed on its system, and the Code Participants facilities.
Sri Lanka	• Section 1.13 of the Grid Code specifies that all communication between transmission licensee and user shall be in writing, except where operation timescales require oral, facsimile or electronic communication. • Section 3.13 of the Grid Code specifies that voice and data communication facilities shall be secured against unauthorised access in accordance with the standards specified.

2.3.7.2. SCADA / EMS for real-time operations

The control, data acquisition and monitoring of the power system relied on manual labour and analogue equipment. With increase in the size and complexity of the system, a more efficient and fully automated system is required. Supervisory Control and Data Acquisition (SCADA) system gathers information and data from various power system elements (such as generators, sub-stations, etc.) in real-time. Using SCADA systems, electrical utilities can detect current flow and line voltage, monitor circuit breaker / isolator operations, and take transmission elements online or offline. Energy Management Systems (EMS) are used by power system operators to monitor power grid operating conditions and control grids in a reliable, secure, and economical manner. An energy management system interfaces with the grid through a SCADA system. The SCADA system transmits thousands of measurements at critical points of a power system in real time to the EMS and command signals from the EMS to field devices to take control actions. Thus, SCADA and EMS help achieve flexibility and reliability in real-time operations of the power system.

Country	SCADA / EMS for real-time operations
Afghanistan	No information available in public domain.
Bangladesh	• Clause 5.4.7 and 5.4.8 of Bangladesh Electricity Grid Code Regulations, 2019 states that SCADA and EMS system shall be owned and maintained by the Licensee for existing Power stations and SCADA Control (for example RTU/SAS) and EMS interface shall be installed, owned & maintained by the respective generator or bulk power consumer or other user for new power stations. • Section 13.5 states that the system operator and the licensee shall install and make operative an operational metering data collection system, under SCADA for storage, display and processing of metering data. For generators, distribution utilities, bulk consumers and other users, the equipment within their site for communication (voice & data), SCADA control (for example RTU/Gateways) shall be installed, owned & maintained by the respective users. • Necessary data shall be collected/acquired; stored and real-time data is to be displayed at the NLDC. No power station and transmission system substation shall be commissioned without communication & SCADA integration
Bhutan	BEA has mentioned the use of SCADA by the operator for running the scheduling application software, Resource Scheduling Commitment (RSC)under section 4.2 of Operationalization of grid code regulations 2008 (published in November 2017).

Country	SCADA / EMS for real-time operations
India	• The RLDCs and NLDC are Control Centre based organizations. The SCADA/EMS, IT system and other facilities are established for smooth operation of the functions comprising of system operation and market operation in real time, operational planning, post operation analysis, scheduling, energy accounting, reporting systems, etc. • Clause 4.6.3 of the IEGC 2010 mandates the use of Data Acquisition System / Disturbance Recorder / Event Logging Facilities / Fault Locator (including time synchronization equipment) in the ISTS for recording of dynamic performance of the system. • Section 6.2 of the IEGC 2010 mandates use of appropriate meters and data acquisition system facility for accounting of DSM / UI charges and transfer of information to concerned SLDC and RLDC.
Maldives	Currently Maldives does not have transmission grid.
Nepal	• Section 6.9.1.2 of the Grid code states that the communication and SCADA system for the grid and the connection points shall be planned and designed by the system operator • Section 6.9.1.3 and 6.9.1.4 of the Grid code specifies that the grid owner shall be responsible for providing communication equipment and SCADA equipment at grid substations and related system development at LDC and the communication and SCADA equipment at Connection Points on User's side and related development at LDC shall be the responsibility of generators and other users.
Pakistan	• OC 6.3 of Grid Code 2005 states that communication systems shall provide channels for direct telephone, facsimile and SCADA links (Remote Terminal Unit) between the System Operator and Code Participants. • The SCADA and SCADA Communication System shall be used by NTDC and Code Participants to monitor and control the NTDC transmission network, including 500 kV and 220 kV grid stations, and to dispatch Generators connected to the transmission network. NTDC shall operate, maintain, expand and upgrade from time to time, this SCADA system and a supporting dedicated communication system. • The SCADA system shall also include data from Generators and other Code Participant facilities as required by NTDC.
Sri Lanka	• Section 3.13 of the Grid Code states that a fully functional communication and SCADA System will be established and maintained by the Transmission Licensee. • The Transmission Licensee will provide the necessary facilities at the interconnection point for the user to upload data to the SCADA system and to receive control signals from the SCADA system in accordance with the Connection Agreement. • Communication and SCADA systems shall have the capability for the System Operator to carry out switching operations in the Transmission System and data acquisition.

2.3.7.3. WAMS / PMU for real-time operations

Wide Area Measurement System (WAMS)/ Phasor Measurement Unit (PMU) is technology-based solution to monitor power system dynamics in real time, to identify system stability related weakness and to help design and implement counter measures. PMU can deliver precisely time-synchronized values of voltage and current phasors and other power system related quantities like frequency, ROCOF, breaker positions, etc. WAMS provides visibility that is based on real-time data streamed from Phasor Measurement Units (PMU).

Country	WAMS / PMU for real-time operations
Afghanistan	No information available in public domain.
Bangladesh	Section 13.8 of Bangladesh Electricity Grid Code Regulations, 2019 specifies that Single Buyer shall be responsible for providing and installing the equipment including any Remote Terminal Units (RTUs)/ IEDs / PMUs / Gateways within the generator or distribution utility or bulk power consumer sites.
Bhutan	No information available in public domain.
India	• In order to achieve the goal of Power for All, Ministry of Power, Government of India initiated and supported various smart grid projects. The installation of phasor measurement unit (PMU) based wide area measurement system (WAMS) is one of such major initiative.[83] • WAMS implementation consists of PMUs along with GPS installed at selected substations in the grid and a Phasor Data Concentrator (PDC) and other associated equipment. From the phasor data, load angle between different pockets of the grid is available more accurately with updation time of order from few milliseconds and this enhances the capability of the tools available to grid operator. This historical data shall be useful for post event analysis of any grid incidences.
Maldives	Currently Maldives does not have transmission grid.
Nepal	No information available in public domain.
Pakistan	No information available in public domain.
Sri Lanka	No information available in public domain.

2.3.7.4. Cyber Security - Policy, Framework, Action Plan

Country	Cyber Security - Policy, Framework, Action Plan
Afghanistan	No information available in public domain.
Bangladesh	No information available in public domain.
Bhutan	No information available in public domain.
India	• Clause 4.6.5 of the IEGC 2010 and its amendments specifies that all utilities shall have in place, a cyber security framework to identify the critical cyber assets and protect them to support reliable operation of the grid. • A new code named 'Cyber Security' has been added to the Expert Group Report: Review of IEGC, January 2020. The code provides for identification of critical information infrastructure, appointment of information security officer as per the Information Technology Rules 2018 and take necessary measures in accordance with guidelines by National Critical Information Infrastructure Protection Centre.
Maldives	Currently Maldives does not have transmission grid.
Nepal	No information available in public domain.
Pakistan	No information available in public domain.

Country	Cyber Security - Policy, Framework, Action Plan
Sri Lanka	No information available in public domain.

2.3.8. Monitoring and compliance

The regulatory interventions can only be effective in practice through judicious monitoring of compliance and transparent governance procedures. The presence of robust institutions for monitoring and oversight plays a crucial role in enforcement of rules, policies, standards, and regulations required to maintain grid discipline and reliability. This section focuses on various aspects of monitoring and compliance that are prevalent in SAR countries.

2.3.8.1. Clear demarcation of monitoring and compliance responsibilities

The clear demarcation of monitoring and oversight responsibilities is arguably the first step towards effective enforcement of regulatory interventions. Having a dedicated institution(s) with clearly defined responsibilities ensures at least some degree of independence and focusing of more resources towards these efforts, which in turn ensures more transparent governance as the institution(s) has more leeway to draft effective regulations, standards, codes, and procedures. Comparison of this aspect in various SAR countries is discussed in the following table:

Country	Clear demarcation of monitoring and compliance responsibilities
Afghanistan	No information available in public domain.
Bangladesh	• As per the Bangladesh Energy Regulatory Commission Act, 2003, it is the responsibility of BERC to "collect, review, maintain and publish statistics of energy" and "to frame codes and standards and make enforcement of those compulsory with a view to ensuring quality of service". [Source: http://www.sreda.gov.bd/d3pbs_uploads/files/acts_2_bangladesh_energy_regulatory_commission_act_2003.pdf]
Bhutan	• As per clause 11 of the Electricity Act of Bhutan (2001), Bhutan Electricity Authority (BEA) is responsible for developing regulations, standards (including performance standards), codes, principles and procedures. It also monitors the performance of licensees and their compliance with provision of this Act, regulations, standards, codes, licenses and contracts approved by the authority and concession agreements entered into between the minister and licensees. [Source: https://www.nab.gov.bt/assets/uploads/docs/acts/2014/Electricity_act_2001_Eng.pdf]
India	• RLDC, SLDC & NLDC have clearly demarcated responsibilities in the Electricity Act, 2003 for monitoring and maintaining grid stability and reliability, • As per Central Electricity Regulatory Commission (Indian Electricity Grid Code) Regulations, 2010, RPCs are responsible for conducting third-party protection audits and implementation of islanding schemes • CERC and RPCs are responsible for oversight and monitoring. • Section 73 of the Electricity Act, 2003 determines functions of central electricity authority (CEA). It mandates CEA to specify the technical standards for construction of

Country	Clear demarcation of monitoring and compliance responsibilities
	electrical plants, electric lines and connectivity to the grid. CEA also outlines safety requirements for construction, operation and maintenance of electrical plants and electric lines. As a critical function CEA specifies the Grid Standards for operation and maintenance of transmission lines. [Source 1: http://www.cercind.gov.in/Regulations/Signed-IEGC.pdf Source 2: http://www.cercind.gov.in/Act-with-amendment.pdf]
Maldives	Currently Maldives does not have transmission grid.
Nepal	• As per Chapter 2 "Grid Code Management" of NEA Grid Code a Grid Code Management Committee (GCMC) is established by Nepal Electricity Authority (NEA), which inter alia, is responsible for monitoring implementation of the Grid Code provisions like: • Monitor implementation of the Grid Code; • Review, evaluate, and when appropriate, approve suggestions for amendments to the Grid Code submitted by any User of the Grid; • Recommend to the NEA Management amendments to the Grid Code that the committee believes to be desirable or necessary. • Coordinate Grid Code dispute resolution and, if necessary, make appropriate recommendations to the NEA Management for final decision; • Issue guidance on implementation of the Grid Code to the Users of the Grid when requested; • Recommend to NEA Management a course of actions against a Party who fails to comply with any provision of the Grid Code; and • Prepare Grid Code Management Committee reports on the activities of the committee for submission to NEA Management.
Pakistan	As per Section 7 of Regulation of Generation, Transmission and Distribution of Electric Power (Amendment) Act, 2018, it is the responsibility of NEPRA to "specify and enforce performance standards for generation, transmission and distribution companies and persons licensed or registered under this Act;" [Source: https://nepra.org.pk/Legislation/1-Act/NEPRA%20Act%20May%202%202018.pdf]
Sri Lanka	• Ceylon Electricity Board (CEB), which functions as an integrated utility in Sri Lanka, also functions as a System Operator, • No clear oversight/ monitoring responsibilities assigned.

2.3.8.2. Reporting: periodic reports covering performance of the integrated grid

The second crucial aspect of transparent governance is periodic reporting of performance parameters. Availability of crucial information in the public domain leads to more accountability and public scrutiny. In the comparison of reporting standards in various SAR countries, we have looked at the type and quality of reports that are published in the public domain, which includes but is not limited to:

- Frequency profile;
- Demand met (peak, off-peak and average);

- Instances and quantum of curtailment of renewable energy;
- Demand and energy unserved in MW and MWh;
- Constraints and instances of congestion in transmission system;
- Instances of persistent/significant non-compliance of Grid Code; and
- Cyber threat / attack information.

Country	Reporting: periodic reports covering performance of the integrated grid
Afghanistan	No information available in public domain.
Bangladesh	• No explicit provision in the Grid Code for reporting performance parameters, • No website exists for NLDC. The data published by Power Grid Corporation of Bangladesh (PGCB) on behalf of NLDC is limited to hourly generation and load shedding data. [**Source:** Power Grid Company of Bangladesh Ltd. (http://pgcb.gov.bd/site/page/420a1727-2eab-4874-a387-a018165b6334)]
Bhutan	• As per clause 6.14 of the Bhutan Electricity Authority Grid Code Regulation, 2008, Bhutan Power System Operator to prepare quarterly and annual reports assessing the performance of the transmission system and submit it to all Licensees, Authority and the Ministry (annual reports to only the Ministry and Authority). • No provision for making the information available in the public domain. • However, daily, quarterly and annual reports are published on the Bhutan Power System Operator website (http://bpso.bpc.bt/#) with information in respect of frequency profile, voltage profile, major outages of feeder and equipment etc. [Source: http://www.bea.gov.bt/wp-content/uploads/2013/12/Grid-Code-Regulation.pdf]
India	• As per clause 5.5 of Central Electricity Regulatory Commission (Indian Electricity Grid Code) Regulations, 2010, Daily/weekly/monthly reports are required to be published by RLDC/NLDC covering performance of the regional/ national/ integrated grid, • Weekly reports contain the following: frequency profile, voltage profile of important substations and sub-stations normally having low /high voltages, major generation and transmission outages, transmission constraints, instances of persistent/significant non-compliance of IEGC, instances of congestion in transmission system, instances of inordinate delays in restoration of transmission elements and generating units, non-compliance of instructions of SLDC by SEB/distribution licenses / bulk consumers, to curtail drawl resulting in non-compliance of IEGC, • RLDC is also required to publish quarterly report that brings out system constraints, reasons for not meeting the requirements, if any, of security standards and quality of service, along with details of various actions taken by different persons, and the persons responsible for causing the constraints, • Each RLDC website publishes weekly information on frequency (for each time block of 15 minutes), Injection/ drawl details for CGSs, discrepancy reports, CGS-wise schedule etc. • NLDC website publishes daily, weekly and monthly reports covering performance of the national/ integrated grid. [Source: http://www.cercind.gov.in/Regulations/Signed-IEGC.pdf]

Country	Reporting: periodic reports covering performance of the integrated grid
Maldives	Currently Maldives does not have transmission grid.
Nepal	• As per chapter 11 "Reports" of Nepal Electricity Authority Grid Code, 2005, GCMC is required to submit trimester/annual reports on grid management to NEA, • System operator, grid owner, generators, distributors and other stakeholders prepare reports pertaining to planning studies, grid performance appraisals, connection requirement, grid management, scheduling and dispatch etc., which are typically submitted to GCMC, • The reports are primarily intended for internal use cases and there is no provision in the Grid Code for making the information available in the public domain.
Pakistan	• National Electric Power Regulatory Authority (NEPRA) publishes annual performance evaluation reports for National Transmission & Dispatch Company (NTDC) and K-Electric (https://nepra.org.pk/publications/Performance%20Reports.php), • The report analyses performance on parameters such as system duration of interruption, system frequency of interruption, energy not served (ENS), loss of supply incidents, system collapses/major disturbances, voltage variations violating prescribed limits, frequency variations violating prescribed limits etc. • However, the monitoring is only done on annual basis with the last report published for 2018-19 (https://nepra.org.pk/Standards/2020/PER%20K-Electric%20-%20%20NTDC%202018-19.pdf).

Sri Lanka	• As per clause 4.14.1 of The Grid Code of the Transmission Licensee, Ceylon Electricity Board (2015), it is the system operator's responsibility to analyze all transmission system failures and preparing reports with recommendations for performance improvement.
	• System Operator documents three kinds of reports (submitted to PUCSL):
	  ○ **Daily Reports** include a summary of incidents, events such as system loadings at night peak, day peak and off peak, generation by plant, system failures, demand control activities, planned outages of generating units, etc.
	  ○ **Outage Reports** are event reports which summarize events leading to the total system outage or partial shutdown, restoration activities, and actual restoration times of the relevant Generators and the Transmission System
	  ○ **Monthly reports** include data relating to system outages, demand control measures, quality of supply indicators, etc.
	• The reports are primarily intended for internal use cases and there is no provision in the Grid Code for making the information available in the public domain.
	[Source: https://ceb.lk/front_img/img_reports/1532500179Grid_Code_of_Transmission_Division.pdf]

2.3.8.3. Scope for independent third-party audits such as protection and compliance audits

Regular independent audits are vital in analyzing the existing framework. Compliance audits ensure that the transmission system users are compliant with provisions of the Grid Code and other relevant Codes/ Regulations. It also helps in identifying the flaws in the current framework and provisions and helps improve the existing provisions. Protection audits are conducted to proactively inspect predetermined parameters such as Transformer ratios, stability test results of protection system, setting of synchro check relay etc.to avoid unintended tripping in transmission lines and substations. Details of provisions regarding requirements for conducting independent third-party audits such as protection and compliance audits in the relevant regulations/ grid code of SAR countries is discussed in the following table:

Country	Scope for independent third-party audits such as protection and compliance audits
Afghanistan	No data available in the public domain.
Bangladesh	No provision for independent protection/ compliance audits.
Bhutan	• Section 10 of BEA Safety Regulation 2008 states that Safety Audits may be undertaken by the Authority's own staff or by an appropriately qualified contractor engaged by the Authority for the purpose.
India	• Third-party protection audits managed by regional RPCs for their respective jurisdictions • The Grid Code empowers RPCs in India to "undertake operational planning studies including protection studies for stable operation of the grid" • Third-party/ independent audit reports published by ERPC on their website, but not by other RPCs • Protection Audit Manuals/Checklists available on RPC websites • No scope for compliance audits [Source: http://www.cercind.gov.in/Regulations/Signed-IEGC.pdf]
Nepal	No provision for independent protection/ compliance audits.
Maldives	Currently Maldives does not have transmission grid.
Pakistan	No provision for independent protection/ compliance audits.
Sri Lanka	

2.3.8.4. Periodic monitoring of actual performance of grid operators and grid users against standards of performance (SOP)

Country	Periodic monitoring of actual performance of grid operators and grid users against standards of performance (SOP)
Afghanistan	No data available in the public domain.
Bangladesh	• According to clause 17.3.2 of Bangladesh Energy Regulatory Commission Electricity Grid Code, 2018, BERC to calculate a reliability index to assess the performance of Transmission Licensee (by using indices such as Availability Factor, AACIR - Average Annual Customer Interruption Rate, MTTR - Mean Time to Repair, MTBF - Mean Time Between Failures etc.). • No further details provided in the Grid Code and no other Regulation is available on the BERC website regarding the same. [Source: http://berc.portal.gov.bd/sites/default/files/files/berc.portal.gov.bd/notices/82138506_08a5_4f09_a28a_b0c57ca9b367/Grid%20Code%202018%20-%2011.11.2018%20-%20Corrected%20Version.pdf]

Country	Periodic monitoring of actual performance of grid operators and grid users against standards of performance (SOP)
Bhutan	• As per clause 6.14 of the Bhutan Electricity Authority Grid Code Regulation, 2008 Bhutan Power System Operator to prepare quarterly and annual reports assessing the performance of the transmission system and submit it to all Licensees, Authority and the Ministry (annual reports to only the Ministry and Authority). • No provision for making the information available in the public domain. [Source: http://www.bea.gov.bt/wp-content/uploads/2013/12/Grid-Code-Regulation.pdf]
India	• The Grid Code empowers the Central Electricity Regulatory Commission (Indian Electricity Grid Code) Regulations, 2010, NLDC/RLDC in consultation with CEA, CTU, RPC and the Regional Entities to plan the protection schemes, • As per clause 5.5 of the Daily/Weekly/Monthly reports published by RLDC/NLDC covering performance of the regional/ national/ integrated grid, • Weekly reports contain the following: frequency profile, voltage profile of important substations and sub-stations normally having low /high voltages, major generation and transmission outages, transmission constraints, instances of persistent/significant non-compliance of IEGC, instances of congestion in transmission system, instances of inordinate delays in restoration of transmission elements and generating units, non-compliance of instructions of SLDC by SEB/distribution licenses / bulk consumers, to curtail drawl resulting in non-compliance of IEGC, • RLDC also publishes quarterly report that brings out system constraints, reasons for not meeting the requirements, if any, of security standards and quality of service, along with details of various actions taken by different persons, and the persons responsible for causing the constraints. [Source: http://www.cercind.gov.in/Regulations/Signed-IEGC.pdf]
Maldives	Currently Maldives does not have transmission grid.

Nepal	• As per chapter 11 "Reports" of the Nepal Electricity Authority Grid Code, 2005, performance standards for voltage variations, frequency variations and transmission loss are specified.
	• The system operator and grid owner jointly submit monthly report on grid performance to GCMC containing the following:
	  ○ Transmission availability
	  ○ Transmission reliability
	  ○ Record of safety performance, including details of accidents
	• No further details on computation/ determination of transmission reliability,
	• The System Planning Department of NEA is tasked with "Annually, reviewing performance of the grid for the immediate past year in terms of its capability to serve future generation and demand".

Pakistan	• National Electric Power Regulatory Authority (NEPRA) publishes annual performance evaluation reports for National Transmission & Despatch Company (NTDC) (https://nepra.org.pk/publications/Performance%20Reports.php), • The report analyses performance on parameters such as System duration of interruption, system frequency of interruption, energy not served (ENS), loss of supply incidents, system collapses/major disturbances, voltage variations violating prescribed limits, frequency variations violating prescribed limits etc. • However, it is observed that monitoring is only done on annual basis with the last report published for 2017-18.

Country	Periodic monitoring of actual performance of grid operators and grid users against standards of performance (SOP)
Sri Lanka	• Detailed performance standards prescribed via Electricity (Transmission) Performance Standards Regulation (ETPSR) & Electricity (Distribution) Performance Standards Regulation with Public Utilities Commission of Sri Lanka (PUCSL) acting as the oversight agency • ETPSR also prescribes a commercial mechanism via a formula to 'claw back' allowed revenue from transmission licensee on account of non-compliance of overall performance standards. The main indices utilised for deciding the same are Transmission System Average Interruption Frequency Index (TSAIFI) and Transmission System Average Interruption Duration Index (TSAIDI) [**Source 1:** Electricity (Transmission) Performance Standards Regulation (https://www.ceb.lk/front_img/img_reports/1532499150Electricity_Transmission_Performance_Standared_Regulation1.pdf) **Source 2:** Electricity (Distribution) Performance Standards Regulation (https://www.ceb.lk/front_img/img_reports/1532498750Electricity_Distribution_Performance_Standared_Regulation1.pdf)]

End Notes on Chapter 2.

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https://ieeexplore.ieee.org/document/7581347, accessed June 2020

3. Chapter 3 - Assess level of implementation and compliance of identified measures (Step-3)

3.1. Afghanistan

<table>
<tr><th>Institutions</th><th>Functions</th><th>Level of monitoring</th></tr>
<tr><td>Regulator</td><td>There is no credible information (in English) in public domain about a functioning independent Energy sector regulator in Afghanistan.</td><td rowspan="3">There are no reports available in the public domain regarding Afghanistan’s transmission system performance providing any insight into the level of monitoring and implementation by the concerned institutions.</td></tr>
<tr><td>System Operator
DABS</td><td rowspan="2">Da Afghanistan Breshna Sherkat is the integrated utility cum system operator. There is no independent system operator in Afghanistan.</td></tr>
<tr><td>Transmission Operator
DABS</td></tr>
</table>

3.2. Bangladesh

<table>
<tr><th>Institutions</th><th>Functions</th><th>Level of monitoring</th></tr>
<tr><td>Regulator
Bangladesh Energy Regulatory Commission (BERC)</td><td>Energy regulatory commission was established in 2003 with a mandate to regulate electricity, gas and petroleum products. It’s entrusted with key following responsibilities:
Ensure uniform operational standards and help ensure quality of supply.
Develop performance and incentive-based regulation.
Enforce fiscal discipline in the sector.</td><td rowspan="2">BERC has recently published its draft electricity grid code, 2019 which comprises of provisions related to monitoring of performance standards.
However, no reports, documents, orders etc. regarding grid discipline and grid reliability were available on BERC’s website. Therefore, no conclusion can be drawn regarding level of monitoring for implementation and compliance by BERC.
Power Grid Company of Bangladesh publishes daily and monthly</td></tr>
<tr><td>System Operator
Load Despatch Centre (LDC)</td><td>System operator function is housed under PGCB. It monitors the power system and publishes relevant information.</td></tr>
</table>

Institutions	Functions	Level of monitoring
Transmission Operator Power Grid Company of Bangladesh Ltd. (PGCB)	PGCB was incorporated in 1996 for power transmission business in the country. It is entrusted with reliable and quality transmission service in the country.	operational information in compliance to grid code for monitoring purpose on its website.[84] The information is available from 2013 onwards.

To determine the effectiveness of the regulatory monitoring, analysis of transmission system performance over the years based on data available in the public domain was conducted. Following are the insights from the analysis.

Table 36: Availability of transmission system in Bangladesh[85]

Parameters	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19
Transmission Line availability (%)	99.96	99.98	99.97	99.98	99.97	99.99	99.99
Grid substation availability (%)	99.98	99.96	99.99	99.99	99.98	99.99	99.99

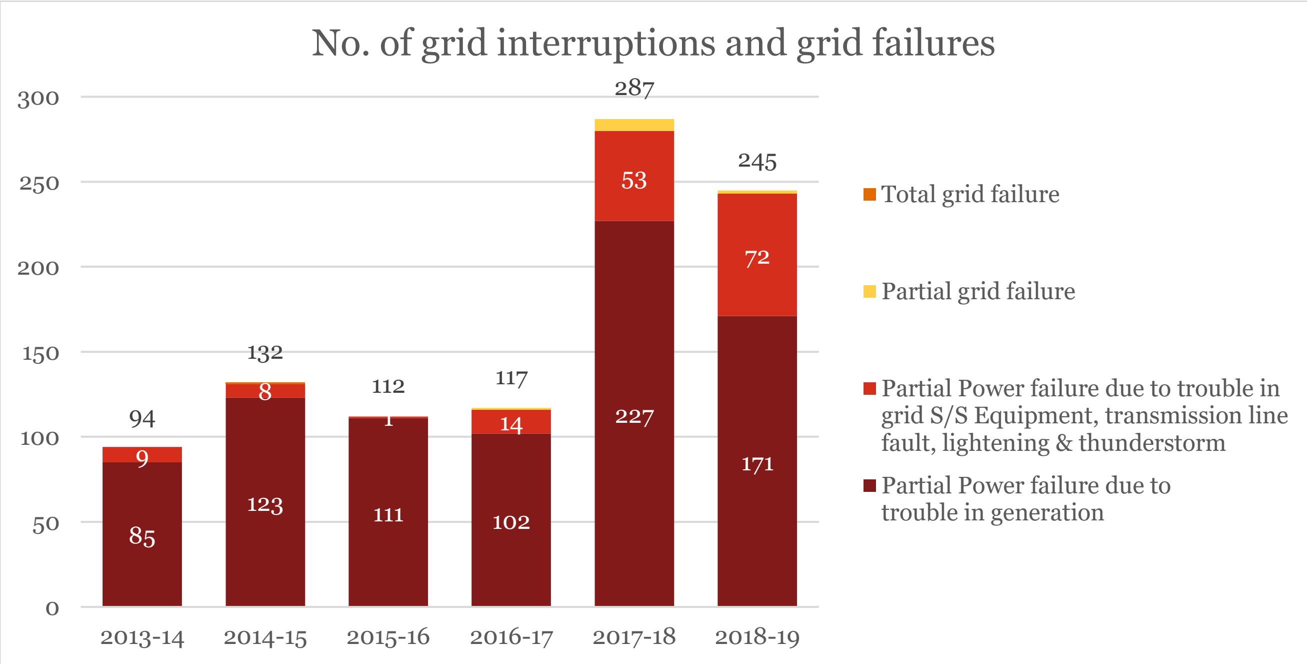

Figure 30: No. of grid interruptions and grid failures in Bangladesh[86]

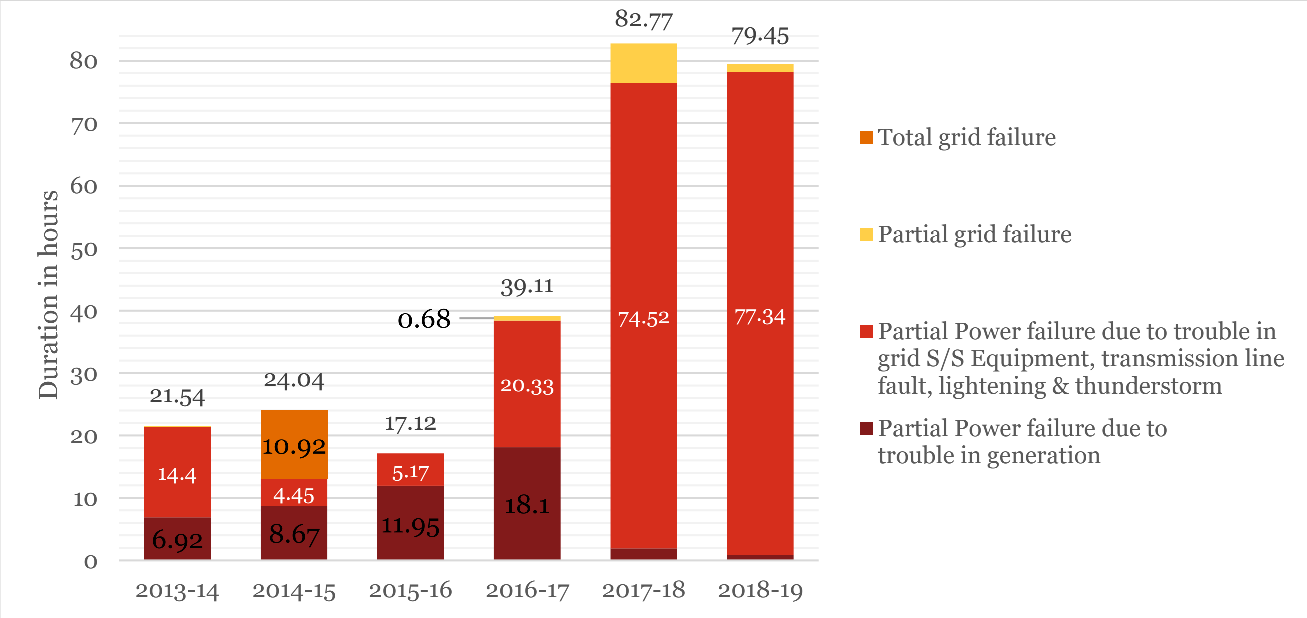

Figure 31: Total duration (in hours) of grid interruptions and grid failure in Bangladesh[87]

Following observations could be inferred from above trends:

1. The availability of the transmission system has been consistently above 99%.

2. No. of interruptions due to problems in transmission system shows increasing trend over the time. There was one complete grid failure[88] on 1st of November 2014 that lasted for over 10 hours. Post 2014, no complete grid failure has occurred.

3. An increasing trend is observed in total duration (in hours) of grid interruptions and grid failures over the years.

This suggests that, even though the transmission system availability is over 99%, the number of instances of grid interruptions and partial grid failures have increased leading to increase in total duration of grid interruptions and grid failures. Based on this observation, it may be concluded that, the regulatory framework has not been able to improve grid discipline and grid reliability in Bangladesh.

The details of the level of implementation based on key indicators for Bangladesh are discussed under this section:

3.2.1. Assessing level of implementation and compliance of identified measures for System Planning

Identified measures	Availability of Provision/Regulation	Level of implementation and compliance
Contingency criterion	Yes, please refer section 2.3.1.1 of this report.	Single outage contingencies of facilities (N-1) were considered under clause 9.1.2 Planning Criteria of Power System Master Plan 2010 with following technical parameters: - Facilities loading < 100%

Identified measures	Availability of Provision/Regulation	Level of implementation and compliance
		- Steady-state voltage range: +/- 10% - Transiently stable to 3-phase to ground fault with normal clearing.
System planning studies for addition of generation capacity from renewable energy sources	Yes, please refer section2.3.1.2 of this report.	As per the Power System Master Plan (PSMP) 2016 which was published in 2018, under clause 13.2.1 Renewable Targeted Generation Capacity defines renewable energy policy target 10%, as per plan the renewable based capacity will be 9,400 MW by 2041 and 2,800 MW by 2021.
System planning studies for CBET (cross-border electricity trade) growth	Yes, please refer section 2.3.1.3 of this report.	In the Power System Master Plan of 2016, electricity imports out of hydropower generation via power interconnections with neighbouring countries of namely Bhutan, Nepal, Myanmar, and the Indian States of the North East and West Bengal for stable base load supply, energy fuel diversification, and climate change mitigation has been considered.
Frequency variation limits	Yes, please refer section 2.3.1.4 of this report.	No information available (or not in English language) on implementation and compliance in the public domain.
Voltage variation limits	Yes, please refer section 2.3.1.5 of this report.	PGCB/NLDC publish voltage profile information in its daily and monthly reports. All the limits related to voltage profile are specified under Bangladesh Electricity Grid Code Regulations 2019. Key information captured under the report are as follows: 1. Maximum and Minimum voltage at substation. [PGCB Daily & Monthly Reports http://pgcb.gov.bd/site/page/0dd38e19-7c70-4582-95ba-078fccb609a8/- http://pgcb.gov.bd/site/page/0cd0c563-4f06-473a-9a7e-c45ead947140/-]

3.2.2. Assessing level of implementation and compliance of identified measures for System construction and safety

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
General safety requirements pertaining to construction, installation, protection, operation, and maintenance of electric lines	Yes, please refer section2.3.2.1 of this report.	Newly Installed / renovated transmission lines or substations are to be tested at the Central testing laboratory at Rampura. PGCB has published a safety manual that lays down the general safety requirements for working on electric lines. Internal audit is conducted to determine whether health & safety system conforms to planned arrangements, is properly implemented & maintained, etc. [https://web.pgcb.gov.bd/qms_documents/QP-RTS-1.PDF/download] [health & safety system audit https://web.pgcb.gov.bd/ohsas_documents/5/download]
Safety provisions for electrical installations and apparatus of voltage exceeding 650 volts	Yes, please refer quality management manuals published by PGCB.	Scheduled & random inspections are conducted for checking if the substations. [https://web.pgcb.gov.bd/qms_documents/QP-SIS-1.pdf/download]
Safety requirements for overhead transmission lines	Yes, please refer quality management manuals published by PGCB.	Officer in-charge of the line inspects the line bi-monthly. Internal audit is conducted by PGCB to determine whether health & safety system conforms to planned arrangements, is properly implemented & maintained, etc. Safety procedure for both man and equipment to be followed during maintenance of overhead transmission lined is laid down by PGCB. [https://web.pgcb.gov.bd/qms_documents/QP-TLM-1.pdf/download]
Capacity building for system construction and safety	Yes, please refer quality management manuals published by PGCB.	Trainings on Electrical Safety & hazards and Occupational Health & Safety management system is conducted by the PGCB & Bangladesh Power Management Institute respectively. [Annual training Plan - PGCB http://pgcb.gov.bd/sites/default/files/files/pgcb.portal.gov.bd/download/c161a0ab_7b5e_4293_b734_49d5f47f2da2/Annual_Training_Plan_2019-20%20(1).pdf]
System safety	Yes, please refer quality management	Internal audit is conducted by PGCB to determine whether health & safety system conforms to planned arrangements, is properly implemented & maintained, etc.

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
	manuals published by PGCB	

3.2.3. Assessing level of implementation and compliance of identified measures for Grid connection

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Detailed procedure for grid connections including RE Generating Companies - Time Frame of processing of application, Standard formats for applicants and model connection agreement	Yes, please refer section 2.3.3.1 of this report.	Detailed procedures and requirements for interconnection are laid down for various users like the generators (new/existing power station), distribution utility, bulk power consumers, etc. in Bangladesh Electricity Grid Code Regulations, 2019. An application is submitted by the user seeking to establish connection. The application shall include details like site, connection point and step-up voltage for connection, station capacity and generating unit data, etc. [Bangladesh Electricity Grid Code 2019]
Details of test required for conventional and non-conventional energy sources prior to trial run for declaration of commercial operation	Yes, please refer section 2.3.3.2 of this report.	Details of tests required are given in the grid Code. But no information is available on implementation and compliance in the public domain.

3.2.4. Assessing level of implementation and compliance of identified measures for System protection, testing and commissioning

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Protection philosophy	No.	Not Applicable.
Protection audit plans with scope of dependability, security, and reliability index	No.	Not Applicable.

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
System / Special protection schemes	Yes, please refer section 2.3.4.3 of this report.	No information available (or not in English language) on implementation and compliance in the public domain.
Testing and commissioning guidelines	Yes, please refer section 2.3.4.4 of this report.	Testing and Commissioning guidelines are published by the PGCB. [https://web.pgcb.gov.bd/qms_documents/QP-SPM-1.pdf/download]

3.2.5. Assessing level of implementation and compliance of identified measures for System operation

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Generation Reserves - Primary, Secondary and Tertiary Reserves, Governor Droop Response, Automatic Generation Control Frequency Control - Primary, Secondary and Tertiary Control	Yes, please refer section 2.3.5.1 of this report.	No information available (or not in English language) on implementation and compliance in the public domain.
System Security - Islanding Schemes, Automatic Voltage Regulators/ Power System Stabilizers for Gencos, Maximum Continuous Rating	Yes, please refer section 2.3.5.3 of this report.	No information available (or not in English language) on implementation and compliance in the public domain.
Demand Management - Under Frequency Management / Load Shedding	Yes, please refer section 2.3.5.4 of this report.	Detailed work instructions for demand management is laid down by the PGCB.
Demand Estimation for Operational Planning	Yes, please refer section 2.3.6.3 of this report.	To facilitate the preparation of generation schedule and load shed planning, daily demand planning is made on the basis of the following: 1. Season & weather condition 2.Previous days tears demand condition (As applicable) 3.Working day or holiday

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
		4.Existence of any emergency priority situation, etc. [https://web.pgcb.gov.bd/qms_documents/QP-PSO-1.pdf/download]
Outage Planning- Procedure for Planned, Forced and Emergency outages, Frequency of Outage Planning (Monthly/Quarterly/Yearly)	Yes, please refer section 2.3.5.5 of this report.	PGCB publishes details of planned, forced and emergency outages in its monthly reports. It includes details such as duration and cause of the outage and unserved load and energy.
Grid recovery procedures - System restoration plans / procedures for partial and total grid failure	Yes, please refer section 2.3.5.6 of this report.	PGCB has published the restoration process in case of partial and full grid failure. [https://web.pgcb.gov.bd/qms_documents/QP-PSO-1.pdf/download]
Commercial mechanisms such as frequency-linked Unscheduled Interchange (UI) or Deviation Settlement Mechanism (DSM) for grid discipline and frequency control	No.	Not Applicable.

3.2.6. Assessing level of implementation and compliance of identified measures for Scheduling and despatch

Identified measures	Availability of Provision/Regulation	Level of implementation and compliance
Detailed Procedure and Timelines for Scheduling and Despatch	Yes, please refer section2.3.6.1of this report.	PGCB has published the scheduling and despatch procedures under their power system operation and control procedures. [https://web.pgcb.gov.bd/qms_documents/QP-PSO-1.pdf/download]
Declaration discipline	No.	Not Applicable.
Short-term demand estimation and	Yes, please refer section2.3.6.3of this report.	No information available (or not in English language) on implementation and compliance in the public domain.

Identified measures	Availability of Provision/Regulation	Level of implementation and compliance
resource management		
Ramping rate to be declared for scheduling	Yes, please refer section2.3.6.4of this report.	No information available (or not in English language) on implementation and compliance in the public domain.
Scheduling of wind and solar generation	Yes, please refer section2.3.6.5 of the report.	No information available (or not in English language) on implementation and compliance in the public domain.
Scheduling of inter-regional and cross-border transactions	Yes, please refer section2.3.6.6of this report.	No information available (or not in English language) on implementation and compliance in the public domain.

3.2.7. Assessing level of implementation and compliance of identified measures for Information and communications technology including cyber security

Identified measures	Availability of Provision/Regulation	Level of implementation and compliance
Communication facilities for data and voice	Yes, please refer section 2.3.7.1 of this report.	Communication Network consists of the following sub systems in Bangladesh: a) Transmission network system b) VoIP (Voice Over Internet Protocol) Network system c) Administrative Telephone network system Transmission network system consists of SDH (Synchronous Digital hierarchy) & PDH (Plesiochronous Digital Hierarchy) system. The role of these equipment to transmit sub-station/power station voice & data to NLDC for smooth power network operation and management. Voice over IP Telephony system & Administrative telephony system both are used for voice communication among NLDC, sub-station & power station for power network operation and management. PGCB has published the procedure for Communication Network Management system maintenance wherein each back up station or master station would be inspected visually twice in a month. [https://web.pgcb.gov.bd/qms_documents/QP-CNS-1.pdf/download]

Identified measures	Availability of Provision/Regulation	Level of implementation and compliance
IT infrastructure (servers, computers, peripherals, etc.) available	Yes, please refer section 7.5 of BERC Grid Code 2019	No information available (or not in English language) on implementation and compliance in the public domain.
SCADA / EMS for real-time operations	Yes, please refer section 2.3.7.2 of this report.	Supervisory Control And Data Acquisition (SCADA) has started functioning within the Four zones of BPDB. Provided that 34 sub-stations within Chattogram zone, 18 sub-stations within Sylhet zone, 17 sub-stations within Mymenshing zone, 10 sub-stations within Cumilla zone are connected under the SCADA of respective zone. BPDB also has a plan to set up one SCADA in Dhaka to monitor/control all SCADA of BPDB centrally[89]. Each Area Control Centre for SCADA/EMS would be inspected visually twice in a year and Back up station would be inspected visually twice in a month. [https://web.pgcb.gov.bd/qms_documents/QP-SMD-1.pdf/download]
WAMS / PMU for real-time operations	Yes, please refer section 2.3.7.3 of this report.	No information available (or not in English language) on implementation and compliance in the public domain.
Technology solutions for managing real-time and back-office operations - power scheduling, energy accounting, deviation settlement, open access transactions, web portal, etc.	No.	Not Applicable.
Cyber Security - Policy, Framework, Action Plan	No.	Not Applicable.

3.2.8. Assessing level of implementation and compliance of identified measures for Monitoring and compliance

Identified measures	Availability of Provision/Regulation	Level of implementation and compliance
Clear demarcation of monitoring and compliance responsibilities	Yes, please refer section2.3.8.1 of this report.	No information available in English language on implementation and compliance in the public domain. The Annual Report for BERC is not published in English.
Reporting: periodic reports covering performance of the integrated grid - Frequency profile - Demand met (peak, off-peak and average) - Instances and quantum of curtailment of renewable energy - Demand and energy unserved in MW	Yes, please refer section2.3.8.2 of this report.	PGCB publishes monthly reports including the following details: 1. Demand met (Peak & average) 2. Demand and Energy unserved (MW & MWh) 3. Consolidated Statement of Transmission lines and substations performance

Identified measures	Availability of Provision/Regulation	Level of implementation and compliance
and MWh - Constraints and instances of congestion in transmission system - Instances of persistent/significant non-compliance of Grid Code - Cyber threat / attack information		4. Overall Power interruption report of the system
Scope for self-audit, independent third-party compliance audit	No, only Internal audits are conducted by PGCB.	Not Applicable.
Periodic monitoring of actual performance of grid operators and grid users against standards of performance (SOP)	Yes, please refer section2.3.8.4 of this report.	PGCB maintains a record of actual performance of users against standards of performance (SOP).

3.3. Bhutan

<table>
<tr><th>Institutions</th><th>Functions</th><th>Level of monitoring</th></tr>
<tr><td>Regulator
Bhutan Electricity Authority (BEA)</td><td>Initially established as functional autonomous agency, later on in 2010 granted with full autonomy by the Royal Government of Bhutan. It is entrusted with the following responsibilities:
Develop regulations, standards, codes, principles and procedures.
Monitor the performance of licensees and their compliance
Grid Code was issues in 2008 and reprinted in 2011</td><td rowspan="3">• Grid Code, 2008, mandates BPSO for reporting of transmission system performance.
• BPSO publishes transmission system performance reports on regular intervals (daily, quarterly and annually) on its website. [http://bpso.bpc.bt/category/management-report/]
[http://bpso.bpc.bt/category/quarterly/]
[http://bpso.bpc.bt/annual-reports/]
• BEA conducts safety audits to verify the enforcement of the Safety Rules and Safety Management System in BPC.</td></tr>
<tr><td>System Operator
Bhutan Power System Operator (BPSO)</td><td>Initially known as National Load Dispatch Center of Bhutan, BPSO came into existence in 2011. It operated under the ambit of Bhutan Power Corporation Limited. It is entrusted with key system operator responsibilities like scheduling and dispatching, transmission outage coordination, monitoring import and export of electricity and prepare forecasting, etc.</td></tr>
<tr><td>Transmission Operator
Bhutan Power Corporation Ltd. (BPC)</td><td>The entity was created in 2002 to adopt greater efficiency and better delivery of electricity. It has been issued with T&D license by BEA for providing transmission access for generating stations for domestic supply as well as export.</td></tr>
</table>

To determine the effectiveness of the regulatory monitoring, analysis of transmission system performance over the years based on data available in the public domain was conducted. Following are the insights from the analysis.

Table 37: Frequency variation in transmission grids of Bhutan[90]

Parameters	Units	2016	2017	2018	2019	2016	2017	2018	2019
Frequency Variation		***Western Grid (Semtokha substation)***				***Eastern Grid (Kurichhu Hydropower Plant)***			
Normal	% of time	99.16%	97.79%	90.95%	90.48%	98.40%	97.63%	89.57%	89.18%
Alert	% of time	0.02%	0.03%	0.03%	0.01%	0.12%	0.18%	0.03%	0.09%
Emergency	% of time	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	0.00%	0.02%
Blackout/Others	% of time	0.82%	2.17%	0.73%	1.42%	1.49%	2.16%	2.06%	2.41%

Table 38: Voltage variation in transmission grids of Bhutan[91]

Parameters	Units	2016	2017	2018	2019	2016	2017	2018	2019
Voltage Variation		*400kV Bus Voltage Operation State (%) (both East and West Grids)*				*220kV Bus Voltage Operation State (%) (both East and West Grids)*			
Normal	% of time	98.10%	98.10%	89.68%	89.73%	92.91%	92.91%	97.70%	97.72%
Alert	% of time	0.79%	0.79%	0.07%	0.02%	5.94%	5.94%	0.39%	0.38%
Emergency	% of time	0.00%	0.00%	0.00%	0.00%	0.02%	0.02%	0.00%	0.00%
Blackout/Others	% of time	1.11%	1.11%	1.92%	1.92%	1.13%	1.13%	1.90%	1.90%

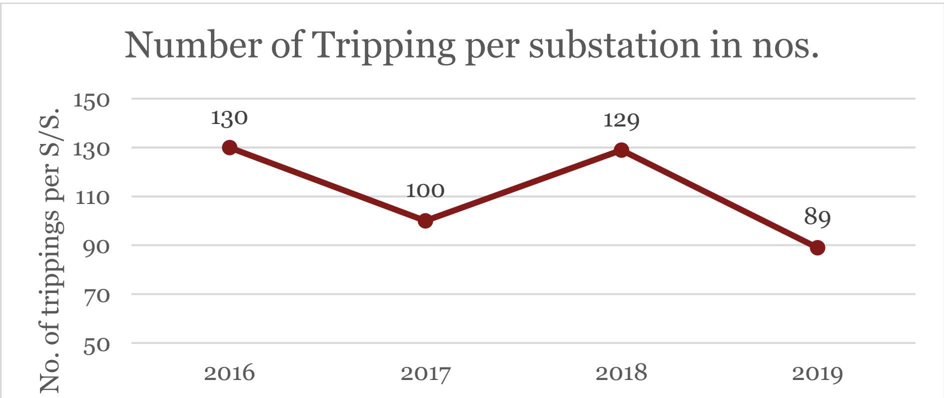

Figure 32: No. of tripping per substation in Bhutan[92]

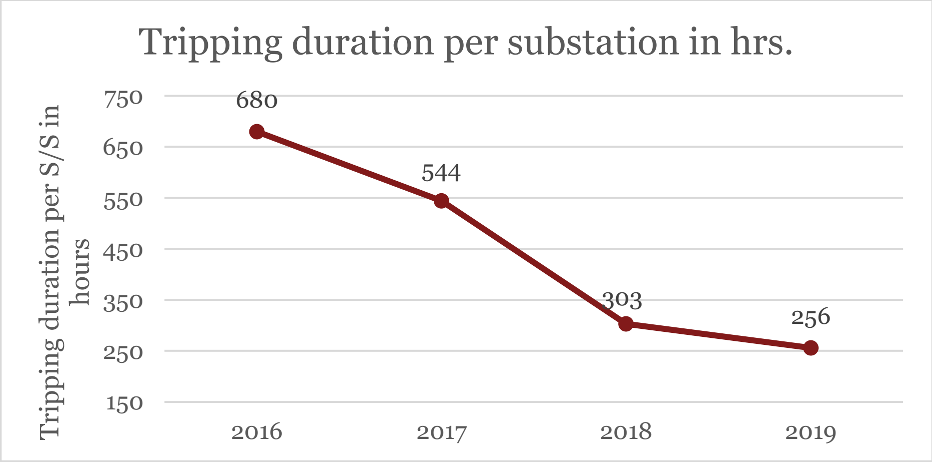

Figure 33: Tripping duration per substation (hours) in Bhutan[93]

Following observations could be inferred from above trends:

1. For the Eastern grid, the percentage of time the frequency and voltage are under normal conditions have been decreasing over the years.
2. For the Western grid, the percentage of time the frequency is under normal conditions have been decreasing over the years whereas the percentage of time the voltage is under normal conditions have been increasing over the years.
3. There is increase in the percentage of time the system is under blackout condition for both eastern and western grids.
4. Number of tripping per substation (in nos.) and tripping duration per substation (in hours) are decreasing over the years.

This suggests that there are mixed signals regarding deterioration in time frequency of both the grid is within the normal range while there is deterioration and improvement in the voltage variation of eastern and western grids respectively. No. of tripping and tripping duration per substation has shown improvements over the years. Therefore, in general, there have been improvements in the level of implementation and compliance of the regulations.

The details of the level of implementation based on key indicators for Bhutan are discussed under this section:

3.3.1. Assessing level of implementation and compliance of identified measures for System Planning

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Contingency criterion	Yes, please refer section 2.3.1.1 of this report.	Bhutan Power System Contingency Plan and Operating Procedures is a dynamic document published by BPC and is updated with change in power system network. It covers the system improvement features, Bus Configuration, configuration of system under normal condition, Contingency and operating procedures in case of failures or shutdown.
System planning studies for addition of generation capacity from renewable energy sources	No, Specific provision regarding RE system integration in system planning studies is not observed.	Not Applicable.
System planning studies for CBET (cross-border electricity trade) growth	Yes, please refer section 2.3.1.3 of this report.	While updating NTGMP, identification of cross border transmission links and their landing points in India were discussed with relevant GoI agencies to capture their future development plan of transmission system and development of national grid including interconnection links and pooling substations.
Frequency variation limits	Yes, please refer section 2.3.1.4 of this report.	Frequency profile of selected substations for the western and eastern grid is published by BPSO in their annual report. All the limits related to frequency profile are specified under Bhutan Grid Code Regulations 2008. Key information captured under the report is the percentage of time the frequency is under the following states: 1. Normal state (within the limit of 49.5Hz and 50.5Hz) 2. Alert state (beyond the normal operating limit but within 49.0Hz to 51.0Hz) 3. Emergency state (There is generation deficiency and frequency is below 49.0Hz)
Voltage variation limits	Yes, please refer section 2.3.1.5 of this report.	Voltage profile of selected substations is published by the BPSO in their annual report. All the limits related to voltage profile are specified under Bhutan Grid Code Regulations 2008. Key information captured under the report is the percentage of time the

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
		voltage at all connection points are under the following states: 1. Normal state (within 0.95 times and 1.05 times of the normal values) 2. Alert state (outside the normal limit but within the limits of 0.9 times and 1.1 times of the normal values) 3. Emergency state (outside the limits of 0.9 times and 1.1 times of nominal values).

3.3.2. Assessing level of implementation and compliance of identified measures for System construction and safety

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
General safety requirements pertaining to construction, installation, protection, operation and maintenance of electric lines	Yes, please refer section2.3.2.1 of this report.	BEA has established the safety principles for equipment maintenance under Operationalization of grid code regulations 2008 (published in November 2017). The Bhutan Electricity Authority (BEA) shall conduct safety audits in accordance to the requirements of the Section 10 of Safety Regulation 2008 of the BEA. [http://www.bea.gov.bt/safety-audit/]
Safety provisions for electrical installations and apparatus of voltage exceeding 650 volts	Yes, please refer Operationalization of Grid Code Regulations 2008	BEA has established the safety principles for equipment maintenance under Operationalization of Grid Code Regulations 2008 (published in November 2017).
Safety requirements for overhead transmission lines	Yes, please refer Safety Code 2008 and Grid Code 2008	BEA has published the safety requirements to be followed. BEA has established the safety principles for equipment maintenance under Operationalization of grid code regulations 2008 (published in November 2017) that includes safety principles on maintenance of cross border transmission lines and established the safety requirements such as clearance for overhead transmission lines in Safety Code 2008. The BEA may initiate an announced or unannounced

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
		investigation/inspection. [http://www.bea.gov.bt/outdoor/]
Capacity building for system construction and safety	No.	Not Applicable.
System safety	Yes, please refer section10 of Safety Regulation 2008 of the BEA	The Bhutan Electricity Authority (BEA) shall conduct safety audits in accordance to the requirements of the Section 10 of Safety Regulation 2008 of the BEA. [http://www.bea.gov.bt/safety-audit/]

3.3.3. Assessing level of implementation and compliance of identified measures for Grid connection

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Detailed procedure for grid connections including RE Generating Companies - Time Frame of processing of application, Standard formats for applicants and model connection agreement	Yes, please refer section 2.3.3.1 of this report.	Detailed procedure for users seeking interconnection is given in the Bhutan Electricity Authority Grid Code Regulation 2008.
Details of test required for conventional and non-conventional energy sources prior to trial run for declaration of commercial operation	Yes, please refer section 2.3.3.2 of this report.	No information available on implementation and compliance in the public domain.

3.3.4. Assessing level of implementation and compliance of identified measures for System protection, testing and commissioning

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Protection philosophy	Yes, please refer section 2.3.4.1of this report.	No information available (or not in English language) on implementation and compliance in the public domain.
Protection audit plans with scope of dependability, security and reliability index	No.	Not Applicable.
System / Special protection schemes	Yes, please refer section 2.3.4.3 of this report.	No information available (or not in English language) on implementation and compliance in the public domain.
Testing and commissioning guidelines	No.	Not Applicable.

3.3.5. Assessing level of implementation and compliance of identified measures for System operation

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Generation Reserves - Primary, Secondary and Tertiary Reserves, Governor Droop Response, Automatic Generation Control Frequency Control - Primary, Secondary and Tertiary Control	Yes, please refer section 2.3.5.1 of this report.	No information available (or not in English language) on implementation and compliance in the public domain.
System Security - Islanding Schemes, Automatic Voltage Regulators/ Power System Stabilizers for Gencos, Maximum Continuous Rating	Yes, please refer section 2.3.5.3 of this report.	Operationalization of grid code regulations 2008 (published in November 2017) mentions that AVRs are used for voltage control for Generation Companies.
Demand Management - Under Frequency Management / Load Shedding	Yes, please refer section 2.3.5.4 of this report.	No information available (or not in English language) on implementation and compliance in the public domain.

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Demand Estimation for Operational Planning	Yes, please refer section 2.3.6.3 of this report.	Distribution and Customer Service Department (DCSD) shall submit the day ahead demand of 19 ESDs in 96 blocks.
Outage Planning- Procedure for Planned, Forced and Emergency outages, Frequency of Outage Planning (Monthly/Quarterly/Yearly)	Yes, please refer section 2.3.5.5 of this report.	BEA has established the process for planned, emergency and preventive maintenance under Operationalization of Grid Code Regulations 2008.
Grid recovery procedures - System restoration plans / procedures for partial and total grid failure	Yes, please refer section 2.3.5.6	System restoration under different scenarios are covered in "Bhutan Power System Contingency Plan, 2017" issued by BPSO. All stakeholders are to follow the operating norms detailed in contingency plan.
Commercial mechanisms such as frequency-linked Unscheduled Interchange (UI) or Deviation Settlement Mechanism (DSM) for grid discipline and frequency control	No commercial penalty/ incentive mechanism for frequency management.	Not Applicable.

3.3.6. Assessing level of implementation and compliance of identified measures for Scheduling and despatch

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Detailed Procedure and Timelines for Scheduling and Despatch	Yes, please refer section 2.3.6.1of this report.	BEA has established the detailed procedure and timelines for scheduling and dispatch under Operationalization of grid code regulations 2008.
Declaration discipline	No clause for mis-declaration is given in the grid code.	Not Applicable.
Short-term demand estimation and resource management	Yes, please refer section 2.3.6.3of this report.	Distribution and Customer Service Department (DCSD) shall submit the day ahead demand of 19 ESDs in 96 blocks.

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Ramping rate to be declared for scheduling	Yes, please refer section 2.3.6.4of this report.	No information available (or not in English language) on implementation and compliance in the public domain.
Scheduling of wind and solar generation	No specific clause for scheduling of Wind and solar generation in the grid code.	Not Applicable.
Scheduling of inter-regional and cross-border transactions	Yes, please refer section 2.3.6.6of this report.	Detailed scheduling and despatch procedure is given in Operationalization of grid code regulations 2008 in line with the Grid code regulations.

3.3.7. Assessing level of implementation and compliance of identified measures for Information and communications technology including cyber security

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Communication facilities for data and voice	Yes, please refer section 2.3.7.1 of this report.	Station in-charge/shift in-charge shall be responsible for all communications between the System Operator and the respective end users/field operators.
IT infrastructure (servers, computers, peripherals, etc.) available	No	Basic IT infrastructure is available in Bhutan. Bhutan has also developed the ICT network by deploying the fibre optic cable network along with the transmission network.
SCADA / EMS for real-time operations	Yes, please refer section 2.3.7.2 of this report.	SCADA is used to record data and for real-time operations (BPSO annual report). BEA has mentioned the use of SCADA by the operator for running the scheduling application software, Resource Scheduling Commitment (RSC)under Operationalization of grid code regulations 2008 (published in November 2017).
WAMS / PMU for real-time operations	No.	Open Systems International, Inc. (OSI) has been awarded a contract by Bhutan Power Corporation Limited (BPC) of the Kingdom of Bhutan to deliver a state-of-the-art Advanced Distribution Management System (ADMS) based on OSI's monarch (Multi-platform Open Network Architecture) real-time automation and visualization platform[94].

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Technology solutions for managing real-time and back-office operations - power scheduling, energy accounting, deviation settlement, open access transactions, web portal, etc.	Yes, please refer Operationalization of grid code regulations 2008	BEA has mentioned the use of SCADA by the operator for running the scheduling application software, Resource Scheduling Commitment (RSC)under Operationalization of grid code regulations 2008 (published in November 2017).
Cyber Security - Policy, Framework, Action Plan	No.	Not Applicable.

3.3.8. Assessing level of implementation and compliance of identified measures for Monitoring and compliance

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Clear demarcation of monitoring and compliance responsibilities	Yes, please refer section 2.3.8.1 of this report.	BEA has developed and published the Act, regulations and codes on its website. It also monitors the performance of licensees and their compliance.
Reporting: periodic reports covering performance of the integrated grid - Frequency profile - Demand met (peak, off-peak and average) - Instances and quantum of curtailment of renewable energy - Demand and energy unserved in MW and MWh - Constraints and instances of congestion in transmission system - Instances of persistent/significant non-compliance of Grid Code - Cyber threat / attack information	Yes, please refer section 2.3.8.2 of this report.	The Annual report of BPSO is published that covers performance of the grid. It includes the following details: 1. Frequency profile, 2. Peak demand, energy availability and requirement for the country, 3. Major generating stations and transmission lines outages, and 4. Transmission constraints, etc.

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Scope for self-audit, independent third-party compliance audit	Yes, please refer section 2.3.8.3 of this report.	The Monitoring Division of BEA has conducted electrical safety audits of BPC.
Periodic monitoring of actual performance of grid operators and grid users against standards of performance (SOP)	Yes, please refer section2.3.8.4 of this report.	BPC published certain performance parameters of the grid in the annual report, but the periodic monitoring reports prepared by BPC for all Licensees, Authority and the Ministry are not available in the public domain.

3.4. India

<table>
<tr><th>Institutions</th><th>Functions</th><th>Level of monitoring</th></tr>
<tr><td>Regulator
Central Electricity Regulatory Commission (CERC)</td><td>CERC was established under Electricity Act, 2003 to discharge mandatory and advisory functions. Key functions are listed below:
▪ Regulate the inter-State transmission of electricity.
▪ Issue license to function as transmission licensee and electricity trader.
▪ Specify Grid Code having regard to Grid Standards.
▪ Enforce the standards with respect to quality, continuity and reliability of service by licensees.</td><td rowspan="2">• CERC had published Indian electricity grid code in 2010 and there have been subsequent six amendments till date to update the grid code from time to time. CERC conducts active monitoring of compliance by various stakeholders regarding the provisions of grid discipline and grid reliability in related
• CERC deviation settlement Regulation helps promote grid discipline. Respective Regional Load Despatch Centers carry out deviation settlement according to the Regulations.
• The Power System wing of the CEA conducts studies related to power system planning, appraisal, power system engineering and technology</td></tr>
<tr><td>Technical Standardising Agency
Central Electricity Authority (CEA)</td><td>CEA was established to perform statutory functions by proving technical standards & regulations for power sector stakeholders. Its key functions are as follows:
▪ Formulation of electricity plans.
▪ Ensure safety and security in power system.</td></tr>
</table>

Institutions	Functions	Level of monitoring
	▪ Promote R&D and state-of-art technology in power sector.	development, project monitoring and power communication development.
System Operator National Load Despatch Centre (NLDC) with the support of Reginal Load Despatch Centres (RLDCs)	NLDC has been constituted as per Ministry of Power (MOP) notification dated 2nd March 2005 and is the apex body to ensure integrated operation of the national power system. Its key functions are as follows: ▪ Supervision Over the Regional Load Despatch Centers ▪ Monitoring of operations and grid security of the national grid ▪ Coordination with Regional Power Committees for regional outage schedule ▪ Coordination for trans-national exchange of power.	• NLDC publishes system operation reports on grid frequency and voltage profile, regional deviations, ancillary service and system reliability indices report etc. on regular interval (daily, monthly, quarterly and annually). • RPC is composed of individual committees for operation, protection and communication etc. which recommend and publish information related to observation made on status of grid discipline and grid reliability for specific region.
Regional Power Committees Northern, Western, Southern, Eastern and North Eastern Regions (RPCs)	These regional committees are established through Electricity Act 2003 by GoI. RPCs are entrusted with following key functions: ▪ Undertake regional operation analysis for improving grid performance. ▪ Conduct operational planning studies including protection studies. ▪ Planning relating to inter-state/ intra-state transmission system with CTU/STU.	
Transmission Operator Power Grid Corporation of India Ltd. (PGCIL) and other Inter-state Transmission Licensees	PGCIL is delegated to undertakes transmission of electricity through ISTS. It discharges all functions of planning co-ordination relating to ISTS with all concerned authorities.	

To determine the effectiveness of the regulatory monitoring, analysis of transmission system performance over the years based on data available in the public domain was conducted. Following are the insights from the analysis.

Table 39: Frequency variation in India Transmission grid[95]

Parameters	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Normal (% of time)	52.06	66.72	72.38	76.24	76.15	72.9
Applicable normal range of grid frequency	49.9 Hz. - 50.05 Hz.	49.9 Hz. - 50.05 Hz.	49.9 Hz. - 50.05 Hz.	49.95 Hz - 50.05 Hz[2]	49.95 Hz - 50.05 Hz	49.95 Hz - 50.05 Hz
<49.9 Hz. (% of time)	26.10	13.45	7.46	10.55	11.89	6.53
>50.5 Hz. (% of time)	21.81	19.82	20.16	13.21	11.96	20.56
Frequency Deviation Index	NA	33.16	27.62	23.76	23.85	27.09

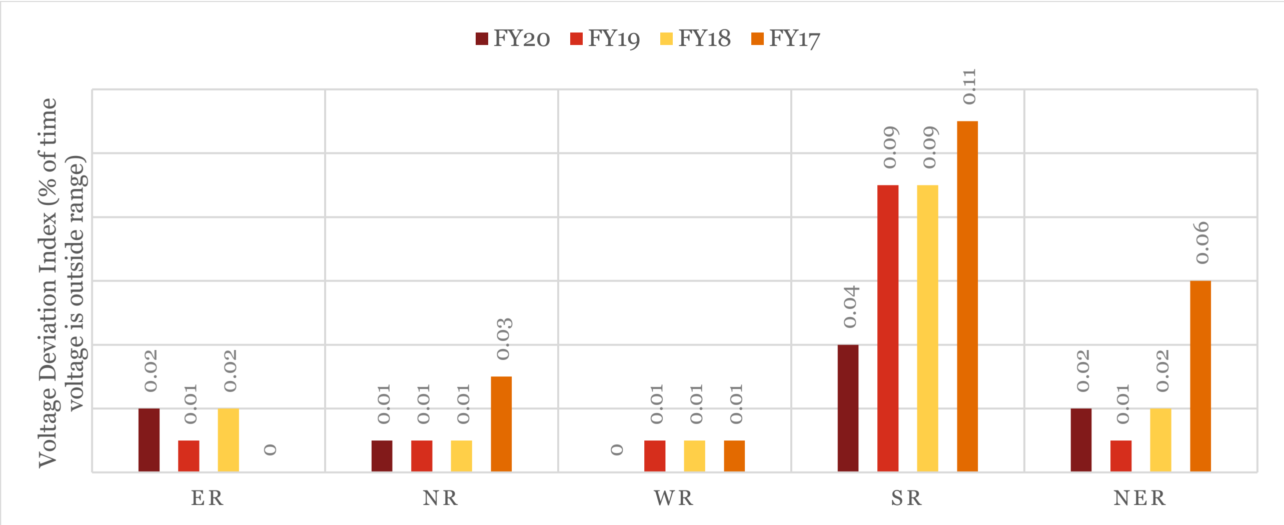

Figure 34: Frequency Deviation Index for ER, NR, WR, SR and NER grids in India[96]

Table 40: Percentage Weighted Average Over drawal (+ve) or Under drawal (-ve) in ER, NR, WR, SR and NER grids in India[97]

FY	ER	NR	WR	SR	NER
FY20	2.19	-0.38	-0.09	0.14	-0.57
FY19	-2.03	0.83	4.47	0.17	-0.30
FY18	0.85	0.46	5.92	1.32	2.28
FY17	1.98	0.39	-0.42	2.00	5.89
FY16	1.54	0.70	-0.03	3.31	7.69
FY 15	0.64	1.51	-0.44	2.62	6.43

[2] Indian grid frequency was tightened from 49.9 Hz.- 50.05 Hz. to 49.95 Hz. – 50.05 Hz. from 12th April 2017 onwards through fifth Amendment to CERC (Indian Electricity Grid Code) Regulations, 2010.

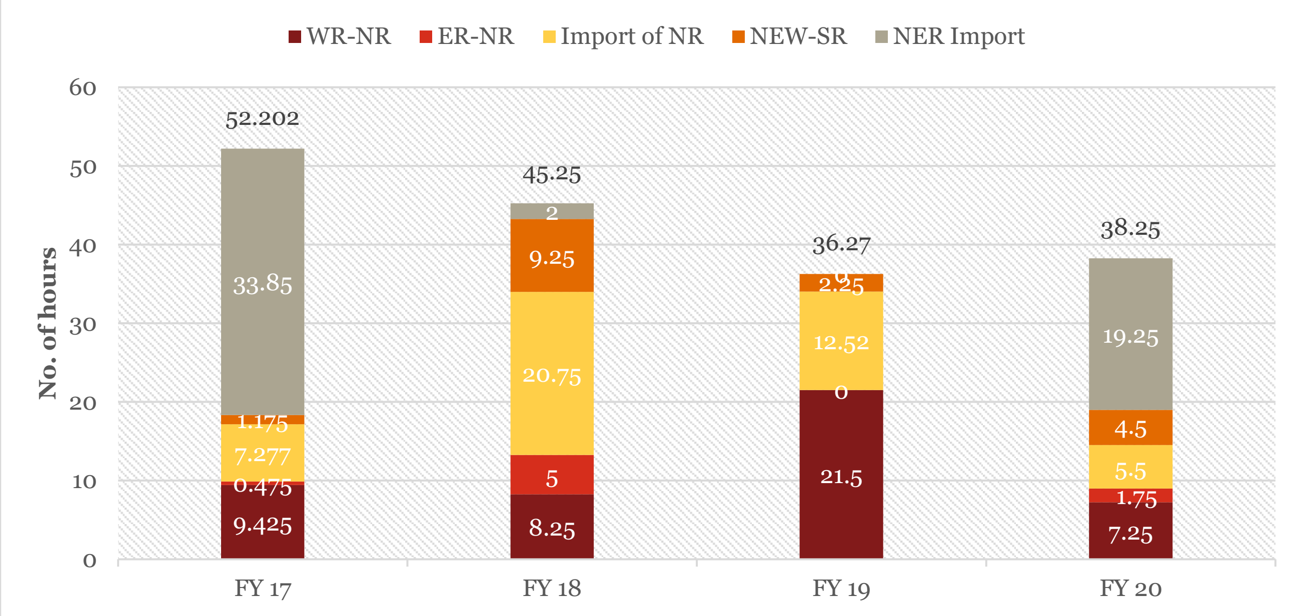

Figure 35:No. of hours of N-1 criterion violation in WR-NR, ER-NR, Import of NR, New SR and NER import[98]

Analysis of grid incidents and grid disturbances:

Category GI-1 of grid incidence is defined as tripping of one or more power system elements of the grid like a generator, transmission line, transformer, shunt reactor, series capacitor and Static VAR Compensator, which requires re-scheduling of generation or load, without total loss of supply at a sub-station or loss of integrity of the grid at 220 kV (132 kV in the case of North-Eastern Region).

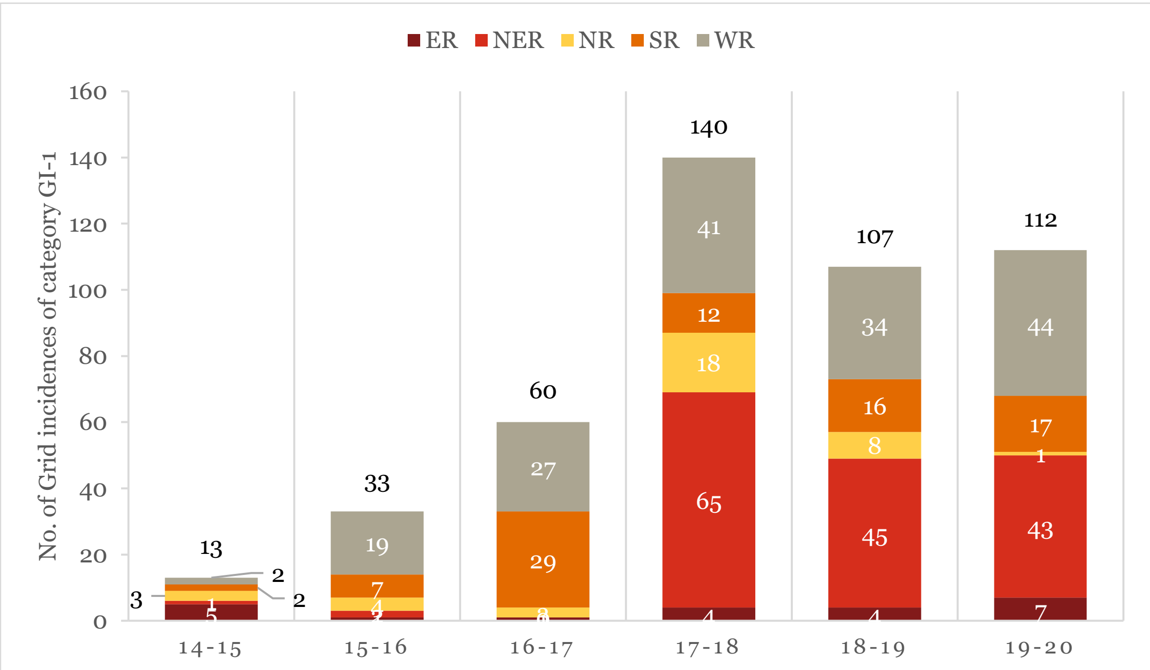

Figure 36: No. of grid incidences of category GI-1[99]

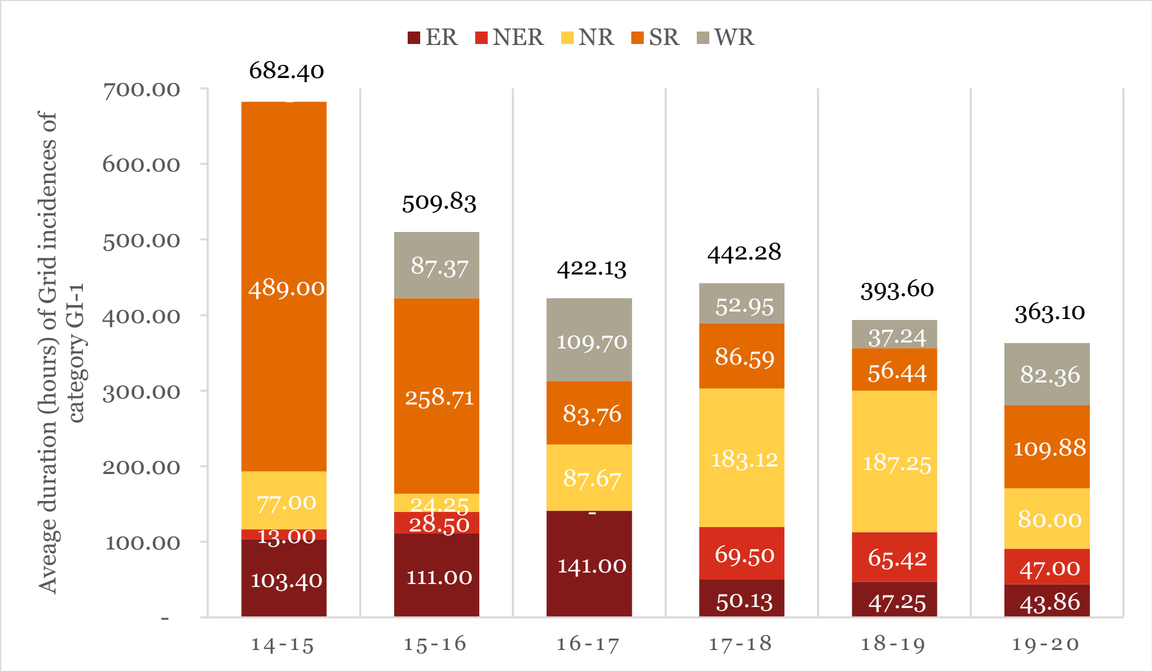

Figure 37: Average duration (hours) of grid incidences of category GI-1[100]

Category GI-2 of grid incidence is defined as tripping of one or more power system elements of the grid like a generator, transmission line, transformer, shunt reactor, series capacitor and Static VAR Compensator, which requires re-scheduling of generation or load, without total loss of supply at a sub-station or loss of integrity of the grid at 400 kV and above (220 kV and above in the case of North-Eastern Region)

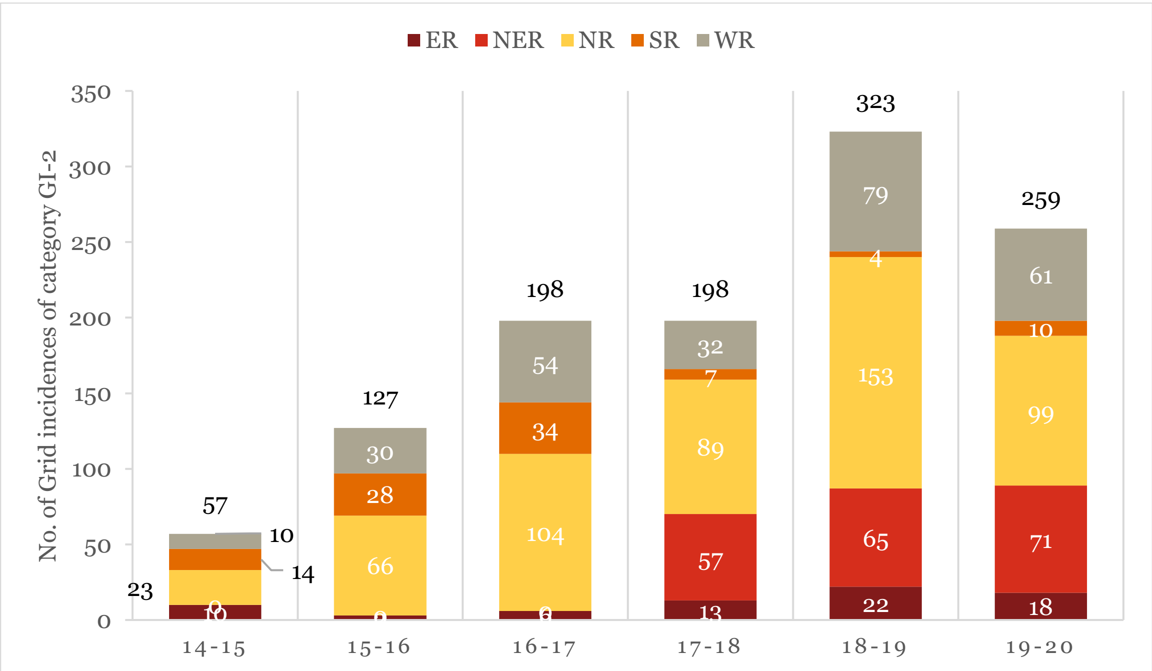

Figure 38: No. of grid incidences of category GI-2[101]

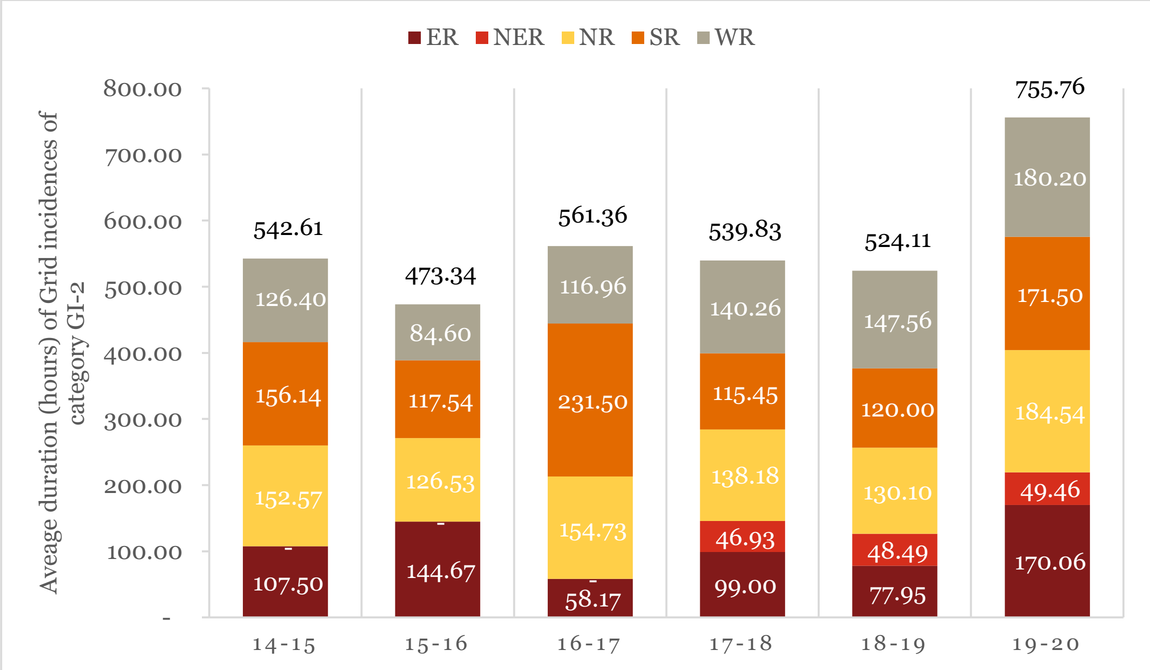

Figure 39: Average duration (hours) of grid incidences of category GI-2[102]

Category GD-1 of grid disturbance is defined as the grid disturbance when lessthan10%. of the antecedent generation or load in a regional grid is lost.

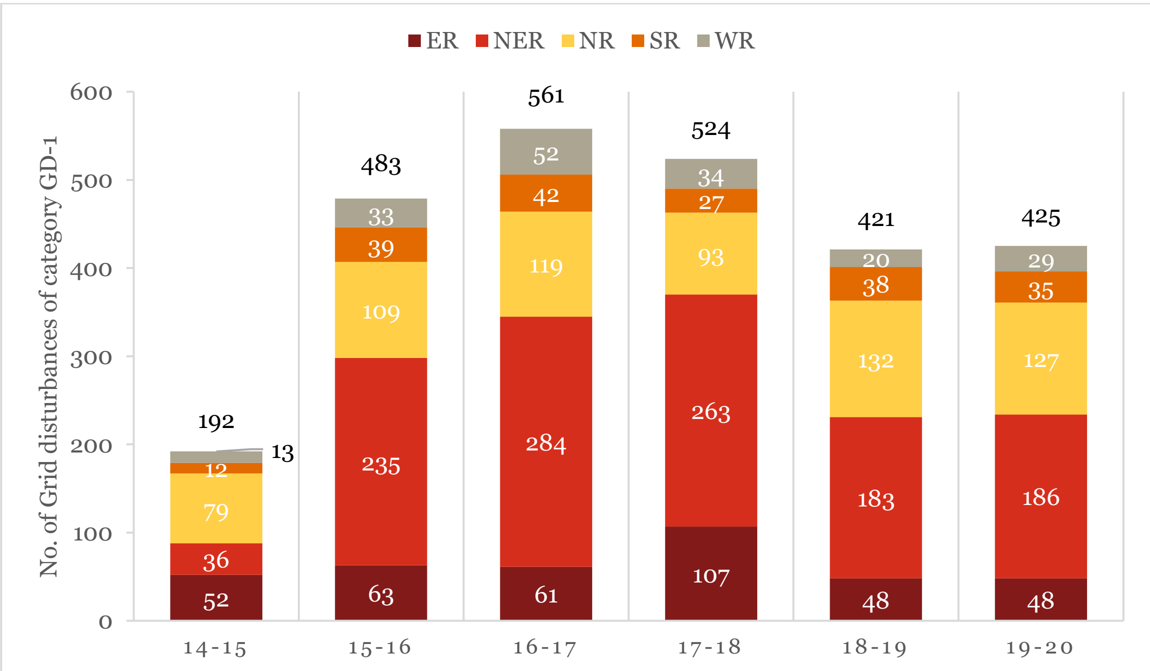

Figure 40: No. of grid disturbance of category GD-1[103]

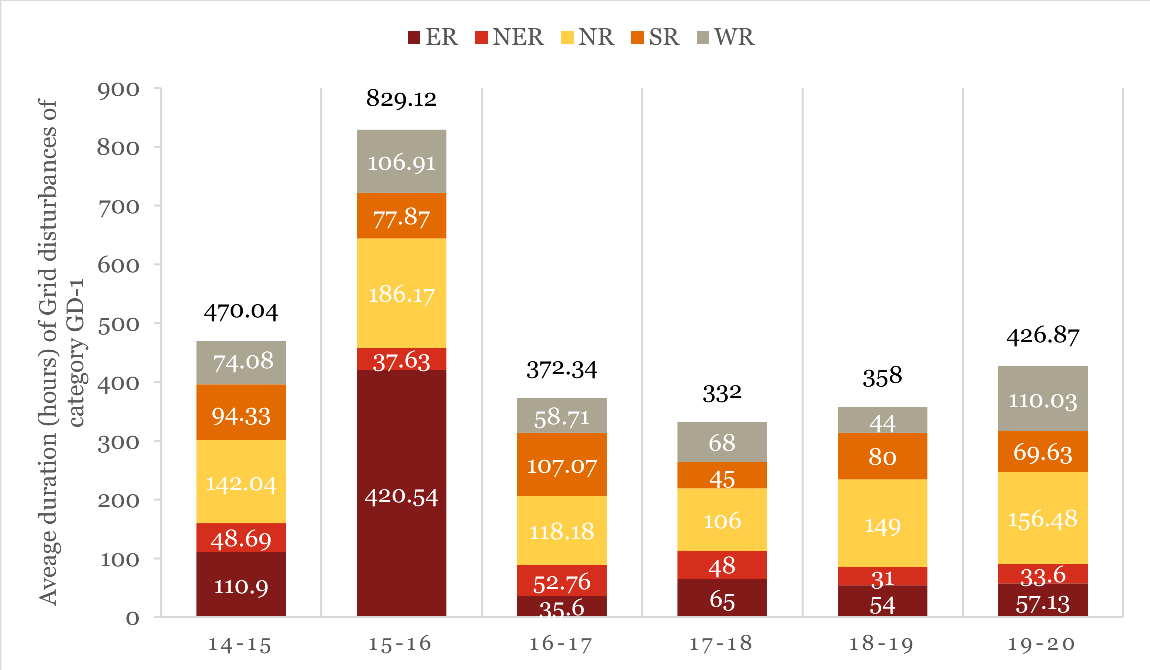

Figure 41: Average duration (hours) of grid disturbance of category GD-1[104]

Category GD-2 of grid disturbance is defined as the grid disturbance when 10% to less than 20% of the antecedent generation or load in a regional grid is lost.

Since 2014-15 till 2019-20 no grid disturbances of GD-2 category were observed in ER, NR, SR and WR grids. GD-2 category grid disturbances were observed only in NER grid.

Table 41: Grid disturbances of GD-2 category observed in NER grid[105]

NER Grid	14-15	15-16	16-17	17-18	18-19	19-20
No. of GD-2	3	5	4	6	2	2
Average duration (hours) of GD-2	119.33	32	28	18	15	59

No specific trend is observed.

Category GD-3 of grid disturbance is defined as the grid disturbance when 20% to less than 30% of the antecedent generation or load in a regional grid is lost.

Since 2014-15 till 2019-20 no grid disturbances of GD-3 category were observed in ER, NR, SR and WR grids. GD-3 category grid disturbances were observed only in NER grid.

Table 42: Grid disturbances of GD-3 category observed in NER grid[106]

NER Grid	14-15	15-16	16-17	17-18	18-19	19-20
No. of GD-3	2	2	0	2	1	0
Average duration (hours) of GD-3	105.5	47	0	17	35	0

No specific trend is observed.

Category GD-4 of grid disturbance is defined as the grid disturbance when 30% to less than 40%ofthe antecedent generation or load in a regional grid is lost.

Category GD-5 of grid disturbance is defined as the grid disturbance when 40% or more of the antecedent generation or load in a regional grid is lost.

Category GD-4 and GD-5 grid disturbances are rare compared to GD-1, GD-2 and GD-3 category disturbances. However, over the years from 2014-15, they have occurred infrequently in NER grid only.

Table 43: Grid disturbances of GD-4 and GD-5 category observed in NER grid[107]

NER	14-15	15-16	16-17	17-18	18-19	19-20
No. of GD-4	0	0	1	1	0	0
No. of GD-5	0	0	1	0	0	2

Following observations could be inferred from above trends:

1. For the last 4 years the frequency duration index is in and around value of 25.
2. Over the last few years CERC has been tightening the operational frequency band in a progressive manner.
3. It is observed that, Voltage Deviation Index values for SR grid are much higher than that for ER, NR, WR and NER grids. This shows that on an average 9% of time voltage in SR grid is outside the normal range.
4. Since FY 15 there is consistent trend of over drawal observed in the SR grid. It is observed that, in NER grid over the years, high % of over drawal shave reduced gradually.
5. It is observed that, total no. of hours of N-1 criterion violations has shown a declining trend over the years
6. Declining trend in the average duration (in hours) of Grid Incidences of category GI-1 is observed over the years.
7. No specific trend is observed in no. of incidents and average duration (in hours) of Grid Disturbances of category GD-1.
8. Grid disturbances of category GD-2, GD-3, GD-4 and GD-5 are prevalent in NER grid only, based on observations for past 6 years.

The details of the level of implementation based on key indicators for India are discussed under this section:

3.4.1. Assessing level of implementation and compliance of identified measures for System Planning

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Contingency criterion	Yes, please refer section 2.3.1.1 of this report.	As empowered by the Electricity Act and IEGC, respective RPCs came with their operating procedures. These operating procedures envisage for N-1 and N-1-1 (N-2) contingency conditions to bring the system parameters back within their normal limits, load re-scheduling of generation may have to be applied either manually or through automatic system protection schemes (SPS). [108] RPCs conduct Operation Co-ordination Committee (OCC) meetings to review implementation of contingency levels for transmission elements based on the review of monthly grid operation. In these meetings RPCs review line--wise implementation status of N-1/N-1-1 contingency conditions or recommendations are made to avoid line tripping/faults.[109]
Transient and steady-state stability limits	Yes, please refer IEGC 2010	Voltage-wise fault clearance limits are specified under IEGC (100 ms. for 765 kV & 400kV and 160 ms. for 220kV systems). RPCs publish information related to multiple elements tripping events in the region every month. Based on this information, it has been observed that a few elements remained under fault beyond clearance limits. For example, Maximum fault duration is 2360 ms. in the event of multiple elements tripping at 400/220 kV Daulatabad (Haryana) on 26th February 2020 at 13:26 hrs.[110]
System planning studies for addition of generation capacity from renewable energy sources	Yes, please refer section 2.3.1.2 of this report.	Power Grid Corporation of India Limited (POWERGRID), the Central Transmission Utility (CTU) conducts studies from time to time to plan for integration of RE generators. These studies cover dimensions like estimation of reserve requirements to compensate RE disturbance, variability and intermittency and compliance related to Low Voltage Ride Through (LVRT) etc. Based on these analyses, a road map is prepared for the development of green energy corridors and system updation requirements.[111]
System planning studies for CBET (cross-border electricity	Yes, please refer section 2.3.1.3 of this report.	CEA National Electricity Plan for transmission consider power off take scenarios from neighboring countries while conducting system planning. CEA NEP 2019 envisages cross-border power exchanges with neighboring countries considered for plan period (2017-22) includes about 4500 MW import from Bhutan and 1500 MW & 950MW export to Bangladesh & Nepal respectively.[112]

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
trade) growth		
Frequency variation limits	Yes, please refer section 2.3.1.4 of this report.	Information related to frequency profile of the grid is published by National Load Dispatch Centre (NLDC) under its daily, monthly and year reports. All the limits related to grid frequency are specified under IEGC[113]. The information published related to grid profile are as follows: 1. Average Frequency 2. Max/Min Instantaneous Frequency 3. Max/Min 15-minute Average Frequency 4. No. of hours grid frequency was outside the band (49.9 Hz - 50.05 Hz) 5. Percentage of time the grid frequency remained in the band (< 49.9 Hz, 49.9 Hz - 50.05 Hz, > 50.05 Hz)
Voltage variation limits	Yes, please refer section 2.3.1.5 of this report.	National Load Dispatch Centre (NLDC) publishes region--wise voltage profile information in its monthly reports. All the limits related to voltage profile are specified under IEGC. Key information captured under the report are as follows[114]: 1. Voltage deviation index (% of time voltage is outside the prescribed limits) 2. Number of hours voltage was outside IEGC band during the month 3. Maximum and Minimum voltage at substations
Estimation and declaration of transmission capabilities in advance	Yes, please refer section 2.3.1.6 of this report.	Information related to Total Transfer Capability is published by National Load Dispatch Centre (NLDC) on a monthly basis. This information is published for Inter Country, Inter Regional and Intra Regional.[115] Key parameters covered under these reports are as follows: 1. Total Transfer Capability (TTC) 2. Reliability Margin 3. Available Transfer Capability (ATC)

3.4.2. Assessing level of implementation and compliance of identified measures for System construction and safety

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
General safety requirements	Yes, please refer	Inspection of safety requirement pertaining to construction, installation, protection, operation and maintenance is done in two

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
pertaining to construction, installation, protection, operation and maintenance of electric lines	section2.3.2.1 of this report.	stages. First is before commissioning of the lines/substation by Electricity Safety Inspector, a summary report published by Chief Electrical Inspectorate Division of CEA. Second is periodic audit of transmission lines it's been conducted by Regional Inspectorial Organization of CEA; a summary report is published. In these reports only name of the site, date of inspection and date of reporting is published.[116]
Safety provisions for electrical installations and apparatus of voltage exceeding 650 volts	Yes, please refer CEA Regulation 2007 & 2008	Standing Committee on Electrical Safety of CEA conducts a meeting on a yearly basis, the agenda of these meeting are mostly for reviewing safety standards related to RoWs, firefighting systems and best practices related to stringing.[117]
Safety requirements for overhead transmission lines	Yes, please refer CEA Regulation 2007 & 2008	Pilot audit of transmission lines are done by Chief Electrical Inspectorate Division of CEA. For this, region-wise critical elements are selected based on their loading and previous faults. The published report consists of information related to tests/checks that were conducted for audits. Observations and recommendations are made based on visual, dimension based and level of corrosion etc.[118]
Capacity building for system construction and safety	Yes, please refer CEA Regulation 2007 & 2008	Regional Inspectorate Offices (RIOs) of CEA conducts awareness generation program for electrical safety standards amongst different stakeholders.[119]
System safety	Yes, please refer CEA Regulation 2007 & 2008	Regional Inspectorate Offices (RIOs) of CEA conduct system safety audit to investigate problems due to any induced voltage from HT lines. This encompasses two dimensions. First, is checks whether the system operation is in prescribed limits or not and the second is the impact on humans exposed to these networks.[120]

3.4.3. Assessing level of implementation and compliance of identified measures for Grid connection

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Detailed procedure for grid connections including RE Generating Companies - Time Frame of processing of application, Standard formats for applicants and model connection agreement	Yes, please refer section 2.3.3.1 of this report.	Procedure for RE is being issued in accordance with Regulation 27 of the Central Electricity Regulatory Commission (Grant of Connectivity, Long-term Access and Medium-term Open Access in inter-State Transmission and related matters) Regulations, 2009. These procedures are helpful for Grant of Connectivity to the transmission lines or associated facilities of the inter-State transmission system (ISTS), the applications are received by the Central Transmission Utility (CTU). The application shall include details like site identification and land acquisition, environmental clearance for the power station and forest clearance (if applicable) for the land for the power station etc.[121]
Details of test required for conventional and non-conventional energy sources	Yes, please refer section 2.3.3.2 of this report.	Conventional Generators Procedures for grant of connectivity list down details of test and studies needed before applying for connectivity. These information requirements are under specific connectivity formats/schedules. 1. Rating of Generating Units (Schedule IV of Con 4 format) 2. Generator Data for Fault (Short Circuit Studies) (Schedule V of Con 4 format) 3. Dynamic Simulation Data (Schedule VI of Con 4 format) 4. Two Winding Transformer Data (Schedule VII of Con 4 format) 5. Three Winding Transformer Data (Schedule VIII of Con 4 format) 6. Acceptable IEEE standard excitation model available with PSS/E simulation package used by POWERGRID (Annexure-II)[122] RE Generators Procedures for grant of connectivity list down details of test and studies needed before applying for connectivity. These information requirements are under specific connectivity formats/schedules[123]. (i) Planned capacity (not less than 100 MVA or 50 MVA in case of NER) (ii) Voltages, MVA Capacity, No. & Rating of Transformers (iii) EHV Switchyard configuration, bays and status

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
		(iv) Low Voltage switchgear configuration, no. of sections, no. of bays in each section and status (v) Single Line Diagram of generator pooling station (vi) Date of Award of generator pooling station (vii) Progress of generator pooling station erection: Switchyard, Main Transformers, Low Voltage Switchgear.

3.4.4. Assessing level of implementation and compliance of identified measures for System protection, testing and commissioning

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Protection philosophy	Yes, please refer section 2.3.4.1of this report.	RPCs of each region prepare and publish their agreed protection philosophy for implementation, it consists of the following parameters[124]: 1. Protection setting for lines 2. Power Swing Blocking 3. Protection for broken conductor 4. Carrier protection settings 5. Back-up protection 6. Auto reclosing with dead time 7. LBB protection and bus bar protection.
Protection audit plans with scope of dependability, security and reliability index	Yes, please refer section2.3.4.2of this report.	National Load Despatch Centre (NLDC) publishes a daily, weekly and monthly report for monitoring of reliability standards named as "System Reliability Indices Report". These reports cover following information: 1. Percentage (%) of times Available Transfer Capability (ATC) was violated 2. Percentage (%) of times (N-1) Criteria was violated 3. Frequency Deviation Index (FDI) 4. Voltage Deviation Index 5. Phasor Angle. [NLDC Reliability Index - https://posoco.in/reports/system-reliability-indices/monthly-vdittcatc/monthly-vdittcatc-2019-20/]

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
System / Special protection schemes	Yes, please refer section 2.3.4.3 of this report.	RPC's Protection Sub-Committee undertakes review meetings on implementation for protection settings. These meetings are conducted monthly/bimonthly, based on the review committee to suggest measures for bringing improvement in the field of power system protection among the utilities in the region. It also takes follow up action on outstanding issues from previous meetings. [NRPC Protection Sub-Committee Meeting - https://nrpc.gov.in/submeeting-type/protection-sub-committee/?lang=en]
Testing and commissioning guidelines	Yes, please refer section 2.3.4.4 of this report.	Prior to energization the transmission line/substation needs to get clearance from Chief Electrical Inspectorate (CEI) Division of CEA. Therefore, an application for statutory inspection of the electrical installations under Regulations 43 & 32 of the Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations, 2010 for approval of the electrical inspector for energization is required. Later on, the CEI division of CEA publishes information related to the inspections done on a monthly basis. [CEA CEI Format - http://www.cea.nic.in/cei_forms.html]

3.4.5. Assessing level of implementation and compliance of identified measures for System operation

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Generation Reserves - Primary, Secondary and Tertiary Reserves, Governor Droop Response, Automatic Generation Control Frequency Control - Primary, Secondary and Tertiary Control	Yes, please refer section 2.3.5.1 of this report.	Primary Reserve: As per IEGC fifth amendment,5.2 (h) "For the purpose of ensuring primary response, RLDCs/SLDCs shall not schedule the generating station or unit (s) thereof beyond ex-bus generation corresponding to 100% of the Installed capacity of the generating station or unit (s) thereof. The Generating station shall not resort to Valve Wide Open (VWO) operation of units whether running on full load or part load and shall ensure that there is margin available for providing Governor action as primary response. There are ongoing initiatives on Primary Control testing for over 240 generating units (pan India) since 2020. Secondary Reserves: Automatic Generation Control (AGC) related information is published by NLDC in its monthly report on

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
		Ancillary Services. Information related to payment of AGC provider from the DSM Pool, AGC Provider Region, Provider-wise Net Energy in MWh, Provider-wise Variable charges in INR etc. are captured in the report. There are ongoing initiatives on secondary control through Automatic Generation Control (AGC) in over 80 GW generation (pan India) which are being planned to get completed by FY 21. Tertiary Reserves: NLDC also publishes real-time data of Reserves Regulation Ancillary Services (RRAS) Instruction Summary, under its reason for response/action, quantum of transaction, transaction type (withdraw/Up/ Down) and details of generators involved in the response/ action. Frequency response characteristic and event description is covered under OCC meetings reports of RPCs. [CERC IEGC- http://www.cercind.gov.in/2016/regulation/9.pdf] [NLDC Ancillary Services- https://posoco.in/reports/ancillary-services-monthly-reports/ancillary-services-monthly-reports-2019-20/] [NLDC RRAS Instruction Summary- http://rras.nldc.in/] [NRPC OCC-https://nrpc.gov.in/submeeting-type/occ/?lang=en]
System Security - Islanding Schemes, Automatic Voltage Regulators/ Power System Stabilizers for Gencos, Maximum Continuous Rating	Yes, please refer section 2.3.5.3 of this report.	System protection and islanding schemes implementation information is mostly published by RPCs by Operation and Protection Coordination Committee on a regular interval. [NRPC OCC- https://nrpc.gov.in/submeeting-type/occ/?lang=en] [NPRC PCC- https://nrpc.gov.in/submeeting-type/protection-sub-committee/?lang=en]
Demand Management - Under Frequency Management / Load Shedding	Yes, please refer section 2.3.5.4 of this report.	Information related to demand management is published by RPCs on a regular basis. Report on Under Frequency Load Shedding (UFLS) provides status of implementation in the region, information published in the report consists of target of respective states for reduction scenarios of under frequency, i.e., 49.9 Hz & 0.1 Hz/sec, 49.9 Hz & 0.2 Hz/sec, 49.9 Hz & 0.3 Hz/sec. [WRPC UFLS- http://www.wrpc.gov.in/pcm/protection_under.pdf]

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Demand Estimation for Operational Planning	Yes, please refer section2.3.6.3 of this report.	State Load Despatch Centers conduct estimation of day-ahead system demand and availability of power. This information is not regularly updated by each and every LDCs. [Gujarat SLDC- https://www.sldcguj.com/Operation/Dayaheaddemand.php]
Outage Planning- Procedure for Planned, Forced and Emergency outages, Frequency of Outage Planning (Monthly/Quarterly/Yearly)	Yes, please refer section 2.3.5.5 of this report.	RPCs approve the planned shutdown in its OCC meetings, information captured under the approval note are as follows: 1. Details of requesting agency 2. Element information 3. Approved To Date Time [NRPC- https://nrpc.gov.in/operation-category/approved-shutdown-in-occ/?lang=en]
Active power management; Ancillary services	Yes, please refer section 2.3.5.1 of this report.	For Ancillary Services, NLDC publishes monthly report on implementation of Reserves Regulation Ancillary Services (RRAS). This serves following information: 1. Reasons for Ancillary Services Despatch in the respective month 2. Utilisation of reserves 3. Ancillary services despatched 4. Region-wise participation in RRAS 5. Region-wise energy despatch in Ancillary services 6. Payment to the RRAS Provider(s) from the DSM Pool [NLDC-https://posoco.in/reports/ancillary-services-monthly-reports/ancillary-services-monthly-reports-2019-20/] RPCs also publish details of RRAS Providers, it is a monthly report which include key parameter such as generators fixed and variable costs, ramp-up and ram-down rates, start-up time from cold start and warm start. A separate RRAS weekly account is also made to keep track of commercial settlement. Tertiary Frequency Response through RRAS implemented since 2016. [NRPC RRAS Provider-https://nrpc.gov.in/commercial-category/details-of-rras-providers/?lang=en] [NRPC- RRAS account-]
Reactive power and voltage management	Yes, please refer section	Statement of Reactive Energy is published by RPCs on a weekly basis. This statement comprises of Reactive Energy Exchange in

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
	3.4 9 (e) of IEGC 2010	MVARh and charges in INR. [NRPC- https://nrpc.gov.in/commercial-category/reactive-energy-account/?lang=en]
Grid recovery procedures - System restoration plans / procedures for partial and total grid failure	Yes, please refer section 2.3.5.6 of this report.	RLDCs publish recovery procedures for system revival for their respective regions. Also, separate system restoration procedures are developed by RLDCs. [NRLDC Operating Procedure-https://nrpc.gov.in/wp-content/uploads/2017/12/Operating-Procedure-of-Northern-Region-2017-18.pdf] [NRLDC system restoration procedure-https://upenergy.in/upptcl-pdfs/nr_srp_12_6dec12.pdf]
Commercial mechanisms such as frequency-linked Unscheduled Interchange (UI) or Deviation Settlement Mechanism (DSM) for grid discipline and frequency control	Yes, please refer section 2.3.5.2 of this report.	Central Electricity Regulatory Commission Regulation on Deviation Settlement Mechanism introduced a commercial mechanism of incentive and penalty to promote grid discipline and reliability. RPCs publish Deviation Settlement Account on a weekly basis, account gives details about state-wise schedule, actual & deviation quantum and details of Deviation Amount (in INR) to be Payable/ Receivable. [NRPC- https://nrpc.gov.in/commercial-category/deviation-settlement-account/?lang=en] RLDCs publish month-wise deviation report, it gives information related to deviation quantum up to volume limits and additional deviation, deviation quantum when grid frequency is below 49.85 Hz and above 50.05 Hz. [NRLDC-https://nrldc.in/Websitedata/Docs/Violation_Report/Deviation%20Report.xls]

3.4.6. Assessing level of implementation and compliance of identified measures for Scheduling and despatch

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Detailed Procedure and	Yes, please refer section 2.3.6.1of this report.	RLDCs have already published scheduling and despatch procedures under their operating procedures.

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Timelines for Scheduling and Despatch		[NRLDC-https://nrpc.gov.in/wp-content/uploads/2017/12/Operating-Procedure-of-Northern-Region-2017-18.pdf]
Declaration discipline	Yes, please refer section 2.3.6.2 of this report.	NLDC publishes information related to Declared Capability for ISTS generators. The information captured consist of time block-wise generator's Declared Capability in MW and MWh of specific day. [NLDC-http://wbs.nldc.in:83/wbs/dc.aspx]
Short-term demand estimation and resource management	Yes, please refer section 2.3.6.3of this report.	RPCs in their operating procedures empowers SLDCs to estimate active and reactive demand (MW peak, MW off-peak & energy in MWh/MVArh) on an annual, quarterly, monthly, weekly and ultimately on daily basis, which would be used in the day-ahead scheduling. As per IEGC & Ancillary services procedure, each state has to submit the load forecast on daily basis. At present, states are uploading their day ahead load forecast on NRLDC server in the above format. Each SLDC is expected to maintain a historical database for the purpose and be equipped with the state-of-the-art tools such as Energy Management System (EMS) for demand forecasting [NRPC Operating Procedure (Chapter 8)- https://nrpc.gov.in/wp-content/uploads/2017/12/Operating-Procedure-of-Northern-Region-2017-18.pdf]
Ramping rate to be declared for scheduling	Yes, please refer section 2.3.6.4of this report.	ISGS /Regional Entity generators shall be expected to capable of ramping rate of at least 200 MW/hr. However, since requirement of flexibility increases, generator can give higher ramp rate as per system requirements. Hydroelectric generating stations may be expected to provide a higher ramp rate. [NRPC Operating Procedure (Chapter 9)- https://nrpc.gov.in/wp-content/uploads/2017/12/Operating-Procedure-of-Northern-Region-2017-18.pdf]
Scheduling of wind and solar generation	Yes, please refer section 2.3.6.5of this report.	In accordance with the provisions of IEGC, a detailed procedure for RE scheduling and forecasting is prepared by POSOCO. The procedure empowered RLDCs to conduct RE forecasting. Therefore, RLDCs conduct forecasting for solar and wind generators, based on the information they do scheduling of these sources. [NRLDC Solar Forecast-https://nrldc.in/scheduling/solar-forecast/] [NRLDC RE scheduling procedure-https://nrldc.in/Websitedata/Renewables/pro.pdf]

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Scheduling of inter-regional and cross-border transactions	Yes, please refer section 2.3.6.6of this report.	NLDC publishes drawl schedule of entities connected with Inter State Transmission System (ISTS), the drawal schedule report consist of time block-wise drawal from ISTS, Long-term Agreement, Medium-term Open Access and bilateral sources of the specific entitled inter-regional and cross-border entities is displayed. Also, a separate information related to inter-regional information is displayed. Therefore, to summarise NLDC also publish inter-regional drawal information at all India Level. [NLDC Entitled entity drawal- http://wbs.nldc.in:83/wbs/netdrwlsch.aspx] [NLDC inter-regional drawal- http://wbs.nldc.in:83/wbs/corsch.aspx]
Treatment of infirm power	Yes. CERC (Grant of connectivity, Long-term access and medium-term Open Access in inter-State Transmission and related matter) regulation, 2009	With regards to facilitating of testing and commissioning of new generating units the Regulation 8 (7) of the CERC (Grant of connectivity, Long-term access and medium-term Open Access in inter-State Transmission and related matter) regulation, 2009 as amended time to time provides as under. “(7) Notwithstanding anything contained in Clause (6) of this Regulation and any provision with regard to sale of *infirm power* in the Power Purchase Agreement, a unit of a generation station including a captive generating plant which has been granted connectivity to the inter State Transmission System in accordance with these regulations shall be allowed to interchange *infirm power* with the grid during the commissioning period, including testing and full load testing before the COD, after obtaining prior permission of the concerned Regional Load Despatch Centre for the periods mentioned as under:- (a) Drawal of start-up power shall not exceed 10 months prior to the expected date of first synchronisation and 6 months after the date of first synchronization till the date of COD. (b) *Injection of infirm power* shall not exceed six months from the date of first synchronization.” [CERC (Grant of connectivity, Long-term access and medium-term Open Access in inter-State Transmission and related matter) regulation, 2009 - http://www.cercind.gov.in/2016/regulation/11.pdf]

3.4.7. Assessing level of implementation and compliance of identified measures for Information and communications technology including cyber security

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Communication facilities for data and voice	Yes, please refer section 2.3.7.1 of this report.	RPC's sub-committees on Protection and Telecommunication reviews the implementation status of Power Line Carrier Communication (PLCC) and Optical Ground Wire (OPGW) in their respective regions. The issues related to telecommunication network are taken up in the meetings of these subcommittees and suitable action is recommended. These committees also review the status of additional schemes to boost communication network like "Reliable Communication Scheme (Additional) under Central Sector". [NRPC TeST-https://nrpc.gov.in/submeeting-type/test-sub-committee/?lang=en] [NRPC PCC- https://nrpc.gov.in/submeeting-type/protection-sub-committee/?lang=en]
IT infrastructure (servers, computers, peripherals, etc.) available	No	Power and Telecommunication Coordination Committee of CEA in its Telecommunication Coordination Committee Meeting reviews operational standards of communication technologies used in power system. Based on the assessment recommendations are made to communication stakeholders (BSNL) to upgrade servers and computer peripherals to make communication system more resilient. [CEA PTCC- http://www.cea.nic.in/ptcc_meetings.html] Forum of Load Despatch Center shares best practices of country wide LDCs in their meetings cum workshops. Information related to communication redundancy, IT infrastructure architecture and status sharing of projects like implementation RTU communication (PLCC, Leased Line, VSAT, OPGW and GPRS), AMR, speech communication between SLDC and sub SLDC etc. [FOLD - https://forumofld.in/meetings/minutes-of-meeting/] RPC's sub-committee on Telecommunication, SCADA & Telemetry (TeST) the assess the needs and review the challenges in implementation and operation for operating system upgradation for general computer systems, web server related needs and data synchronisation of RLDC & SLDCs with NLDC etc.

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
		[NRPC Test- https://nrpc.gov.in/submeeting-type/test-sub-committee/?lang=en]
SCADA / EMS for real-time operations	Yes, please refer section 2.3.7.2 of this report.	RPC's sub-committee on Telecommunication, SCADA & Telemetry (TeST) reviews status of implementation and operation of Supervisory Control and Data Acquisition (SCADA) and Remote Terminal Unit (RTU) systems. It also overlooks the replacement of obsolete RTUs, synchronisation level of RTUs, migration to IPv6 technology and Energy Management System (EMS) Tuning etc. [NRPC TeST-https://nrpc.gov.in/submeeting-type/test-sub-committee/?lang=en]
WAMS / PMU for real-time operations	Yes, please refer section 2.3.7.3 of this report.	RPC's sub-committee on Telecommunication, SCADA & Telemetry (TeST) reviews status of upgradation of communication system to Wide Area Measurement System (WAMS) and Advanced Distribution Management Solutions (ADMS) using Multiprotocol Label Switching (MPLS) - VPN (Virtual Private Network) Leased line (2 MBPS Node + 64 kbps sim card) technologies. Possibility of upgradation is explored of communication equipment from Synchronous Transport Module (STM) STM-16 capacity to STM-64 or adopt other latest technology to cater additional requirement for future projects including RTU (Remote Terminal Unit)/SAS (Substation Automation System) data reporting on 104 protocol, new Phasor Measurement Units (PMUs) under WAMS System, AGC Project, establishment of inter-regional control centres of SCADA / PDC (plant data collection), upgradation of NLDC and establishment of Renewable Energy Management Centres (REMC) and backup control centre at Kolkata for WAMS system and other new schemes. [NRPC TeST- https://nrpc.gov.in/submeeting-type/test-sub-committee/?lang=en] NLDC publishes information related to implementation status of telemetry in the country in its report "Region-wise Summary of Telemetry Status". The frequency of publishing this report is not regular as last report was published in December 2018. [NLDC- https://posoco.in/reports/telemetry-status/]
Technology solutions for managing real-time and back-office operations -	Yes, please refer IEGC 2010	Forum of Load Despatch Centre (FOLD) regularly reviews the status of implementation for recommendation of Scheduling, Metering, Accounting and Settlement of Transactions in Electricity (SAMAST) report. This includes IT-based scheduling and despatch, energy accounting and settlement and facilitation of open access transactions. FOLD act as an

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
power scheduling, energy accounting, deviation settlement, open access transactions, web portal, etc.		accelerator for implementation of IT technologies. [FOLD- https://forumofld.in/meetings/minutes-of-meeting/]
Cyber Security - Policy, Framework, Action Plan	Yes, please refer section 2.3.7.4 of this report.	RPC's sub-committee on Telecommunication, SCADA & Telemetry (TeST) reviews cyber security related issues. They look into aspects related to security audit of SCADA systems, formulation of Information Security Management System (ISMS) Policy and Cyber Crisis Management Plan (CCMP) with the help of RLDCs/SLDCs. [NRPC TeST-https://nrpc.gov.in/submeeting-type/test-sub-committee/?lang=en]

3.4.8. Assessing level of implementation and compliance of identified measures for Monitoring and compliance

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Clear demarcation of monitoring and compliance responsibilities	Yes, please refer section 2.3.8.1 of this report.	The Indian Electricity Grid Code (IEGC) have clearly demarcated the roles and responsibilities related to monitoring and compliance of NLDC, RLDC's, RPC's and SLDC's. Also, for non-compliance of any provisions of the IEGC by NLDC, RLDC, SLDC, RPC and any other person the matter may be reported by any person to the CERC through petition. [CERC IEGC- http://www.cercind.gov.in/2016/regulation/9.pdf]
Reporting: periodic reports covering performance of the integrated grid - Frequency profile - Demand met (peak,	Yes, please refer section 2.3.8.2 of this report.	1. Frequency Profile: NLDC publishes daily/monthly and annual report on the grid profile, it provides information like percentage of time grid frequency is within and outside the IEGC band. [NLDC-https://posoco.in/reports/frequency-profile/] 2. Demand Met: NLDC publishes information related to evening peak hour demand met at national level and demand vs

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
off-peak and average) - Instances and quantum of curtailment of renewable energy - Demand and energy unserved in MW and MWh - Constraints and instances of congestion in transmission system - Instances of persistent/significant non-compliance of Grid Code - Cyber threat / attack information		generation plat for maximum demand met for specific day of the month. This information is published under monthly reports. [NLDC-https://posoco.in/reports/monthly-reports/] 3. Curtailment of RE: NLDC only provides format to fill curtailment details. [NLDC- https://posoco.in/re-curtailments/] 4. Energy Unserved: NLDC publishes information related to energy unserved due to grid disturbance, information is represented in MUs [NLDC- https://posoco.in/reports/monthly-reports/] 5. Congestion in transmission system: NLDC provides real time information related to congestion in transmission corridors / control area. [NLDC- http://wbs.nldc.in:82/Web_TTC_ATC.aspx] 6. Instances of non-compliance of Grid Code: This information is captured by different agencies based on roles and responsibilities demarcated in the IEGC and relevant regulations. For example, system protection and islanding information is mostly published by RPCs, safety and inspection is looked after by CEA, Frequency and voltage profile related information is published by NLDC. 7. Cyber security: Presently RPCs look after reviewing of cyber security aspects but are at a nascent stage. [NRPC TeST-https://nrpc.gov.in/submeeting-type/test-sub-committee/?lang=en]
Scope for self-audit, independent third-party compliance audit	Yes, please refer section 2.3.8.3 of this report.	Information related to independent audits of transmission lines are done by Chief Electrical Inspectorate Division of CEA. Based on the audit corrective measures for compliances are proposed. [CEA CEID-http://www.cea.nic.in/cei_audit.html] RPC's Protection Coordination Committee also reviews the inputs of audit points raised by PGCIL/CPRI on monthly basis. [NRPC PCC- https://nrpc.gov.in/submeeting-type/protection-sub-committee/?lang=en]
Periodic monitoring of actual performance of grid operators and grid	Yes, please refer section2.3.8.4 of this report.	In Operation Co-ordination Committee meetings, RPCs discuss actual performance of grid operators against SoP of IEGC and CEA Regulations or any other relevant regulations.

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
users against standards of performance (SOP)		[NLDC OCC- https://nrpc.gov.in/submeeting-type/occ/?lang=en]

3.5. Maldives

There is no transmission grid in the Maldives and therefore, assessment could not be undertaken.

3.6. Nepal

Institutions	Functions	Level of monitoring
Regulator Electricity Regulatory Commission (ERC)	ERC was established in 2017 through Electricity Regulatory Commission Act of 2017. It is entrusted with following key functions: ▪ Technical management of electricity sector ▪ Determination of Tariff and Regulation of Electricity Purchase and Sale ▪ To maintain Competition and Protect the Interest of the Consumers ▪ To enhance the Organizational Capacity of licensees ▪ To make Policy Suggestion and Recommendation ▪ To investigate and inspect the level of compliance of acts, regulations, directives, etc. by licensees and impose fines if necessary ▪ To Resolve Disputes ▪ To conduct public hearing	Neither the ERC nor the RPGCL publishes any information regarding grid discipline and grid reliability aspects of Integrated Nepal Power System in the public domain.
System Operator and Transmission Operator Rastriya Prasaran Grid Co. Ltd. (RPGCL)	RPGCL was created in 2015 to transmit and evacuate the power for the development and operation of the hydropower. It is entrusted with following responsibilities: ▪ Study and Preparation of Transmission Line Master plan considering the demand and supply of electricity for long term. ▪ Development of transmission infrastructure to facilitate the electricity market for the management of transmission grid to reliably supply electricity. ▪ Collection of wheeling charge from transmission grid users.	

Institutions	Functions	Level of monitoring
	▪ Collection of other royalties fixed by the regulator. ▪ Construction, expansion and modernization of transmission lines, substation and Load Dispatch Centers. ▪ The development transmission grid system will be based on the load centers and potential areas of hydropower potential. Also, the consideration of east-west and north south transmission highway will be constructed based on the river systems. ▪ Evaluation, monitoring and control of grid system. ▪ Trunk communication system will be adopted in the transmission grid line. ▪ Development of manpower inside the company and providing the consultancy services. ▪ Ensuring grid transmission access to users. ▪ Conduct audit of electricity transmission and take responsibility for the real time operation.	

No reports are available in public domain to study and assess the performance of the power system in Nepal.

The details of the level of implementation based on key indicators for Nepal are discussed under this section:

3.6.1. Assessing level of implementation and compliance of identified measures for System Planning

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Contingency criterion	Yes, please refer section 2.3.1.1 of this report.	Information regarding N-1 contingency implementation is available in NEA Annual report. Based on the annual report, the country is implementing projects like 132kV Middle Marsyangdi - Dumre - Damauli and 132kV Kusma-Lower Modi transmission lines with an objective to increase the reliability to ensure N-1 contingency of transmission line of the region. [NEA Annual Report FY 2018/19- https://www.nea.org.np/annual_report]
System planning studies for addition of generation capacity	Yes, please refer section 2.3.1.2 of this report.	The transmission plan of Rastriya Prasaran Grid Company Limited (RPGCL), considers existing generation from renewable sources. Alternative Energy Promotion Center and Alternative Energy Development Board work closely for conducting studies on

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
from renewable energy sources		renewable sources. [RPGCL Transmission Plan- http://rpgcl.com/images/category/TSMPN_RPGCL_GoN.pdf] [AEPC- https://www.aepc.gov.np/]
System planning studies for CBET (Cross-Border Electricity Trade) growth	Yes, please refer section 2.3.1.3 of this report.	Considerate amount of planning is done for cross-border transactions with India and China. For future transactions with China, a Transmission line from Chilime substation of Rasuwa district to Ratamate substation of Dhading district is proposed as a cross-border link between Nepal and China. It has been estimated that 15.9 GW of power export to India and China may occur in wet season. [RPGCL Transmission Plan- http://rpgcl.com/images/category/TSMPN_RPGCL_GoN.pdf]
Frequency variation limits	Yes, please refer section 2.3.1.4 of this report.	As per the NEA Annual Report of FY 2019-20, most of the time the system frequency of the grid was maintained at 50 Hz in FY 2019-20. The maximum frequency of 50.85Hz (instantaneous) and minimum frequency of 48.89(instantaneous) Hz were recorded in the year.
Voltage variation limits	Yes, please refer section 2.3.1.5 of this report.	As per the NEA Annual Report of FY 2019-20, the voltage achieved in most of the load centers' substations is in the range of permissible limit of +/- 10% limit at 132 and 66 kV as per NEA Grid Code.
Estimation and declaration of transmission capabilities in advance	No.	Not Applicable.

3.6.2. Assessing level of implementation and compliance of identified measures for System construction and safety

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
General safety requirements pertaining to construction, installation, protection, operation and maintenance of electric lines	Yes, please refer section2.3.2.1 of this report.	No information available (or not in English language) on implementation and

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Safety provisions for electrical installations and apparatus of voltage exceeding 650 volts	Yes, refer Electricity Regulation, 2050 (1993) and NEA Grid Code 2005.	compliance in the public domain.
Safety requirements for overhead transmission lines		
Capacity building for system construction and safety		
System safety		

3.6.3. Assessing level of implementation and compliance of identified measures for Grid connection

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Detailed procedure for grid connections including RE Generating Companies - Time Frame of processing of application, Standard formats for applicants and model connection agreement	Yes, please refer section 2.3.3.1 of this report.	Grid Operation Department (GOD) provides connection facilities to IPPs and bulk consumers at different voltage levels by accomplishing connection agreement as per NEA grid code 2005.
Details of test required for conventional and non-conventional energy sources	Yes, please refer section 2.3.3.2 of this report.	No information available (or not in English language) in the public domain on implementation and compliance.

3.6.4. Assessing level of implementation and compliance of identified measures for System protection, testing and commissioning

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Protection philosophy	Yes, please refer section 2.3.4.1of this report.	No information available (or not in English language) on implementation and compliance in the public domain.
Protection audit plans with scope of dependability, security and reliability index	Yes, please refer section 2.3.4.2of this report.	
System / Special protection schemes	Yes, please refer section 2.3.4.3 of this report.	

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Testing and commissioning guidelines	Yes, please refer section 2.3.4.4 of this report.	

3.6.5. Assessing level of implementation and compliance of identified measures for System operation

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Generation Reserves - Primary, Secondary and Tertiary Reserves, Governor Droop Response, Automatic Generation Control Frequency Control - Primary, Secondary and Tertiary Control	Yes, please refer section 2.3.5.1 of this report.	No information available (or not in English language) on implementation and compliance in the public domain.
System Security - Islanding Schemes, Automatic Voltage Regulators/ Power System Stabilizers for Gencos, Maximum Continuous Rating	Yes, please refer section 2.3.5.3 of this report.	As stated in NEA Annual report 2019-20, Automatic Voltage Regulator systems are installed in the generating unit.
Demand Management - Under Frequency Management / Load Shedding	Yes, please refer section 2.3.5.4 of this report.	As per the NEA Annual Report 2019-20, demand side management activities such as GIS mapping, HVDS implementation, network AMR metering, customer smart metering, real time feeder power monitoring, feeder energy accounting/audit, technical/ commercial feeder loss assessment, consumer service management etc. are planned.
Demand Estimation for Operational Planning	Yes, please refer section2.3.6.3 of this report.	No information available (or not in English language) on implementation and compliance in the public domain.
Outage Planning- Procedure for Planned, Forced and Emergency outages, Frequency of Outage Planning (Monthly/Quarterly/Yearly)	Yes, please refer section 2.3.5.5 of this report.	No information available (or not in English language) in the public domain on implementation and compliance.
Grid recovery procedures - System restoration plans / procedures for partial and total grid failure	Yes, please refer section 2.3.5.6	No information available (or not in English language) in the public domain on implementation and compliance.

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Commercial mechanisms such as frequency-linked Unscheduled Interchange (UI) or Deviation Settlement Mechanism (DSM) for grid discipline and frequency control	No.	Not Applicable.

3.6.6. Assessing level of implementation and compliance of identified measures for Scheduling and dispatch

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Detailed Procedure and Timelines for Scheduling and Dispatch	Yes, please refer section 2.3.6.1of this report.	No information available (or not in English language) in the public domain on implementation and compliance.
Declaration discipline	Provisions related to mis-declaration of generation availability by generating stations are not present in Grid code or any other Regulations however such provisions are present in individual PPA's signed between NEA and the licensee. Typically used formula for the penalty is: *Compensation Amount for mis-declaration by generating stations in Nepali Rupees = [0.8 x Electrical energy based on the availability declaration made such that the total contract energy to be delivered to NEA in the duration of month is not exceeded - any energy that the plant is unable to deliver because of NEA or because of*	

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
	Scheduled Outage or because of emergency repair and maintenance or because of force majeure] x electricity purchase rate of for the month per kilowatt-hour. For Run-of-the-river (ROR) hydroelectricity power plants and Peaking Run-of-the-river (PROR) hydroelectricity power plants of less than 10 Megawatt are exempted from penalty for mis-declaration of generation availability. *"Point No. 4 (a) of Schedule 5 of Electricity Regulatory Commission, Bylaw relating to purchase / sale of electricity and conditions to be fulfilled by the licensees, 2076 states "Electricity Buyer shall not impose any penalties on the Electricity Seller based on the availability declaration of the Electricity Seller for ROR and PROR Projects of less than 10 Megawatt"*, This indicates that such clauses of penalty for misdeclaration by Generating companies are prevalent in Nepal.	
Short-term demand estimation and resource management	Yes, please refer section 2.3.6.3of this report.	
Ramping rate to be declared for scheduling	Yes, please refer section 2.3.6.4of this report.	

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Scheduling of wind and solar generation	Yes, please refer section 2.3.6.5of this report.	
Scheduling of inter-regional and cross-border transactions	Yes, please refer section 2.3.6.6of this report.	
Treatment of infirm power	No.	

3.6.7. Assessing level of implementation and compliance of identified measures for Information and communications technology including cyber security

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Communication facilities for data and voice	Yes, please refer section 2.3.7.1 of this report.	No information available (or not in English language) on implementation and compliance in the public domain.
IT infrastructure (servers, computers, peripherals, etc.) available	Yes, please refer section 6.9 of NEA grid Code	
SCADA / EMS for real-time operations	Yes, please refer section 2.3.7.2 of this report.	
WAMS / PMU for real-time operations	No.	
Technology solutions for managing real-time and back-office operations - power scheduling, energy accounting, deviation settlement, open access transactions, web portal, etc.	No.	
Cyber Security - Policy, Framework, Action Plan	No.	

3.6.8. Assessing level of implementation and compliance of identified measures for Monitoring and compliance

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Reporting: periodic reports covering performance of the integrated grid - Frequency profile - Demand met (peak, off-peak and average) - Instances and quantum of curtailment of renewable energy	Yes, please refer section 2.3.8.1 of this report.	No information available (or not in English language) on implementation and

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
- Demand and energy unserved in MW and MWh - Constraints and instances of congestion in transmission system - Instances of persistent/significant non-compliance of Grid Code - Cyber threat / attack information		compliance in the public domain.
Scope for self-audit, independent third-party compliance audit	No.	
Periodic monitoring of actual performance of grid operators and grid users against standards of performance (SOP)	Yes, please refer section 2.3.8.3 of this report.	

3.7. Pakistan

Institutions	Functions	Level of monitoring
Regulator National Electric Power Regulatory Authority (NEPRA)	NEPRA was established to exclusively regulate electricity generation, transmission and distribution business. It has following key functions: Specify procedures and standards for registration of persons providing electric power services. ▪ Specify and enforce performance standards. ▪ Issue guidelines and standard operating procedures. ▪ Encourage uniform industry standards and code of conduct.	• NEPRA had published its grid code in 2005 and subsequently it was amended only once since then. • NERPA also publishes transmission performance evaluation report annually. The reports from 2010 onwards till 2018 are available on NEPRA's website. • On yearly basis, NTDC publishes Power System Statistics report. However, this report does not capture any specific details regarding grid discipline and grid reliability aspects.
System Operator National Transmission & Despatch Company (NTDC)	NTDC was established with an aim to provide power transmission service in the country. It also discharges system operator function by providing economic despatch	

Institutions	Functions	Level of monitoring
Transmission Operator National Transmission & Despatch Company (NTDC)	and ensure safe, secure & reliable supply. Being a system operator NTDC is responsible for Power System Operation and Control of the national grid.	

To determine the effectiveness of the regulatory monitoring, analysis of transmission system performance over the years based on data available in the public domain was conducted. Following are the insights from the analysis:

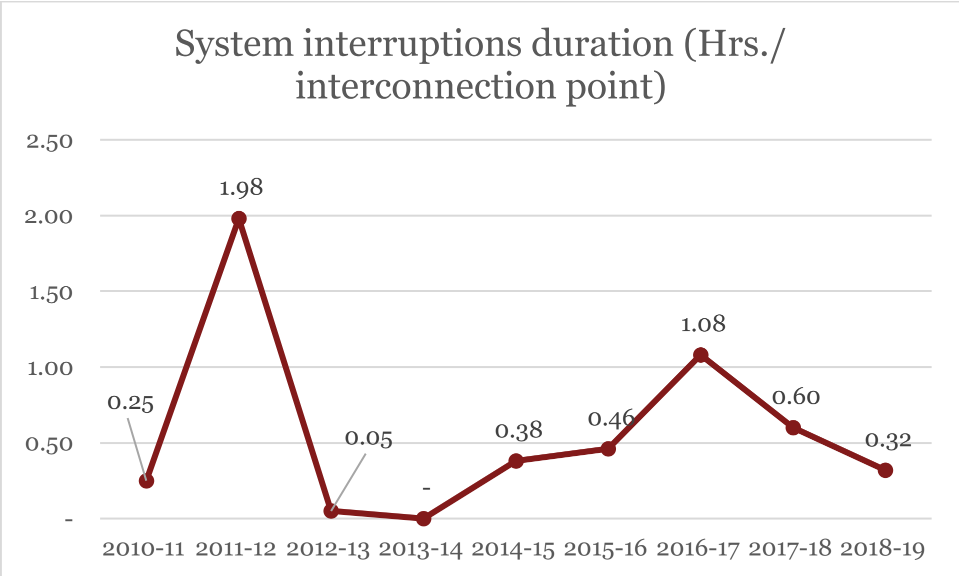

Figure 42: System interruptions duration (Hrs./ interconnection point) for transmission grid in Pakistan[125]

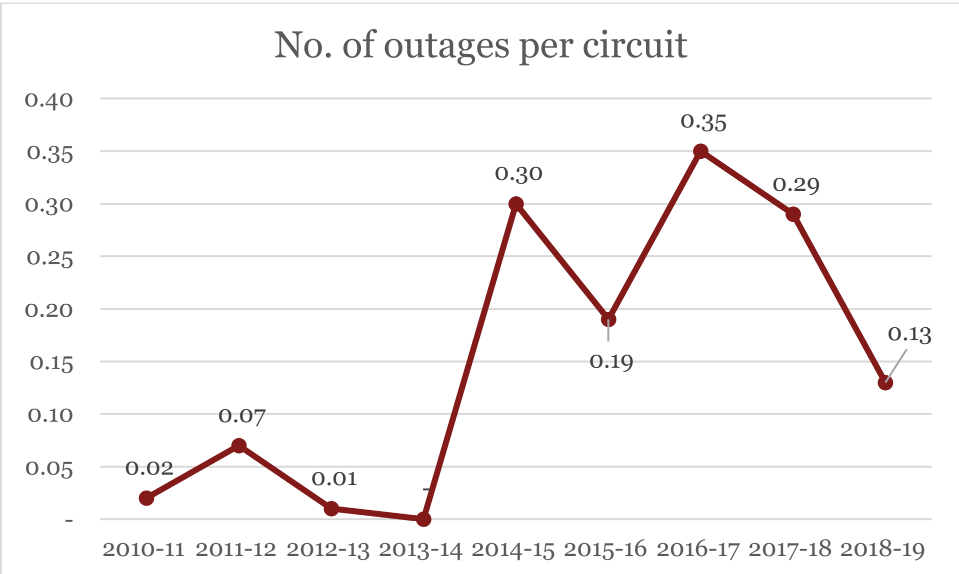

Figure 43: No. of outages per circuit for transmission grid of Pakistan[126]

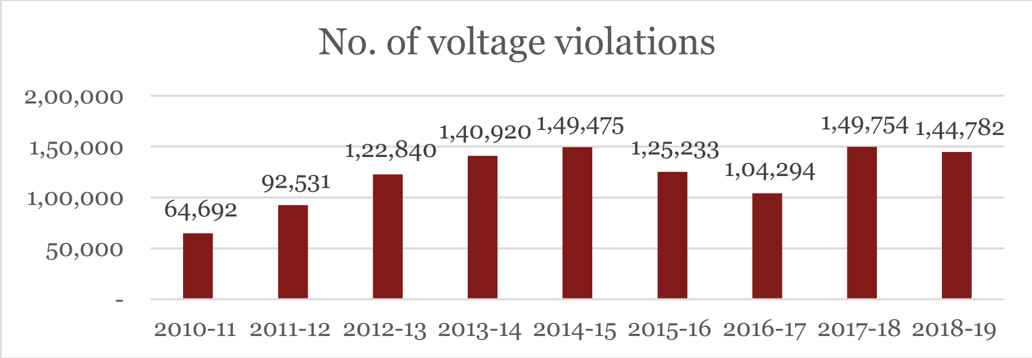

Figure 44: No. of voltage violations for transmission grid in Pakistan[127]

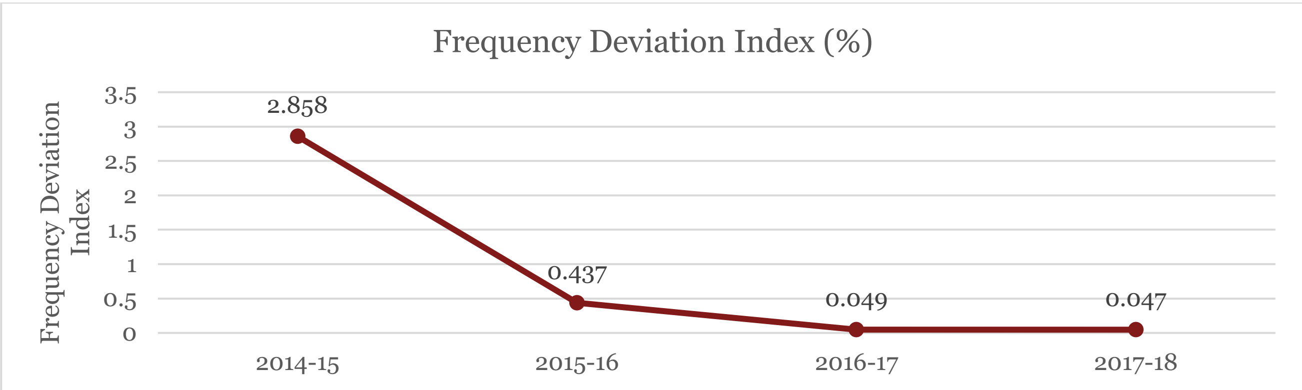

Figure 45: Frequency deviation index for transmission grid in Pakistan[128]

Following observations could be inferred from above trends:

1. No specific trend can be observed in system interruption duration (hours/ interconnection point) over the years.
2. An increasing trend in the no. of outages per circuit is observed over the years.
3. No of voltage violations increased from 2010-11 till 2014-15. A declining trend is observed since then with the exception of 2017-18.
4. The frequency deviation index has shown a declining trend over the years.

This suggests that, the regulatory framework has aided in improving the transmission grid frequency in Pakistan. However, it has not aided in improvement in reducing no. of outages per circuit.

The details of the level of implementation based on key indicators for Pakistan are discussed under this section:

3.7.1. Assessing level of implementation and compliance of identified measures for System Planning

Identified measures	Availability of Provision/ Regulatio	Level of implementation and compliance
Contingency criterion	Yes, please refer section 2.3.1.1 of this report.	No information available (or not in English language) on implementation and compliance in the public domain.

Identified measures	Availability of Provision/ Regulatio	Level of implementation and compliance
System planning studies for addition of generation capacity from renewable energy sources	Yes, please refer section 2.3.1.2 of this report.	Indicative Generation Capacity Expansion Plan (IGCEP) 2018-40 published by NEPRA forecasts RE (including Hydro) capacity addition of 324 MW in 2020 and 838 MW in 2021. [Indicative Generation Capacity Expansion Plan (IGCEP) 2018-40 - https://nepra.org.pk/Admission%20Notices/2019/09-September/IGCEP%20Plan%20(2018-40).pdf]
System planning studies for CBET (cross border electricity trade) growth	Yes, please refer section 2.3.1.3 of this report.	Import from Iran and Tajikistan via Afghanistan has been envisaged (ongoing transaction).
Frequency variation limits	Yes, please refer section 2.3.1.4 of this report.	As per NEPRA performance evaluation report 2018-19, NTDC system frequency varied from 49.44 Hertz to 50.79 Hertz and has violated the prescribed limits 25 times in FY 2018-19.
Voltage variation limits	Yes, please refer section 2.3.1.5 of this report.	NEPRA performance evaluation report 2018-19 gives details of voltage variation in the given year. However, reports for years 2019-20 and onwards are not available in the public domain.

3.7.2. Assessing level of implementation and compliance of identified measures for System construction and safety

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
General safety requirements pertaining to construction, installation, protection, operation and maintenance of electric lines	Yes, please refer section 2.3.2.1 of this report.	Non-compliance is subject to penalties as per NEPRA Fees & Fines Rules (2002)
Safety provisions for electrical installations and apparatus of voltage exceeding 650 volts	Yes, please refer NEPRA power safety code for Transmission and distribution lines.	
Safety requirements for overhead transmission lines		
Capacity building for system construction and safety		
System safety		

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance

3.7.3. Assessing level of implementation and compliance of identified measures for Grid connection

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Detailed procedure for grid connections including RE Generating Companies - Time Frame of processing of application, Standard formats for applicants and model connection agreement	Yes, please refer section 2.3.3.1 of this report.	NTDC processes the connection applications as submitted by the users.
Details of test required for conventional and non-conventional energy sources	Yes, please refer section 2.3.3.2 of this report.	No information available (or not in English language) in the public domain on implementation and compliance.

3.7.4. Assessing level of implementation and compliance of identified measures for System protection, testing and commissioning

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Protection philosophy	No.	Not Applicable.
Protection audit plans with scope of dependability, security and reliability index	No.	Not Applicable.
System / Special protection schemes	Yes, please refer section 2.3.4.3 of this report.	No information available (or not in English language) in the public domain on implementation and compliance.
Testing and commissioning guidelines	Yes, please refer section 2.3.4.4 of this report.	No information available (or not in English language) in the public domain on implementation and compliance.

3.7.5. Assessing level of implementation and compliance of identified measures for System operation

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Generation Reserves - Primary, Secondary and Tertiary Reserves, Governor Droop Response, Automatic Generation Control Frequency Control - Primary, Secondary and Tertiary Control	Yes, please refer section 2.3.5.1 of this report.	No information available (or not in English language) on implementation and compliance in the public domain.
System Security - Islanding Schemes, Automatic Voltage Regulators/ Power System Stabilizers for Gencos, Maximum Continuous Rating	Yes, please refer section 2.3.5.3 of this report.	No information available (or not in English language) in the public domain on implementation and compliance.
Demand Management - Under Frequency Management / Load Shedding	Yes, please refer section 2.3.5.4 of this report.	No information available (or not in English language) in the public domain on implementation and compliance.
Outage Planning- Procedure for Planned, Forced and Emergency outages, Frequency of Outage Planning (Monthly/Quarterly/Yearly)	Yes, please refer section 2.3.5.5 of this report.	No information available (or not in English language) in the public domain on implementation and compliance.
Grid recovery procedures - System restoration plans / procedures for partial and total grid failure	Yes, please refer section2.3.5.6 of this report.	No information available (or not in English language) in the public domain on implementation and compliance.
Commercial mechanisms such as frequency-linked Unscheduled Interchange (UI) or Deviation Settlement Mechanism (DSM) for grid discipline and frequency control	No.	Not Applicable.

3.7.6. Assessing level of implementation and compliance of identified measures for Scheduling and despatch

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Detailed Procedure and Timelines for Scheduling and Despatch	Yes, please refer section 2.3.6.1of this report.	No information available (or not in English language) on

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Declaration discipline	No.	implementation and compliance in the public domain.
Short-term demand estimation and resource management	Yes, please refer section 2.3.6.3of this report.	
Ramping rate to be declared for scheduling	Yes, please refer section 2.3.6.4of this report.	
Scheduling of wind and solar generation	Yes, please refer section 2.3.6.5of this report.	
Scheduling of inter-regional and cross-border transactions	Yes, please refer section 2.3.6.6of this report.	
Treatment of infirm power	No.	

3.7.7. Assessing level of implementation and compliance of identified measures for Information and communications technology including cyber security

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Communication facilities for data and voice	Yes, please refer section 2.3.7.1 of this report.	No information available (or not in English language) in the public domain on implementation and compliance.
IT infrastructure (servers, computers, peripherals, etc.) available	No.	Not Applicable.
SCADA / EMS for real-time operations	Yes, please refer section 2.3.7.2 of this report.	No information available (or not in English language) in the public domain on implementation and compliance.
WAMS / PMU for real-time operations	No.	Not Applicable.
Technology solutions for managing real-time and back-office operations - power scheduling, energy accounting, deviation settlement, open access transactions, web portal, etc.	No.	Not Applicable.
Cyber Security - Policy, Framework, Action Plan	No.	Not Applicable.

3.7.8. Assessing level of implementation and compliance of identified measures for Monitoring and compliance

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Reporting: periodic reports covering performance of the integrated grid - Frequency profile - Demand met (peak, off-peak and average) - Instances and quantum of curtailment of renewable energy - Demand and energy unserved in MW and MWh - Constraints and instances of congestion in transmission system - Instances of persistent/significant non-compliance of Grid Code - Cyber threat / attack information	Yes, please refer section 2.3.8.1 of this report.	No information available (or not in English language) on implementation and compliance in the public domain.
Scope for self-audit, independent third-party compliance audit	No.	Not Applicable.
Periodic monitoring of actual performance of grid operators and grid users against standards of performance (SOP)	Yes, please refer section 2.3.8.3 of this report.	• National Electric Power Regulatory Authority (NEPRA) publishes annual performance evaluation reports for National Transmission & Despatch Company (NTDC). • However, the monitoring is only done on annual basis with the last report published for 2018-19.

3.8. Sri Lanka

Institutions	Functions	Level of monitoring
Regulator Public Utilities Commission of Sri Lanka (PUCSL)	PUCSL is the economic, technical and safety regulator of the electricity industry in Sri Lanka and designated as regulator for petroleum and water services industries. It trusted with following key objectives:	• A total system failure occurred in the Sri Lankan Transmission Licensee's network on the 27th of September 2015, at 23:57. The restoration of the power system took more than four hours. Subsequently, PUCSL requested explanations/ information from the transmission licensee, i.e., CEB regarding this event.

Institutions	Functions	Level of monitoring
	▪ Promote efficient in operations ▪ Establish safety standards ▪ Maintain its fairness, impartiality and transparency in decision making	• Manitoba Hydro International (MHI) was contracted by PUCSL to study the event and provide recommendations[129]. The study was conducted in close collaboration with engineers from PUCSL and the CEB. However, no subsequent report is present in the public domain documenting whether the recommendations suggested in the report on grid collapse were implemented or not. • Transmission Performance Regulations were prepared by PUCL in 2016according to the Sri Lanka Electricity Act, and the same are in effect. The Regulations include a methodology for implementation of the same, by the Transmission Licensee and the PUCSL. Hence, there is a legal requirement for the PUCSL to implement the regulations together with the Transmission Licensee. In 2020, PUCSL plans[130] to implement the regulation in three stages, Preliminary stage, where Transmission Licensee is required to acquire resources required to implement the regulations, Adaptation stage, where the Transmission Licensee and PUCSL are required to commence the performance measurements and assessment programmes and hands-on stage, where the Transmission Licensee and PUCSL need to set the performance levels. In the same time Transmission Licensee and the PUCSL will work together to set up databases to measure and assess the performance indices identified in the regulations and to develop quarterly reports where PUCSL monitors the actual performances and upgrade targets when necessary. • As per the Annual Report of PUCSL, Licensing Division of PUCSL is required to publish monthly reports of transmission grid performance as per the regulations however, till date no performance reports are available in the public domain
System Operator and Transmission Operator	Ceylon Electricity Board (CEB) is entrusted with developing and maintaining an efficient, coordinated and economical system of electricity supply. It also discharges functions of system operator in the country. The system operation unit responsible to ensure reliability, maintain frequency & voltage, scheduling & dispatch and balancing generation & demand etc.	

Institutions	Functions	Level of monitoring
		detailing the performance parameters as per the Transmission Performance Regulations. • Further it is observed that, reports capturing some performance parameters are available for time period from 2011 to 2014. No reports are available after 2014 in the public domain.

To determine the effectiveness of the regulatory monitoring, analysis of transmission system performance over the years based on data available in the public domain was conducted. Following are the insights from the analysis:

Table 44: Transmission system availability in Sri Lanka[131]

Parameters	Availability of Transmission Lines (%)	Availability of 132kV Transmission Lines (%)	Availability of 220kV Transmission Lines (%)	Total System Availability of Transmission Transformers (%)
2011	99.65	99.58	99.98	97.84
2012	99.88	99.95	99.54	97.91
2013	99.24	99.23	99.28	95.91
2014 H1	99.94	99.93	99.88	97.97

Table 45: Average frequency of outages in Sri Lanka's transmission grid[132]

Parameters	2011	2012	2013	2014 H1
Average Frequency of Outages per 100km of 132kV lines	5.42	6.93	4.71 (First half)	3.75
Average Frequency of Outages per 100km of 220kV lines	2.14	3.53	0.88 (First half)	0.88
Average Frequency of Planned Outages per 100km of lines	0.21	0.1	NA	NA
Average Frequency of Forced Outages per 100km of lines	4.54	6.13	NA	NA

Table 46: Transmission line interruption duration index in hours for Sri Lanka transmission grid[133]

Parameters	2011	2012	2013	2014 H1
Transmission Line Interruption Duration index (hours)	30.85	10.33	51.9 (First half)	2.78
220kV Line Interruption Duration index (hours)	1.38	6.81	0.47 (First half)	0.88
132kV Line Interruption Duration index (hours)	30.8	3.52	51.41 (First half)	3.2
Substation Transformer Interruption duration index (hours)	188.87	183.4	79.7 (First half)	88.1

(lower value of interruption duration index signifies better performance)

Table 47: Sri Lanka transmission grid frequency deviation[134]

Parameters	2011	2012	2013	2014 H1
Average Frequency value in Hz.	NA	50.14	NA	50.03
Frequency within normal operating limit (49.5Hz to 50.5Hz) (% of time)	99.8	99.77	99.97	99.9
Frequency within Alert State (49.0Hz to 51.0Hz) (% of time)	0.19	0.23	0.03	0.1
Frequency within Emergency State (<49 Hz) (% of time)	0.01	0.0013	0.0014	0.0071

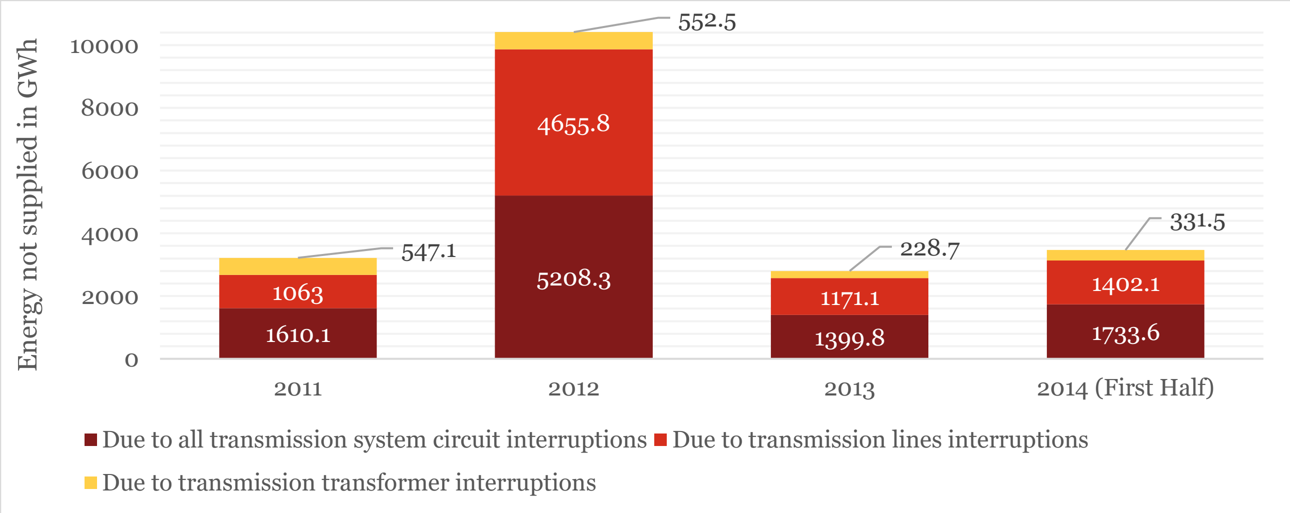

Figure 46: Energy not supplied due to interruptions[135]

Following observations are made based on transmission grid performance data of 2011 to 2014 (First half):

1. The availability of the Transmission lines is above 99% whereas that of transformers is above 97%.
2. The average frequency of outages per 100 km of 132 kV lines and 220 kV lines shows declining general trend. No conclusion can be drawn from data for average frequency of planned outages per 100 km of lines and average frequency of forced outages per 100 km of lines as the data is insufficient to draw any conclusion.
3. Transmission line interruption duration index (in hours) does not signify any general trend.
4. The Frequency of transmission grid in Sri Lanka has remained in the normal operating limit of 49.5 Hz. to 50.5 Hz. for about ~ 99.8% of the times over the years.
5. The Energy not supplied (in MWh) has been on an average 3162 MWh for the years except 2012 wherein it was as high as 10416 MWh.

Based on this limited data and its analysis it may be inferred that, overall there has been minor improvement in the overall reliability of the transmission system.

The details of the level of implementation based on key indicators for Sri Lanka are discussed under this section:

3.8.1. Assessing level of implementation and compliance of identified measures for System Planning

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Contingency criterion	Yes, please refer section 2.3.1.1 of this report.	No official information available in the public domain. A news report from 2015 raises concerns over the reliability of national power supply and its future and refers to Additional General Manager of CEB speaking about difficulties in maintaining the 'n-1' reliability standard in urban areas

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
		[Sri Lanka's island-wide blackout signals power supply reliability issue - https://www.lankabusinessonline.com/sri-lankas-island-wide-blackout-signals-power-supply-reliability-issue/]
System planning studies for addition of generation capacity from renewable energy sources	Yes, please refer section 2.3.1.2 of this report.	A draft 'Long-term Generation Expansion Plan' for 2020-2039 was published in March 2020, which envisages addition of 140 MW and 392 MW of renewable energy capacity (including hydro power) for 2020 and 2021 respectively. The plan also envisages substantial RE capacity addition each year till 2040. CEB issues tenders for establishment of 150 MW of solar PV power plants (March 2020) and 60 MW of wind power plants [CEB Long-term Generation Expansion Plan 2020-2039 (Draft) - https://www.ceb.lk/front_img/img_reports/1591174971Revised_LTGEP_2020-2039.pdf Request for Proposals for the Establishment of 150 MM AC Solar PV Power Plants in (1-10) MM AC Capacity on Build, Own and Operate Basis https://www.ceb.lk/front_img/tender_pdf/200306050307Paper_advertisement_All_GSS_English_150MW_AC_Solar_PV.pdf Request for Proposals for the Establishment of 60 MW Wind Power Plants in (1 - 10) MW Capacities on Build Own and Operate Basis - https://www.ceb.lk/front_img/tender_pdf/191128141100Request_For_Proposal.pdf]
System planning studies for CBET (cross-border electricity trade) growth	Yes, please refer section 2.3.1.3 of this report.	As per the website for Ministry of Power, Government of India, an interconnection from Madurai (India) to New Habarana (Sri Lanka) is still under discussion between the two countries. [Interconnection with neighboring countries - https://powermin.nic.in/en/content/interconnection-neighbouring-countries]
Frequency variation limits	Yes, please refer section 2.3.1.4 of this report.	As per CEB Annual Report 2018, the system operation unit is responsible for maintaining the system frequency within the acceptable level of ±1 % of 50Hz of the system by balancing generation-demand of Active power.
Voltage variation limits	Yes, please refer section 2.3.1.5 of this report.	As per CEB Annual Report 2018, the system operation unit is responsible for maintaining the transmission voltage within ±10 % for 132 kV & 220 kV by balancing generation-demand of Reactive power.

3.8.2. Assessing level of implementation and compliance of identified measures for System construction and safety

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
General safety requirements pertaining to construction, installation, protection, operation and maintenance of electric lines	Yes, please refer section2.3.2.1 of this report.	A Safety Committee has been appointed by the Deputy General Manager (North Western Province) and the committee has been conducting continuous training on Safety. Demonstrations of Electrical lines and Equipment are installed in Maho Consumer Service Center and most of the safety trainings are conducted with practical examples.
Safety provisions for electrical installations and apparatus of voltage exceeding 650 volts	Yes, please refer CEB Safety Manual.	
Safety requirements for overhead transmission lines		
Capacity building for system construction and safety		
System safety		

3.8.3. Assessing level of implementation and compliance of identified measures for Grid connection

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Detailed procedure for grid connections including RE Generating Companies - Time Frame of processing of application, Standard formats for applicants and model connection agreement	Yes, please refer section 2.3.3.1 of this report.	No information available (or not in English language) on implementation and compliance in the public domain.
Details of test required for conventional and non-conventional energy sources	Yes, please refer section 2.3.3.2 of this report.	

3.8.4. Assessing level of implementation and compliance of identified measures for System protection, testing and commissioning

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Protection philosophy	No.	Not Applicable.

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Protection audit plans with scope of dependability, security and reliability index	No.	Not Applicable.
System / Special protection schemes	Yes, please refer section 2.3.4.3 of this report.	No information available (or not in English language) in the public domain on implementation and compliance.
Testing and commissioning guidelines	Yes, please refer section 2.3.4.4 of this report.	No information available (or not in English language) in the public domain on implementation and compliance.

3.8.5. Assessing level of implementation and compliance of identified measures for System operation

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Generation Reserves - Primary, Secondary and Tertiary Reserves, Governor Droop Response, Automatic Generation Control Frequency Control - Primary, Secondary and Tertiary Control	Yes, please refer section 2.3.5.1 of this report.	AGC (Automatic Generation Control) application facility was introduced as per CEB Annual Report 2018.
System Security - Islanding Schemes, Automatic Voltage Regulators/ Power System Stabilizers for Gencos, Maximum Continuous Rating	Yes, please refer section 2.3.5.3 of this report.	Automatic Voltage Regulators are installed in generation units.
Demand Management - Under Frequency Management / Load Shedding	Yes, please refer section 2.3.5.4 of this report.	Operations Planning Unit of CEB carries out the fine tuning of UFLS (Under Frequency Load Shedding) Scheme.
Outage Planning- Procedure for Planned, Forced and Emergency outages, Frequency of Outage Planning (Monthly/Quarterly/Yearly)	Yes, please refer section 2.3.5.5 of this report.	Operations Audit Unit of CEB Summarizes and analyzes system equipment outages.
Grid recovery procedures - System restoration plans / procedures for partial and total grid failure	Yes, please refer section2.3.5.6 of this report.	No information available (or not in English language) in the public domain on implementation and compliance.
Commercial mechanisms such as frequency-linked Unscheduled Interchange (UI) or	No.	Not Applicable.

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Deviation Settlement Mechanism (DSM) for grid discipline and frequency control		

3.8.6. Assessing level of implementation and compliance of identified measures for Scheduling and dispatch

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Detailed Procedure and Timelines for Scheduling and Despatch	Yes, please refer section 2.3.6.1of this report.	No information available (or not in English language) on implementation and compliance in the public domain.
Declaration discipline	No.	
Short-term demand estimation and resource management	Yes, please refer section 2.3.6.3of this report.	
Ramping rate to be declared for scheduling	Yes, please refer section 2.3.6.4of this report.	
Scheduling of wind and solar generation	Yes, please refer section 2.3.6.5of this report.	
Scheduling of inter-regional and cross-border transactions	Yes, please refer section 2.3.6.6of this report.	
Treatment of infirm power	No.	

3.8.7. Assessing level of implementation and compliance of identified measures for Information and communications technology including cyber security

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Communication facilities for data and voice	Yes, please refer section 2.3.7.1 of this report.	No information available (or not in English language) on implementation and compliance in the public domain.
IT infrastructure (servers, computers, peripherals, etc.) available	No	
SCADA / EMS for real-time operations	Yes, please refer section 2.3.7.2 of this report.	
WAMS / PMU for real-time operations	Yes, please refer section 2.3.7.3 of this report.	

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Technology solutions for managing real-time and back-office operations - power scheduling, energy accounting, deviation settlement, open access transactions, web portal, etc.	No	
Cyber Security - Policy, Framework, Action Plan	Yes, please refer section 2.3.7.4 of this report.	

3.8.8. Assessing level of implementation and compliance of identified measures for Monitoring and compliance

Identified measures	Availability of Provision/ Regulation	Level of implementation and compliance
Reporting: periodic reports covering performance of the integrated grid - Frequency profile - Demand met (peak, off-peak and average) - Instances and quantum of curtailment of renewable energy - Demand and energy unserved in MW and MWh - Constraints and instances of congestion in transmission system - Instances of persistent/significant non-compliance of Grid Code - Cyber threat / attack information	Yes, please refer section 2.3.8.1 of this report.	No information available (or not in English language) on implementation and compliance in the public domain.
Scope for self-audit, independent third-party compliance audit	Yes, please refer section 2.3.8.2 of this report.	
Periodic monitoring of actual performance of grid operators and grid users against standards of performance (SOP)	Yes, please refer section 2.3.8.3 of this report.	

End Notes on Chapter 3.

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85 Monthly Operational Report, Power Grid Company of Bangladesh Ltd., [http://pgcb.gov.bd/site/page/0cd0c563-4f06-473a-9a7e-c45ead947140/-]
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94https://electricenergyonline.com/article/organization/25253/668510/Bhutan-Power-Corporation-Limited-Selects-OSI-Technology-for-Advanced-Distribution-Management-System.htm (news article) Nov 22, 2017, accessed June 2020
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4. Chapter 4: International experiences and best practices on Regulatory Interventions for Grid Discipline and Grid Reliability

In this chapter, case studies from South Asian Region and Non-South Asian Region have been reviewed and analyzed to glean the technical and administrative regulatory tasks that need to be collectively accomplished from the regulatory perspective that underpins integration/ unification of regional grids of domestic power system of a country, as well as cross-border power grid interconnection. Key lessons learnt from the case studies have been summarized at the end of case studies. From these key lessons, an attempt has been made to arrive at a list of minimum set of regulatory requirements/ ingredients required for grid discipline and grid reliability.

4.1. Brief overview of Non-South Asian Region integration/ unification exercises used as case studies

In this chapter case studies from South Asian Region and Non-South Asian Region have been reviewed and analyzed. Case studies elaborating role played by institutions in maintaining grid discipline and grid reliability, case studies in operational best practices to promote grid discipline and grid reliability as well as case studies elaborating best practices followed in information and communication technology including cybersecurity are provided to glean the key lessons learnt from international experience leading to minimum set of regulatory requirements / ingredients which form the basis for suggesting regulatory measures/ interventions and roadmap in chapter 6.

4.1.1. Nord Pool

The generation systems of the Nordic countries have important complementarities. The original growth of the electricity sector in both Norway and Sweden and northern Finland was based on the potential to exploit hydro power and thus provide affordable power for a growing energy intensive industry. Norway is dominated by hydropower, offering short-term flexibility and cheap hydropower in wet years[3]. Sweden has a more diversified power sector, with hydropower in the north and thermal (including nuclear) in the south. Denmark has a high penetration of wind power whereas, Finland has thermal resources (including nuclear). Norway was first amongst the Nordic region countries to deregulate its power market. In 1996, Norway and Sweden established Nord Pool. By 2000 Finland and Denmark joined the Nord Pool. Subsequently, other regional European countries namely Germany (in 2006), United Kingdom (in 2010) and Baltic Countries (in 2013) joined the Nord Pool. Nord Pool Spot AS operates the Nord Pool. Nord Pool is owned[136] by Euronext (66%), and the Nordic Transmission System Operators and Litgrid (Lithuanian TSO) retain 34% ownership through a joint holding company. Nord Pool AS

[3] Dry years and wet years are years with considerably less or more precipitation than in a normal year. Source: Sigrid Tovrud Climate related alterations in Norwegian and Swedish hydropower production and the resulting impact on the Nordic power market in 2050, Master's Thesis 2017 30 ECTS Faculty of Environmental Sciences and Natural Resource Management (MINA), Norwegian University of Life Sciences. https://pdfs.semanticscholar.org/1def/526e223761a5e5dacb2ecbb460e7ab25daac.pdf

is licensed by the Norwegian Water Resources and Energy Directorate (NVE) to organise and operate a marketplace for trading power, and by the Norwegian Ministry of Petroleum and Energy to facilitate the power market with foreign countries. Nord Pool is appointed as a Nominated Electricity Market Operator (NEMO) in Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Great Britain, Ireland, Latvia, Lithuania, Luxembourg, the Netherlands, Poland and Sweden which signifies Nord Pool's ability to meet the new Network Guidelines on Capacity Allocation and Congestion Management (CACM), which came into force on 14 August 2015. The Nordic cooperation among producers had also included cooperation regarding frequency and regulation power.

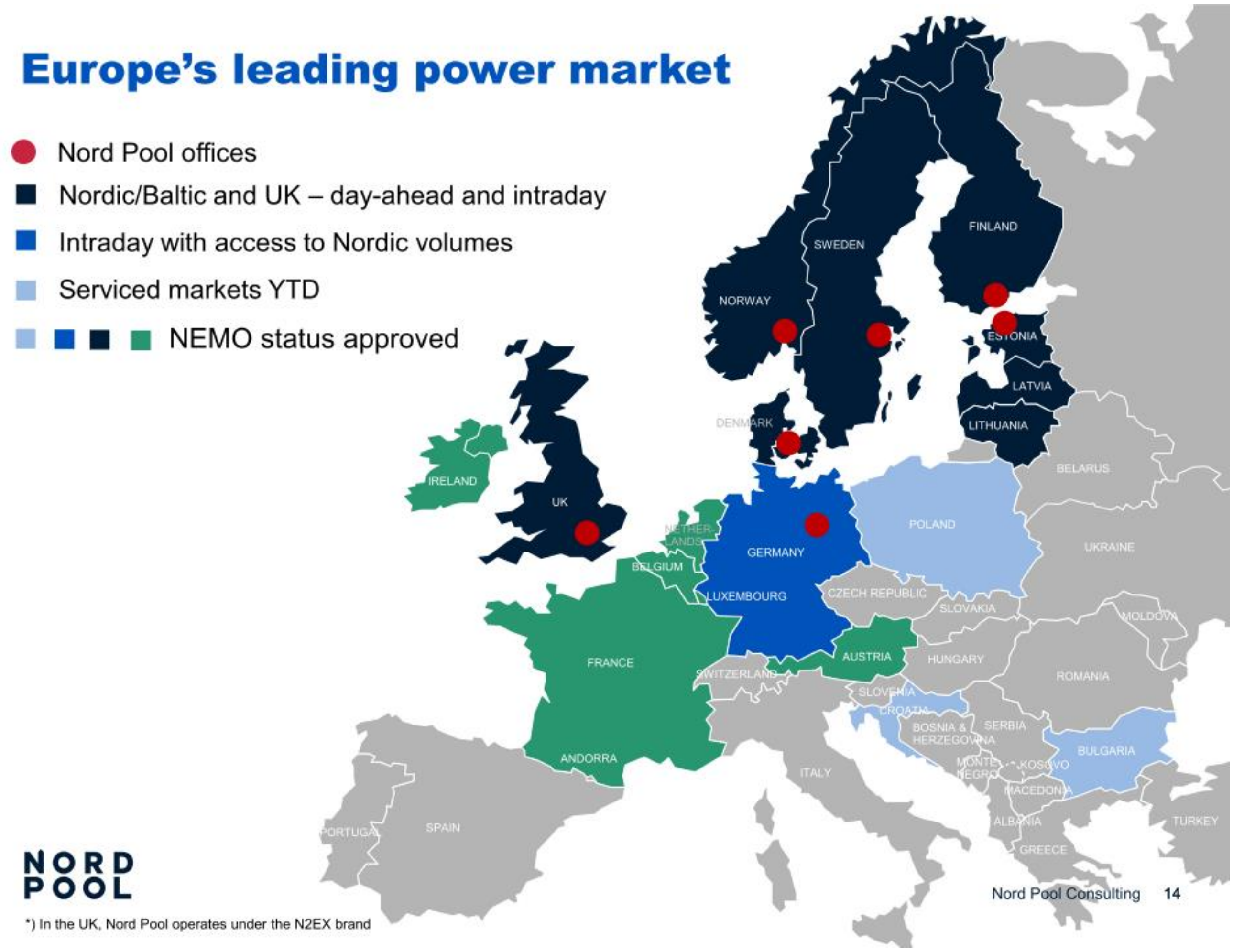


Figure 47: Nord Pool (Source: Nord Pool - Europe's leading power market, 5 April 2017, Haakon Reirsen Lekens, https://orkustofnun.is/media/orkustofnun/Arsfundur-2017-Nord-Pool.pdf)

The European Network of Transmission System Operators for Electricity (ENTSO-E) represents 42 electricity transmission system operators (TSOs) from 35 countries across Europe. ENTSO-E was established and given legal mandates by the EU's Third Legislative Package for the Internal Energy Market in 2009, which aims at further liberalizing the gas and electricity markets in the EU. ENTSO-E members share the objective of setting up the internal energy market and ensuring its optimal functioning, and of supporting the ambitious European energy and climate agenda.

Following the reforms of the Nordic electricity markets and the emerging common electricity market, it became clear that the Nordic energy regulators needed to cooperate, starting with biannual meetings in 1999. NordREG was established as a forum for cooperation between the Nordic energy regulators through a Memorandum of Understanding (MoU), signed in 2002. NordREG's mission[137] is to actively promote legal and institutional framework and conditions necessary for developing the Nordic and European electricity markets. In many issues, the TSOs are the natural actors to propose new solutions to common problems. However, in the case of the Nordic Retail Market, the regulators are in charge of the project aiming to define the design of a common Nordic Retail Market.

The key features of the European model grid code that governs the cross-border flow of electricity within Nordic electricity market are provided in the table below:

Table 48: Key features of European model grid code (Nordic electricity market)

Sr. No.	Particulars	Details
1	Nominal frequency	+/- 100 mHz
2	Maximum instantaneous frequency deviation	1000 mHz.
3	Time to restore frequency	15 minutes
4	Voltage range for unlimited operation	Voltage should stay between 0.9 pu and 1.05 pu for connection points up to 400 kV.
5	Reactive power management measures	Each TSO is entrusted to monitor and manage the following: a) availability of reactive power capacities of power generating facilities, b) management of reactive power capacities of transmission-connected demand facilities. c) availability of reactive power capacities of DSOs. d) ensure transmission-connected equipment dedicated for providing reactive power; and e) compute ratios of active power and reactive power at the interface between the transmission system and transmission connected distribution systems.
6	System protection co-ordination criteria	Each TSO ensure implementation of protection devices to protect the system from the following: a) external and internal short circuit. b) over/under-voltage at the connection point to the transmission system. c) over/under-frequency. d) demand circuit protection. e) unit transformer protection. f) back-up against protection and switchgear malfunction
7	List of structural data to exchange with other TSOs	The list of structural data shall include at least the following data fro m the observability area that shall be agreed between neighbouring TSOs (in principle, at least border substations

Sr. No.	Particulars	Details
		shall be included in the observability area): 1) Normal topology of substations. 2) Technical data on transmission lines. 3) Technical data on transformers, including phase shifting 4) transformers. 5) Technical data on HVDC systems. 6) Technical data on reactors, capacitors and other. 7) Reactive power limits from generation facilities. 8) Operational security limits. 9) Protection set points of transmission lines included as extern al contingencies.
8	List of scheduled data to exchange with other TSOs to coordinate their operational security analysis and to establish the common grid model	TSOs from the same synchronous area shall exchange at least the foll owing: 1) Topology of the transmission grid above 220 kV (including 220 kV). 2) Model of the transmission grid below 220 kV, which has a significant impact. 3) Thermal limits of the transmission elements. 4) Aggregated generation forecast in each node of the transmission grid. 5) For dynamic stability studies, additional data should be exchanged.
9	List of real time data to exchange with other TSOs	1) Frequency 2) Frequency restoration control error 3) Active power exchange between control areas 4) Aggregated generation 5) System state 6) Set point of the load frequency control 7) Substation topology (including availability). 8) Active and reactive power in line bay or transformer bay, includi ng transmission and distribution 9) Active and reactive power in generation bay 10) Reactive power in reactor bay and capacitor bay 11) Bus bar voltage 12) Restrictions (if any) and outages. 13) Positions of tap-changers transformers
10	Contingency analysis	Each TSOs perform contingency analysis in its observability area in order to identify the contingencies which endanger or may endanger the operational security of its control area and to identify the remedial actions that may be necessary to address the contingencies, including

Sr. No.	Particulars	Details
		mitigation of the impact of exceptional contingencies. The starting point for the contingency analysis in the N-Situation shall be the relevant topology of the transmission system which shall include planned outages in the operational planning phases.
11	Outage coordination	TSOs of two or more outage coordination regions can agree to merge them into one unique outage coordination region. In that case they shall identify the regional security coordinator performing the tasks. Each TSO shall provide the regional security coordinator with the information necessary to detect and solve regional outage planning incompatibilities, including at least: (a) Availability plans of its internal relevant assets, stored on the ENTSO for Electricity operational planning data environment (b) Most recent availability plans for all non-relevant assets of its control area which are: (i) capable of influencing the results of the outage planning incompatibility analysis; (ii) modelled in the individual grid models which are used for the outage incompatibility assessment (c) scenarios on which the outage planning incompatibilities have to be investigated and used to build the corresponding common grid models derived from the common grid models for different time-frames established

4.1.2. Regional Mediterranean Electricity Market (RMEM)

The European Union (EU) has developed several initiatives to bring together Mediterranean countries around the subject of energy policy and regulation[138]. The first initiative was the EuroMed Partnership (also called the Barcelona Process) in 1995. For the first time, a multilateral approach was used in the region. This initiative was followed by the more comprehensive European Neighbourhood Policy in 2003 and by the creation of the Union for the Mediterranean (UfM) in 2008. UfM promoted the idea of having multilateral cooperation in the context of an intergovernmental framework. In 2011, in its communication called 'A Partnership for Democracy and Shared Prosperity with the Southern Mediterranean' the EU mentioned the establishment of an EU-Southern Mediterranean Energy Community to foster the development of joint RES investments that could benefit both shores of the Mediterranean. The European Neighbourhood Policy (ENP) encouraged cooperation between the EU and Southern Mediterranean countries through the use of Action Plans that support the advancement of market reforms in the medium-term. However, these Action Plans often lacked practical tools to implement the goals they propose. For this reason, the EU increased the sponsorship of initiatives that are built around a bottom-up approach i.e., initiatives designed by the Southern Mediterranean countries, so that neighboring countries can feel they are a full part of the harmonization process. For this reason, the EU started financing associations such as the Mediterranean Energy Regulators (MEDREG) which works to facilitate and develop regulatory approaches and practices that are coherent at the regional level for energy market integration in the Mediterranean region and the Mediterranean Transmission System Operators (Med-TSO) which brought Northern Mediterranean countries and Southern Mediterranean countries at the same table and work on a useful synthesis of their objectives and experiences.

Figure 48: Mediterranean Interconnection Ring (Image credits: Researchgate)

Following are the objectives and activities of MedTSO:

Med-TSO members share the primary objective of promoting the creation of a Mediterranean energy market, ensuring its optimal functioning through the definition of common methodologies, rules and practices for optimizing the operation of the existing infrastructures and facilitating the development of new ones.

Med-TSO contributes to the achievement of this objective by promoting:

1. the coordination among the Med-TSO countries of their national transmission network development

plans and of their power system operation, studying the development of an integrated, secure and sustainable Mediterranean Power System and promoting cross-border projects aiming at facilitating the integration of new energy sources (especially from renewable energy sources), increasing security and quality of power supply;

2. the use of common criteria and harmonized, transparent and non-discriminatory technical rules for guaranteeing the interoperability of the interconnected power systems;

3. training, knowledge sharing and technical assistance in the region, facilitating the exchange of information, analyses and experiences among the Associates, including the R & D sector;

4. enhanced communication and consultation with stakeholders for improving TSOs operation transparency and facilitating the public acceptance of transmission infrastructures;

5. the cooperation among the Mediterranean TSOs and coordinated approach towards the Institutions (in particular with the association of the Mediterranean Regulators for energy, MEDREG, and the European Network of TSOs for electricity, ENTSO-E);

6. the role of TSOs at regional level, analyzing and taking common positions on issues that can have an impact on the development and operation of transmission systems.

The pursuit of harmonized interconnections in the region has led to some results in the past. The Eight Country Interconnection Project (EIJLLPST) concerning Egypt, Iraq, Jordan, Libya, Lebanon, Palestine, Syria and Turkey has achieved (as on April 2016) the synchronous interconnection of the first seven countries, while Turkey has achieved synchronization with the European system. Algeria, Morocco and Tunisia have worked in the past to achieve synchronization through the Maghreb Countries Interconnection Project (IMME), but the project has so far been unable to go beyond capacity building activities.

Table 49: National electricity systems in the Mediterranean region (2016). Source: Med-TSO & Enerdata

Countries	Total generation (TWh)	Load (TWh)	Exchange balance (Export - Import)(TWh) +ve figure denotes net export while -ve figure denotes net import
Albania	4.5	7.4	2.9
Algeria	64.1	63.9	0.2
Cyprus	4.9	4.9	0.0
Egypt	190.0	190.0	0.0
France	531.3	482.9	41.6
Greece	42.4	51.2	-8.8
Italy	279.7	314.3	-37.1
Jordan	18.3	18.6	-0.3
Libya	36.4	36.4	0.0
Montenegro	2.9	3.2	-0.3
Morocco	30.8	35.4	-5.2
Portugal	55.9	49.3	5.1
Slovenia	15.2	13.8	1.0
Spain	248.4	250.0	-6.4
Tunisia	18.2	18.1	0.1
Turkey	274.4	279.3	-4.9

Electricity systems in the Mediterranean region are very different. On the European side, systems are robust, presenting high levels of consumption and generation as well as properly developed international trade. In the south side of the Mediterranean sea, the systems are not as robust as compared to the EU. At the same time, these countries (Maghreb sub-region: Algeria, Morocco and Tunisia; Mashreq sub-region: Egypt, Iraq, Jordan, Lebanon, Libya, Palestine, Syria and Turkey) have comparable issues regarding access to financing, insufficient development of infrastructures and geographical characteristics that hindered high levels of interconnections. This situation makes security of supply a dominant concern and calls for regular upgrades of the electricity system, regarding both generation and networks, making investment a key issue in most of the countries. Table 1 shows that France, Portugal and Slovenia are big exporters while Greece, Italy and Spain import large amounts of power.

The possibility to combine and operate power systems that have complementarities in terms of load profiles and generation mix in a more integrated way is an added value with direct impact on increasing the energy efficiency as a result of transmission network integration and on reducing the cost and the environmental footprint of electricity. The Northern and Southern shores of the Mediterranean basin present different characteristics that offer potentialities and complementarities. Countries of both banks can use these synergies as key to exchange energy and meet the targets of the energy transition in the next decades. Adequate, integrated and efficient electricity infrastructures, through the shared use of energy, pave the way towards the achievement of development and security goals in the Mediterranean Region. This has been the key motivation behind RMEM. RMEM is still an evolving International Interconnection/ Market experience.

The key features of the Med-TSO model grid code that governs the cross-border flow of electricity within regional Mediterranean electricity market are provided in the table below:

Table 50: Key features of Med-TSO grid code (Mediterranean electricity market)

Sr. No.	Particulars	Details
1	Nominal frequency	50 Hz.
2	Standard frequency range	Between 20 mHz. and 200 mHz.
3	Time to restore frequency	10 minutes to 20 minutes.
4	Voltage range for unlimited operation	1) Between 110 kV and 300 kV the voltage should stay between0. 9 pu and 1.118 pu. 2) Between 300 kV and 400 kV the voltage should stay between 0 .9 pu and 1.05 pu.
5	Reactive power management measures	1) Each TSO entitled to use all available transmission connected reactive power capabilities within its power system f or effective reactive power management and maintaining the v oltage ranges. 2) Each TSO to ensure reactive power reserve, with adequate volume and time response, in order to keep the voltages within its power system and on interconnectors within the voltage ranges. 3) TSOs interconnected by AC interconnectors shall jointly specif y the adequate voltage control regime in order to ensure that t he common operational security limits established arein accor dance with the mutually agreed common operational security limits.
6	System protection co-ordination criteria	1) Each TSO shall operate its transmission system with the prote ction and backup protection equipment in order to automatica lly prevent the propagation of disturbances that could endange r the operational security of its own transmission system and o f the interconnected system.

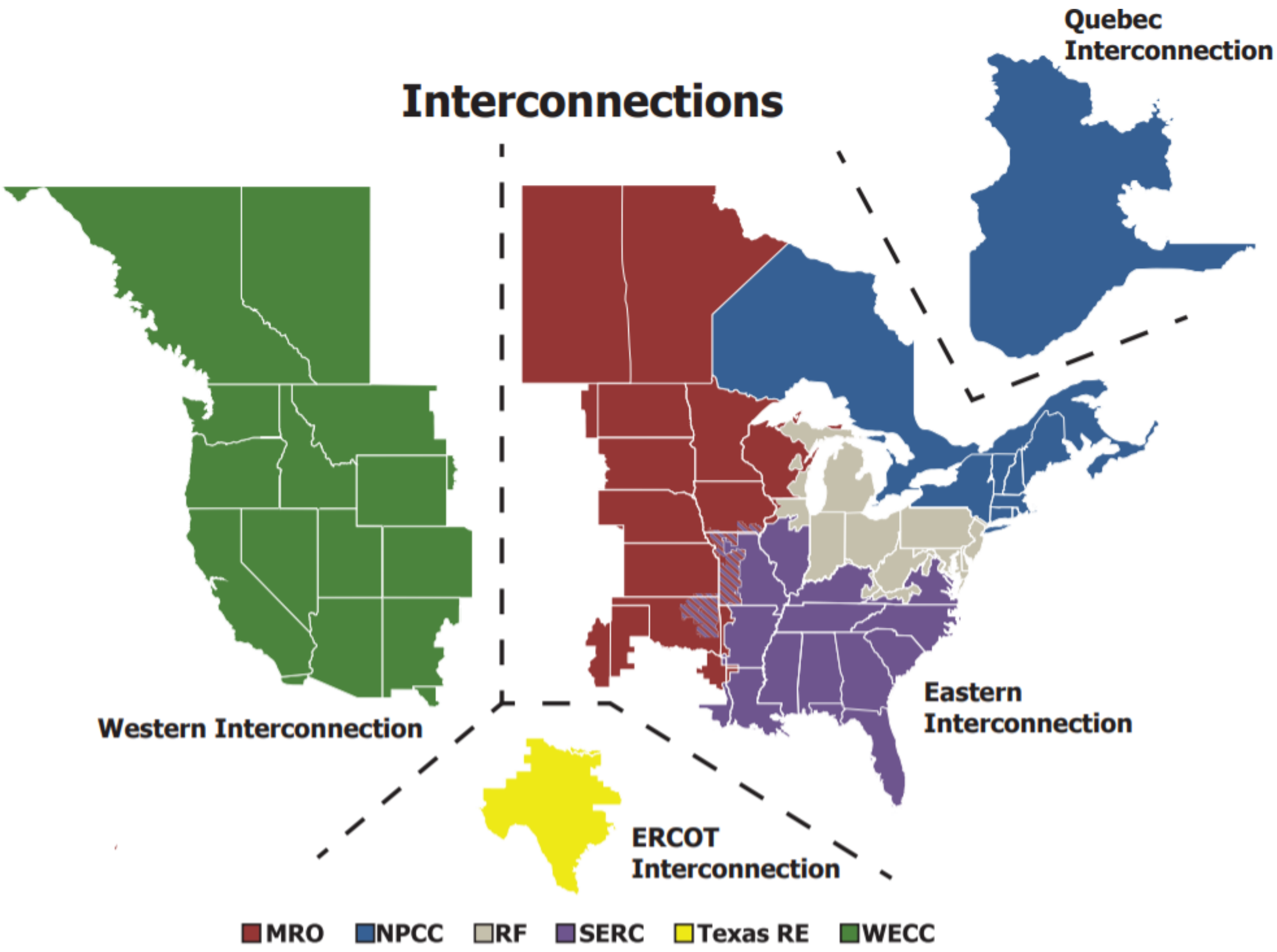
Sr. No.	Particulars	Details
		2) Each TSO shall specify setpoints for the protection equipment of its transmission system that ensures reliable, fast and selecti ve fault clearing, including backup protection for fault clearing in case of malfunction of the primary protection system.
7	List of structural data to exchange with other TSOs	The list of structural data shall include at least the following data f rom the observability area that shall be agreed between neighbouring TSOs (in principle, at least border substations shall be included in the observability area): 10) Normal topology of substations. 11) Technical data on transmission lines. 12) Technical data on transformers, including phase shifting 13) transformers. 14) Technical data on HVDC systems. 15) Technical data on reactors, capacitors and other. 16) Reactive power limits from generation facilities. 17) Operational security limits. 18) Protection set points of transmission lines included as exte rnal contingencies.
8	List of scheduled data to exchange with other TSOs to exchange with other TSOs to coordinate their operational security analysis and to establish the common grid mode	TSOs from the same synchronous area shall exchange at least the f ollowing: 6) Topology of the transmission grid above 220 kV (including 220 kV). 7) Model of the transmission grid below 220 kV, which has a significant impact. 8) Thermal limits of the transmission elements. 9) Aggregated generation forecast in each node of the transmission grid. 10) For dynamic stability studies, additional data should be exchanged.
9	List of real time data to exchange with other TSOs	14) Frequency 15) Frequency restoration control error 16) Active power exchange between control areas 17) Aggregated generation 18) System state 19) Set point of the load frequency control 20) Substation topology (including availability). 21) Active and reactive power in line bay or transformer bay, incl uding transmission and distribution 22) Active and reactive power in generation bay 23) Reactive power in reactor bay and capacitor bay

Sr. No.	Particulars	Details
		24) Bus bar voltage 25) Restrictions (if any) and outages. 26) Positions of tap-changers transformers
10	Contingency analysis	1) Each TSO shall establish a contingency list, including the internal and external contingencies of its observability area , by assessing whether any of those contingencies endangers t he operational security of the TSO's control area. The conti ngency list shall include both ordinary contingencies and exceptional contingencies. 2) The external contingency list should be agreed by neighbouring TSOs in the bilateral corresponding internal TSO-TSO agreements. 3) Each TSO shall assess the risks associated with the contingencies after simulating each contingency from its contingency list and after assessing whether it can maintain its transmission system within the operational security limits in the (N-1) situation. When a TSO assesses that the risks associated with a contingency are so significant that it might not be able to prepare and activate remedial actions in a timel y manner to prevent non-compliance with the (N-1) criterion or that there is a risk of propagation of a distur bance to the interconnected transmission system, the TSO shall prepare and activate remedial actions to achieve com pliance with the (N-1) criterion as soon as possible. In case of an (N-1) situation caused by a disturbance, each TSO should inform neighbouring TSOs about the external contingencies and also about any topological change included in the external contingency list.
11	Outage coordination	Due to the importance of quick access to information about outages, all TSOs should perform the two following steps: 1) Definition of assets (network elements and generation and co nsumption units) with cross border (XB) relevance, to be incl uded in the contingency list that should be agreed by neighbo uring TSOs in the bilateral corresponding internal TSO-TSO agreement. 2) On a year ahead timeframe, outage planning agents of XB rele vant generation and consumption shall provide their proposal s for outages (Availability Plans) to the connecting TSO.

4.1.3. North American Region

The electric power system of the United States is physically interconnected with the power systems of both Canada and Mexico, although it is much more integrated with the former. The U.S. and Canadian systems operate at synchronous (i.e., compatible) frequencies, with over 30 major transmission connections between the two countries. Conversely, there are only a handful of cross-border interconnections with Mexico - and only the connections with California are fully synchronized with the U.S. grid[139]. The degree of grid integration has been a key determinant of historical electricity trade and prospects for future trade between the United States and its neighbours.

The changing nature of the generation portfolios among the United States, Canada, and Mexico has also been a factor affecting electricity trade and may represent an opportunity for increased trade in line with their pursuit of economic and environmental goals. Notably, in 2016, the United States signed an agreement with Canada and Mexico pledging to increase carbon-free sources of electricity, with a North American total goal of at least 50% of electric energy from "wind, solar, and other carbon-free sources of electricity by 2025."[140]. The growing role of renewable resources for domestic power production and potential export is, therefore, a topic of particular interest.



MRO	Midwest Reliability Organization
NPCC	Northeast Power Coordinating Council
RF	ReliabilityFirst
SERC	SERC Reliability Corporation
Texas RE	Texas Reliability Entity
WECC	Western Electricity Coordinating Council

Figure 49 North American Region Interconnections (Source: NERC, https://www.nerc.com/AboutNERC/keyplayers/PublishingImages/NERC%20Interconnections.pdf)

Electric Power Resources profiles of Mexico, the United States, and Canada are quite different from one another in terms of overall size. Mexico has the smallest electricity sector, with 68 Gigawatts (GW) of available generating capacity, including both state-owned and other generators[141]. Canada has an installed base of approximately 133 GW[142]. The United States' electricity sector is massive by comparison, with total generation capacity around 1,100 GW - over five times the capacity of the other two countries combined[143].

U.S. Electric Power import and exports over the last decade, the United States has experienced a marked trend of growing net electricity imports from both Canada and Mexico, although Canada is, by far, the greater trade partner. U.S. electricity imports have increased overall since 2006, while U.S. exports to Canada and Mexico have decreased over the same period. U.S. exports to Mexico have been relatively low and flat. The value of electricity imports from Canada to the United States rose (overall) from approximately US$1.9 billion in 2011 to about US$2.95 billion in 2015[144].

The United States and Mexico have traded electricity since 1905, but this trade is confined to the few places where transmission lines cross the U.S.-Mexico border. Between California and Mexico, electricity is imported from a handful of generators to supply the San Diego area. In the case of Texas, electricity trade has been somewhat episodic, occurring mainly during periods of constrained supply within the Texas or Mexican transmission systems[145].

The key features of the North American Regional model grid code that governs the cross-border flow of electricity within North American regional electricity market are provided in the table below:

Figure 50 Power Trade in the Region (Source: U.S. Energy Information Administration, Online data, Table 2.13, December 20, 2016, https://www.eia.gov/electricity/annual/html/epa_02_13.html)

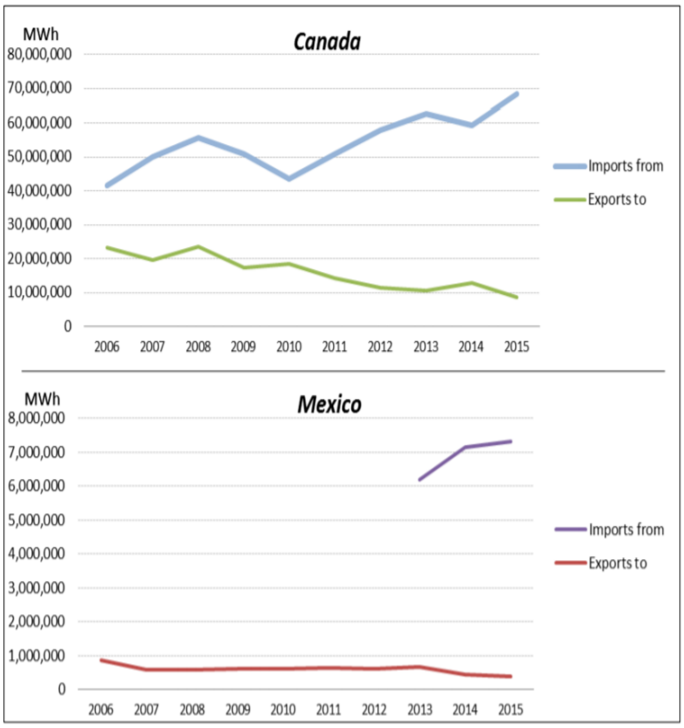


Table 51: Key features of North American regional model grid code

Sr. No.	Particulars	Details
1	Nominal frequency	60 Hz
2	Standard frequency range	Between 59.5 Hz to 60.5 Hz
3	Voltage range for unlimited operation	Voltage should stay between 0.9 pu and 1.05 pu for connection points up to 400 kV.
4	Reactive power management measures	For reactive power assessment Reliability Coordinating Council Conducts Q-V (power-voltage) and P-V (power-voltage) analysis. QV analysis provides the sensitivity of bus voltage with respect to injections of reactive power at a given bus location. The purpose of QV analysis is to determine how much reactive margin a particular bus has before voltage collapse would occur under pre- and post-contingency operating conditions. P-V analysis provides the sensitivity of bus voltages with respect to increasing transfers of active power (MW) between a source and sink.
5	Protection systems	Transmission Owner implement protective relays, communication systems necessary for correct operation of protective functions, voltage and current sensing inputs to protective relays and associated circuitry from the voltage and current sensing devices,

Sr. No.	Particulars	Details
		station dc supply, and control circuitry associated with protective functions from the station dc supply through the trip coil(s) of the circuit breakers or other interrupting devices.
6	List of structural data to exchange with other TSOs to coordinate their operational security analysis and to establish the common grid mode	Transmission Owners (TOs) provide transmission monitoring at their Control Centers including monitoring of circuit loading, voltages, limit violations and contingency analysis. TO conduct a Real-time Assessment at least once every 20 minutes (assess the reliability of their portions of the bulk power transmission system through a combination of state estimation and contingency analysis.
9	Contingency analysis	In order to meet the requirements of the NERC Reliability Standards to identify their Most Severe Single Contingency (MSSC) to determine their base Contingency Reserve. Many types of resources can be considered for use as Contingency Reserve provided they can be deployed within the appropriate timeframe. As technology and innovations occur this list may continue to grow, but may include: a. Unloaded/loaded generation b. Off-line generation c. Demand resources d. Energy Storage Devices e. Resources such as wind, solar, etc., provided any limitations are considered.
10	Outage coordination	Independent System Operators (ISO) coordinates outage schedules for maintenance, repair and construction within the ISO grid to maintain system reliability, maximize schedule feasibility and ensure effective planning for resource use. ISO prepare transmission outage reports which depicts daily snapshot of transmission facilities that are not operational because of planned or unplanned outages.

4.2. Analysis of International experiences

4.2.1. Role played by Institutions in maintaining grid discipline and grid reliability

In integration/ unification of regional grids of domestic power system of a country as well as cross-border power grid interconnection, several institutions play a pivotal role in co-ordination among the regions / countries, formulation of legislation / regulations / codes / rules etc. that govern the grid discipline and grid reliability in an interconnected system. Following case studies illustrate the role played by key institutions in maintaining grid discipline and grid reliability.

4.2.1.1. Case Study-1: Evolution of Mediterranean Institutional Framework supporting grid discipline and grid reliability

The vision to set up a regional electricity market within the Mediterranean region, namely "Regional Mediterranean Electricity Market (RMEM)" was to improve systems reliability, to reduce reserve margins, to support grid with reactive power, to enable energy exchanges that take advantage of daily and seasonal demand diversity and disparities in marginal production costs, and finally to facilitates and promotes key regional infrastructure development[146]. At the conception (year 2012) of the regional electricity market, there existed following structural/ institutional challenges:

1. Minimal coordinated control over many national networks, making it very difficult to determine and verify if international trade transactions are feasible;

2. No agreed dispatch mechanism and software with a consistent set of data for multiple national systems to enable verification of the feasibility of trade transactions by different national control centers;

3. Limited overarching documents representing a commitment by member countries to pursue power market reform and increased regional integration and trade;

4. Markets that are not liquid (meaning the number of transactions is limited), those are not transparent, and have the majority of trades conducted by government officials, tend to further exacerbate the problem of market liquidity as potential market participants are not trusting that the market price is truly "fair" and governed by market forces. As a result, these potential market participants refuse to participate;

5. While there existed some regional integration organizations in place, they were few in numbers, covering too few countries, and had limited duties and power to enforce their decisions;

6. Minimal harmonization of legislation among the member countries with respect to energy, environment, and safety;

7. Few countries had what could be considered "independent and informed" regulatory agencies. Independence refers to the ability to make decisions in the absence of political interference. Informed means that the members of the regulatory agency have the background, expertise, and skills to make decisions on behalf of all participants in the power sector. Regulation should be the primary job of the staff of the regulatory agencies, which was often not the case in most countries;

8. Most countries did not allow access to their transmission networks under published terms, conditions, and prices - meaning access could not be considered fair and non-discriminatory;

9. There was very little published information concerning market prices and transmission availability; and

10. There was excessive diversity of accounting practices and an absence of secure and stable legal framework among countries.

Despite these challenges, it was felt that regardless of the type of regional trade, there needs to be a legal, regulatory, and governance structure in place conducive to international trade, even if trade is only bilateral between two countries. The participating countries must have the political will to relinquish a portion of their energy supply responsibilities to the greater good of the region.

Accordingly, a roadmap for RMEM integration was prepared. The preliminary stage of this roadmap consisted (i) establishment of regional bodies; Regional Market Operator, Regional Regulatory Agency, (ii) putting the market documents into practice; this includes Regional Market Rules, Commercial Agreements, Grid Code, and Regional Data Base; and (iii) making the necessary adjustments on the national and regional levels, in order to manage the cross-border trading activities.

Establishment of Regional Regulator:

The Regional Regulatory Agency shall have representatives from all of the participating countries. It should have the power to apply sanctions to enforce its decisions or to penalize parties that breach any regional regulations which have been approved.

Features of the Regional Regulator:

Independence: it is important to assure that the regulatory body can give a credible commitment to investors and consumers.

Capacity: the regulator should possess adequate and capable staff and systems to fulfil its mandates. Its capacity could be determined by its information systems and the competence of its professionals, as well as its ability to respond, fairly, technically and quickly to different types of industry problems.

Transparency and fairness: The regulator should be transparent and fair in the context of specifying the rules and explaining the decisions.

Predictability: The regulator should provide written rules in terms of defining methodologies and tariff structures so that they guarantee non-discrimination in tariff determination as well as a reasonable rate of return to the industry.

Efficiency of the Regulator as a decision-maker: This is needed for the sake of accountability. There should be definite procedures for decision making within the organization, consultation with participants in the sector and with consumers, and internal performance.

Responsibilities of the Regional Regulator:

- Endorses and ensures compliance with the regional-market governance documentation (market rules and grid code);
- Monitors the performance of the market and guarantees that it operates in a non-discriminatory way;

- Advises on generation-reserve criteria;
- Advises on rules governing allocation of cross-border transmission capacity to eliminate contingencies;
- Promotes common standards in the member countries with respect to the safety, security, reliability, and quality of service in the generation and supply of electricity to consumers;
- Reviews proposals for expansion of international and regional interconnections;
- Disputes Resolution between members;
- Participates in regional planning; and
- Decides / implements the transition between stages.

<u>Establishment of Regional Market Operator:</u>

The Regional Market Operator shall be responsible for system operation co-ordination, market administration, market operation, and settlement as follows:

- System Operation Coordination
– Scheduling pool interconnectors,
– Monitoring load flows and taking action on variances, and
– Balancing market counterparty for imbalance settlement,
- Market Administration
– Market Monitoring and surveillance,
– Administration of contracts,
– Dispute Management, and
– Membership Administration
- Market Operation
– Managing the Balancing Market, and
– Managing the Day Ahead Market
- Settlement
– Meter Read administration,
– Balancing Market billing,
– Day Ahead Market Settlement, and
– Payment.

<u>Responsibilities of Regional System Operator:</u>

The Regional System Operator shall basically be responsible for:

- Providing oversight on technical aspects of the REM;
- Ensuring fair and non-discriminatory access to grid and international interconnections; and
- Coordinating the efforts of national TSOs to dispatch electricity through the international interconnectors.

In response to these requirements specified in the preliminary stage of the roadmap, a regional regulator (MEDREG) and regional market operator-cum-regional system operator (Med-TSO) were established.

MEDREG stands for the Association of Mediterranean Energy Regulators, which gathers 27 energy regulators from 22 countries, spanning the European Union (EU), the Balkans and the Middle East and North Africa (MENA) region: Albania, Algeria, Bosnia-Herzegovina, Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Jordan, Lebanon, Libya, Malta, Montenegro, Morocco, Palestinian Authority, Portugal, Slovenia, Spain, Tunisia and Turkey are already members. Mauritania has also initiated a process to join the organization[147]. MEDREG works to facilitate and develop regulatory approaches and practices that are coherent at the regional level for energy market integration in the Mediterranean region. MEDREG acts as a collaborative platform for regulators from the Northern and the Southern shore of the Mediterranean to exchange technical knowledge and good practices while supporting each other to reinforce their regulatory capacity. Considering its heterogeneous sub-regional membership, which varies in terms of its geography, economy, culture and specific energy regulations at the national level, MEDREG elaborates comprehensive studies, ad-hoc reports, study visits, workshops and specialized trainings that encourage common regulatory practices while respecting the singularity of its members.

Through the technical support and cooperation facilitated by MEDREG, Mediterranean energy regulators tend to adopt converging regulations and are forging a common regulatory culture in the region, which ultimately should contribute to the progressive creation of a Euro-Mediterranean energy market. The Association is co-funded by the European Union and benefits from the financial contribution of its members.

On 15 November 2007, the Energy Regulatory Authorities and/or Agencies in the Mediterranean region agreed on the Constitutive Act. The MEDREG Constitutive Act Statues[148] was approved by the 16th MEDREG General Assembly meeting on 19th November 2013. The MEDREG Constitutive Act Statues specifies the objective of the Organization, Terms and conditions of Membership, Governing Structure of the Organization (consisting of the General Assembly, the President, the Presidency Board, the Steering Committee and the Secretariat), Decision making process, Resources of the Association, Membership fees, budget and other sundry provisions. MEDREG also has MEDREG Internal Rules[149] which provide more clarity regarding how the various functions would be performed.

Med-TSO is the Association of the Mediterranean Transmission System Operators (TSOs) for electricity, operating the High Voltage Transmission Networks of 19 Mediterranean Countries. It was established on 19 April 2012 in Rome as a technical platform that, using multilateral cooperation as a strategy of regional development, that could facilitate the integration of the Mediterranean Power Systems and foster security and socio--economic development in the Region[150]. Med-TSO members share the primary objective of promoting the creation of a Mediterranean energy market, ensuring its optimal functioning through the definition of common methodologies, rules and practices for optimizing the operation of the existing infrastructures and facilitating the development of new ones.

Med-TSO contributes to the achievement of this objective by promoting:

- the coordination among the Med-TSO countries of their national transmission network development plans and of their power system operation, studying the development of an integrated, secure and sustainable Mediterranean Power System and promoting cross-border projects aiming at facilitating the integration of new energy sources (especially from RES), increasing security and quality of power supply;
- the use of common criteria and harmonized, transparent and non-discriminatory technical rules for guaranteeing the interoperability of the interconnected Power Systems;
- training, knowledge sharing and technical assistance in the Region, facilitating the exchange of information, analyses and experiences among the Associates, including the R & D sector;
- enhanced communication and consultation with stakeholders for improving TSOs operation transparency and facilitating the public acceptance of transmission infrastructures;
- the cooperation among the Mediterranean TSOs and coordinated approach towards the Institutions (in particular with the association of the Mediterranean Regulators for energy, MEDREG, and the European Network of TSOs for electricity, ENTSO-E);
- the role of TSOs at regional level, analyzing and taking common positions on issues that can have an impact on the development and operation of transmission systems.

The activities of Med-TSO are performed through the contribution of the Members within the Working Groups and Technical Committees. The work is set in a matrix scheme, on the basis of geographical or thematic issues (i.e., technical, regulatory, economic and financial issues) crossing the following lines of activities of a TSO: Planning, Operation, Electricity Exchanges. The Technical Committee - 1 Planning conducts following activities:

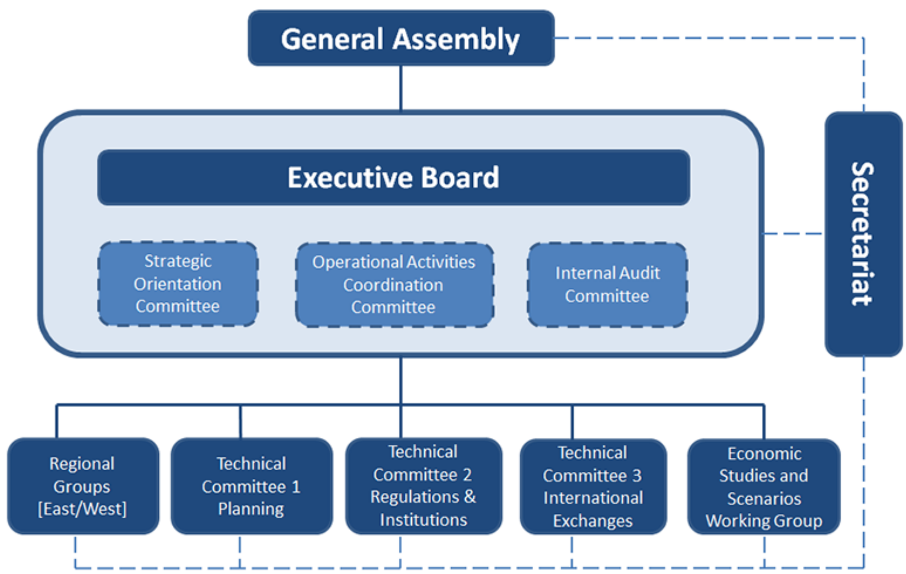


Figure 51: Organization Structure of Med-TSO (Source: Med-TSO Website)

- Transmission infrastructures planning criteria,
- Coordinated assembling of different national development plans,
- Sharing the priorities on the basis of timescale of expected benefits;
- Assessment of the regional scenario, based on the plans of each TSO;
- Assessment of Short-Term Projects;
- Short-term project criteria;
- Mediterranean Reference Grid; and
- Impact of RES introduction on safety and functioning of electricity systems.

Technical Committee - 2 Regulation and Institutions has main target to advance in the definition of common rules for the Mediterranean region from a TSO perspective, particularly in the field of the connection of users to the grid, of the operation of the interconnected power systems and of the system services.

Technical Committee - 3 International Exchanges has the objective of:

- Developing reference projects: demonstrating the feasibility of regional projects through the integration of grids and the increase of electricity exchanges, and
- Application to operational contexts of:
- Schemes for a shared code for the management of the transport grids
- Procedures for the coordination of interconnected grids operations
- Cross-border Cooperation

The Regional Mediterranean Electricity Market is still in an evolving regional co-ordination exercise. However, establishment of key institutions with legal backing has been instrumental in developing regulatory framework for achieving grid discipline and grid reliability from the perspective of integration / unification of regional grids/ cross-border grids in the Mediterranean region.

Key takeaways: The above case study illustrates the importance of establishing key institutions with legal backing and technical capabilities that enable integration / unification of grids while maintaining grid discipline and grid reliability.

4.2.1.2. Case Study-2: The case for institutions that can enforce grid discipline and grid reliability (European Experience)

Union for the Coordination of Transmission of Electricity (UCTE) was formed in 1951 and was tasked[151] with coordination, operation and development of the electricity transmission grid for the Continental European synchronously operated transmission grid, providing a reliable platform to all participants of the Internal Electricity Market and beyond. In 1999, UCTE re-defined itself as an association of TSOs in the context of the Internal Energy Market. Building on its experience with recommendations, UCTE turned to make its technical standards more binding through the Operation Handbook and the Multi-Lateral Agreement[152] between its members. The main term of the Multilateral Agreement was compliance with an Operational Handbook, which had been developed covering following policies:

- Load-Frequency Control and Performance,
- Scheduling and Accounting,
- Operational Security,
- Coordinated Operational Planning,
- Emergency Procedures (Operations),
- Communication Infrastructure,
- Data Exchanges, and
- Operational Training.

These policies/ standards became indispensable for the reliable international operation of the high voltage grids which are all working at the frequency of 50 Hz. Prior to 2005, enforcement of UCTE rules was on a voluntary basis, relying on the common interests of all members in maintaining secure operation within the synchronous zone. However, following a major network failure in 2003, when supply to much of Italy in particular was temporarily lost, it was clear that system security had become more complex. UCTE had also grown geographically such that member interests had possibly become less homogeneous. Therefore, UCTE initiated a project to develop a legally enforceable framework. From 2005, as a condition of membership, each UCTE Member had to sign a Multilateral Agreement. In 2007, the Compliance Monitoring and Enforcement Processes (CMEP) came into regular operation to gather information about member compliance with the Operational Handbook and to impose penalties or remedial measures on transgressors. The UCTE Steering Committee had ultimate responsibility for enforcement. This enforcement was, however, on a civil contractual basis and not on a statutory basis. On 1 July 2009 UCTE was wound up and all operational tasks were transferred to ENTSO-E. Within the European Union Framework regulation is a national responsibility and so each system operator has a direct relationship with the national regulator that has licensed its activity. Therefore, formal enforcement action of the TSOs is performed at the national level. Agency for the Cooperation of Energy Regulators (ACER) assists national regulatory authorities in performing their regulatory function at European level and, where necessary, coordinates their work. Vide REGULATION (EU) 2019/942[153] OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 June 2019 establishing a European Union Agency for the Cooperation of Energy Regulators (recast), ACER was given the responsibility (clause no. 11) to ensure that regulatory functions performed by the regulatory authorities in accordance with Directive (EU) 2019/944 of the European Parliament and of the Council and Directive 2009/73/EC of the European Parliament and of the Council are properly coordinated and, where necessary, completed at Union level. ACER was also given responsibility (clause no. 12) to monitor regional cooperation between transmission system operators in the electricity as well as the execution of the tasks of the ENTSO-E. The respective regulatory authorities in each of the country are required to ensure (clause no. 13) that they co-ordinate among themselves, when carrying out their tasks to ensure that ENTSO-E the European Entity for Distribution System Operators (the 'EU DSO entity'), and the regional coordination centres comply with their obligations under the regulatory framework of the internal energy market and with ACER's decisions.

Key takeaways: The above case study illustrates that, the mechanism for enforcing uniform standards/ rules/ regulations/ codes required for ensuring grid discipline and grid reliability in an integrated grid in Europe developed over time initially through voluntary basis to binding basis as the grid integration matured. This required institutions empowered enough so that they could ensure enforcing the uniform standards/ rules/ regulations/ codes and ensuring their compliance. European experience also showcased how a regional regulator and a regional TSO can work collaboratively with the country regulators and country TSOs without infringing on their sovereign rights and responsibility.

4.2.1.3. Case Study-3: Regional Security Coordination Service Provider (RSC/ RSCSP) - An European Experience

RSCSPs are companies owned by their regional / national TSOs in Europe. They perform services for the TSOs, such as providing a regional model of the grid or advanced calculations to tell TSOs which remedial actions are the most cost-efficient, without being constrained to national borders. Currently, there are three existing RSCSPs in continental Europe. The first RSCs were set up on a voluntary basis by TSOs since 2008, with Coreso (based in Brussels) (https://www.coreso.eu/mission/history-of-coreso/) and TSC (Munich) (https://www.tscnet.eu/about/) as pioneers in Continental Europe. In 2015, one RSC was created in South East

Europe, SCC (Belgrade) (http://www.scc-rsci.com/). In 2016, the Nordic TSOs started discussing the creation of a Nordic RSC. On 10 December 2015, European TSOs and ENTSO-E signed a Multilateral Agreement on participation in RSCs. It requires ENTSO-E members to participate in RSCs or to contract five essential services from them. The agreement also ensures that RSCs develop in a harmonised, interoperable and standardised way under ENTSO-E's coordination, tools, standards, and methodologies. In mid-2016, the System Operation Guideline - one of the EU network codes - registered the RSC into EU law[154] and entrusted with key following responsibilities[155]:

- Regional security coordinator shall be appointed by all TSOs
- Each regional security coordinator shall check the quality of the individual grid models in order to contribute to building the common grid model for each mentioned timeframe in accordance with the methodologies.
- RSC shall request the TSOs concerned to correct their individual grid models in order to achieve their conformity with the quality controls and for their improvement.
- RSC shall perform regional operational security analyses on the basis of the information provided by the relevant TSOs in order to detect any outage planning incompatibility. It shall provide all TSOs of the outage coordination region with a list of detected outage planning incompatibilities and the solutions it proposes to solve those outage planning incompatibilities.
- RSC shall perform regional adequacy assessments for at least the week-ahead timeframe. This is should be done based on information provided by TSOs like expected total load and available resources of demand response, availability of power generation module and operational security limits etc.

TSOs provide data to the RSCSPs; RSCSPs perform analyses and provide results to TSOs. However, TSOs take the final decisions. Full decision-making responsibility remains with the TSOs based on the real-time operational conditions. Usually, TSOs directly implement the recommendations of RSCSPs. Particular collaboration processes are defined for the rare occasions where TSOs estimate that an action recommended by a RSCSP is incompatible with their own system safety constraints. The offices of RSCSPs look like TSOs' control rooms. Engineers work 24 hours a day, every day of the year, in a secured room, facing a giant screen representing in real-time the power flows between different countries and other information such as the quantity of wind or solar power produced in a region. However, RSCSPs are not equipped to take direct control of the grid. This is an essential aspect because it allows RSCSPs to remain light and efficient structures and limit the need for regulatory oversight and regulatory harmonisation. Operating the power grid in real-time remains the responsibility of TSOs, but TSOs will more and more perform this task by relying on the information and strategies provided by the RSCSPs. RSCSPs are the formalisation of the Regional Security Coordination Initiatives in the Nord Pool. All the TSOs procure following 5 services from the RSPSPs:

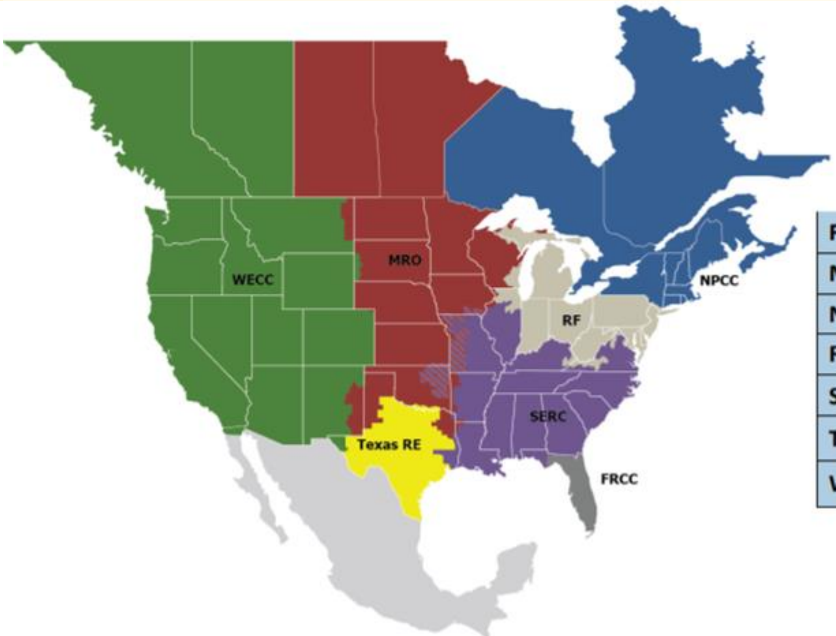
1. Coordinated capacity calculation;
2. Coordinated security analysis;
3. Short and medium-term adequacy forecasts;
4. Outage planning coordination; and
5. Data handling, European Common Grid Models.

RSCSPs help create economies of scale by enabling all TSOs to use the same IT system to perform a task and make use of the expertise of RSCSPs for grid reliability.

Key takeaways: The above case study illustrates that, as the unification / integration of grids across the regions / countries becomes stronger, the complexity of the system increases. This requires establishing institutions providing expert advice on grid security and reliability.

4.2.1.4. Case Study-4: Electricity Reliability Organizations (ERO) of North America

The Electric Reliability Organization (ERO) Enterprise, which consists of the North American Electric Reliability Corporation (NERC) and the seven Regional Entities. The Regional Entities include the Midwest Reliability Organization (MRO), Northeast Power Coordinating Council (NPCC), Reliability First (RF), SERC Reliability Corporation (SERC), Texas Reliability Entity (Texas RE), Florida Reliability Coordinating Council (FRCC) and Western Electricity Coordinating Council (WECC). From NERC's beginning in 1968, there have been several changes in the makeup of several regional councils that were the members of NERC until 2006 when NERC was certified as the ERO. At that time, the regions became regional entities and operated in accordance with delegation agreements with NERC to monitor and enforce NERC reliability standards and conduct various reliability assessments and event analyses within their respective boundaries.



FRCC	Florida Reliability Coordinating Council
MRO	Midwest Reliability Organization
NPCC	Northeast Power Coordinating Council
RF	ReliabilityFirst
SERC	SERC Reliability Corporation
Texas RE	Texas Reliability Entity
WECC	Western Electricity Coordinating Council

Figure 52 Regional Electricity Reliability Organization (Source: NERC, https://www.nerc.com/comm/OC_Reliability_Guidelines_DL/PFC_Reliability_Guideline_rev20190501_v2_final.pdf)

ERO continuously work with users, owners, and operators of Bulk Power System (BPS) assets, government partners, and other stakeholders and industry participants, the ERO Enterprise pursues its mission of assuring effective and efficient reduction of risks to the reliability and security of the BPS.

NERC and the Regional Entities play different, but important and complementary roles in delivering ERO Enterprise programs. NERC provides industry-wide perspective and oversight, and the Regional Entities have unique features and activities that serve the needs of their regional constituents, while ensuring that industry follows NERC and Regional Reliability Standards. The ERO enterprise is explicitly committed to its collective success in achieving its vision of a highly reliable and secure North American BPS.

NERC and the Regional Entities are partners through which the Enterprise will succeed, and are committed to:

- Working together as one team and honoring each of its roles;
- Actively supporting ERO enterprise activities while eliminating unnecessary duplication of work;
- Collaborating in developing clear and consistent guidance across the ERO enterprise;
- Sharing information, knowledge, and resources across the ERO enterprise;
- Developing and sharing harmonized messages across ERO enterprise communications; and
- Supporting innovation, initiatives, and the sharing of best practices across the ERO enterprise.

As the reliability and security ecosystem changes, the ERO enterprise is in a unique position to support industry in ensuring North American BPS reliability, resilience, and security.

NERC NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

The **North American Electric Reliability Corporation (NERC)** was formed on June 1, 1968, as the National Electric Reliability Council. While NERC's formation was the direct result of the 1965 northeast blackout, it was also an important step in the progression of increasing industry coordination and cooperation that has been the hallmark of the electric industry and NERC.

The organization aims to do that, not only by enforcing compliance with mandatory reliability standards, but also by acting as a catalyst for positive change - including shedding light on system weaknesses, helping industry participants operate and plan to the highest possible level, and communicating lessons learned throughout the industry. Since its formation, NERC has continued to adapt to industry and market changes, including the introduction of wholesale and retail electricity competition and the changing economics and policies that are driving the current shift to natural gas, renewable, and distributed energy resources. There are several working group and committees which work closely so that the North American bulk power system (BPS) remains highly reliable.

The Energy Policy Act of 2005 provided the formation of ERO (Electric Reliability Organization) responsible for mandatory, enforceable Reliability Standards developed by industry and adopted and enforced by NERC with oversight by its independent Board, FERC, and Canadian provincial regulators. NERC's area of responsibility spans the continental United States, Canada, and the northern portion of Baja California, Mexico. NERC is the Electric Reliability Organization (ERO) for North America, subject to oversight by the Federal Energy Regulatory Commission (FERC) and governmental authorities in Canada. NERC's jurisdiction includes users, owners, and operators of the bulk power system, which serves more than 400 million people[156].

NERC develops and enforces reliability standards, monitors the bulk-power system and assesses adequacy annually via a 10-year forecast and winter and summer forecasts; audits owners, operators and users for preparedness; and educates and trains industry personnel. Over time, NERC has transformed itself into the world-class organization for electric reliability that it is today.

Key takeaways: The above case study illustrates that, with integration of grids across the regions / countries resulted in complexity of the power system, this requires coordinated and continuous efforts for maintaining system reliability. Maintaining grid reliability includes carrying out three primary functions namely: (1) bulk power system awareness that collects and analyzes information on system disturbances and other incidents that have an impact on the North American bulk power system and disseminates this information to internal departments, registered entities, regional organizations, and governmental agencies as necessary[157]; (2) event analysis; and (3) performance analysis.

Key lessons learnt from international experience are summarized as follows:

1. For development of key institutions having adequate technical capabilities supporting development of regulatory framework from the perspective of integration / unification of regional/ cross-border grids enabling legal, regulatory, and governance structure are a prerequisite as it helps create enabling framework with force of law for development of key institutions. Key institutions founded without the enabling legal, regulatory and governance structure may not be effective, and they may assume only an advisory role without any powers to make rules/ regulations/ codes and/or without any powers to enforce the same.

2. The Regional bodies, consisting of Regional Market Operator / System Operator and a Regional Regulatory Agency, are key institutions supporting the coordination and collaboration among the participating countries. Coordination and collaboration among the participating countries would help building trust and reaching consensus for achieving advancement in CBET along with robust mechanism to ensure grid discipline and grid reliability.

3. The Regional bodies (Regional Market Operator / System Operator and a Regional Regulatory Agency) shall have legal backing through a legal statute which provides them the requisite credibility and powers to function effectively.

4. The Regional Regulatory Agency shall be independent, i.e., devoid of any political interference, should possess adequate and capable staff and systems to fulfil its mandates, should be transparent and fair in the context of specifying the rules and explaining the decisions, should provide written rules in terms of defining methodologies and tariff structures and should function in a rule-based manner so that it remains accountable.

5. The Regional System Operator plays a critical role in developing technical rules, regulations, standards and common criteria that is uniformly followed by all the participating countries and enforcing the same on everyone connected to the interconnected regional/ cross-border grid, resulting in achieving grid discipline and grid reliability in an interconnected regional/ cross-border grid.

6. A central coordinating agency such as Electricity Reliability Organization plays an important role in developing clear and consistent reliability standards that are applicable across the region. A central coordinating agency can also help in monitoring the compliance by stakeholders with regard to the reliability standards.

Based on the international experience highlighted above as well as from key lessons learnt from the international experience; minimum set of regulatory requirements / ingredients are listed below:

1. **Regulatory requirement/ ingredient #1:**For effective regional / cross-border unification/ integration, institutions consisting of Regional Market Operator / System Operator and a Regional Regulatory Agency are required to be established with legal backing through a legal statute which provides them the requisite credibility and powers to function effectively.

4.2.2. Operational best practices to promote grid discipline and grid reliability

Operating an integrated regional transmission system requires coordinated action. In a regional network of different topology operated by different transmission system operators, the TSOs participate to provide a unified platform for electricity market. It's important to have a harmonized standard for system operation, contingency management, outage management, operating reserve management etc. Following case studies from the European region and North American region demonstrate the operational best practices that are prevalent in the region for maintaining grid discipline and grid reliability.

4.2.2.1. Case Study 5: Governing framework in EU for grid discipline and grid reliability

European Union (EU) came up with Commission Regulation (EU) 2017/1485 of 2 August 2017[158] to establish a guideline on electricity transmission system operation. The Regulation lays down detailed guidelines on following key dimensions:

- Requirements and principles concerning operational security;
- Roles and responsibilities for the coordination and data exchange between transmission system operators in close to real-time operation;
- Requirements on outage coordination;
- Requirements for scheduling between the TSOs' control areas;
- Framework for load-frequency control and reserves; and
- Scope of Regional Security Coordinators (RSC).

To ensure a coordinated operation of the regional network, it laid down roles and responsibilities for the member TSOs. Therefore, each TSO shall be responsible for operational security of its control area and, in particular, it shall: (a) Develop and implement network operation tools that are relevant for its control area and related to real-time operation and operational planning; (b) Develop and deploy tools and solutions for the prevention and remedy of disturbances; (c) Use services provided by third parties, through procurement when applicable, such as re-dispatching or countertrading, congestion management services, generation reserves and other ancillary services; (d) Comply with incidents classification scale adopted by ENTSO and submit to ENTSO the information required to perform the tasks for producing the incidents classification scale; and (e) Monitor the appropriateness of the network operation tools on an annual basis. Each TSO shall identify any appropriate improvements to those network operation tools, considering the annual reports prepared by ENTSO for electricity based on the incident's classification.

It is clear from the above that a governing regulation / framework is required to ensure a coordinated operation of the regional network, specifying roles and responsibilities for the member TSOs. The regulations would ensure uniform rules for the participants for non-discriminatory access to the transmission network for cross-border exchanges in electricity. This helps in ensuring grid discipline and grid reliability.

4.2.2.2. Case Study-6: contingency management practice followed in interconnected network under ENTSO

Article 33[159]"Contingency lists" of guideline on electricity transmission system operation empowers each TSO to establish a contingency list, including the internal and external contingencies of its observability area, by assessing whether any of those contingencies endangers the operational security of the TSO's control area. The contingency list shall include both ordinary contingencies and exceptional contingencies. Therefore, each transmission-connected Distribution System Operator (DSO) and Significant Grid User (SGU)[4] which is a power generating facility, shall deliver all information relevant for contingency analysis as requested by the TSO, including forecast and real-time data, with possible data aggregation to establish a contingency list. Each TSO shall classify each contingency on the basis of whether it is ordinary contingency[5], exceptional contingency or out-of-range contingency[6], taking into account the probability of occurrence and the following principles:

a) Each TSO shall classify contingencies for its own control area;
b) When operational or weather conditions significantly increase the probability of an exceptional contingency, each TSO shall include that exceptional contingency in its contingency list; and
c) In order to account for exceptional contingencies with high impact on its own or neighbouring transmission systems, each TSO shall include, such exceptional contingencies in its contingency list.

Article 34[160] "Contingency analysis" of guideline on electricity transmission system operation instructs the TSOs, to perform contingency analysis in its observability area in order to identify the contingencies which endanger or may endanger the operational security of its control area and to identify the remedial actions that may be necessary to address the contingencies, including mitigation of the impact of exceptional contingencies. The starting point for the contingency analysis in the N-Situation[7] shall be the relevant topology of the transmission system which shall include planned outages in the operational planning phases.

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[4]Significant Grid User (SGU) in the terminology used in the European Union Internal Electricity Market. SGU is existing and new Power Generating Facility and Demand Facility deemed by the Transmission System Operator (TSO) as significant because of their impact on the transmission system in terms of the security of supply including provision of ancillary services.
[5] Ordinary Contingencymeans the occurrence of a contingency of a single branch or injection
[6] Exceptional contingency or Out-of-range contingency means the simultaneous occurrence of multiple contingencies without a common cause, or a loss of power generating modules with a total loss of generation capacity exceeding the reference incident
[7] N-Situation is a term used for contingencies that can be N-1 or N-1-1

Article 35[161] "Contingency handling" of guideline on electricity transmission system operation states that, the TSO shall assess the risks associated with the contingencies after simulating each contingency from its contingency list and after assessing whether it can maintain its transmission system within the operational security limits in the (N-1) situation.

When a TSO assesses that the risks associated with a contingency are so significant that it might not be able to prepare and activate remedial actions in a timely manner to prevent non-compliance with the (N-1) criterion or that there is a risk of propagation of a disturbance to the interconnected transmission system, the TSO shall prepare and activate remedial actions to achieve compliance with the (N-1) criterion as soon as possible.

In case of an (N-1) situation caused by a disturbance, each TSO shall activate a remedial action in order to ensure that the transmission system is restored to a normal state as soon as possible and that this (N-1) situation becomes the new N-Situation.

A TSO shall not be required to comply with the (N-1) criterion in the following situations: (a) during switching sequences; and (b) during the time period required to prepare and activate remedial actions.

Key takeaways: The above case study illustrates the regulatory framework governing the contingency planning for the system in EU. The activities are broadly divided into three baskets, namely, (i) Listing of contingencies; (ii) Analysis of contingencies; and (iii) Handling of contingencies. The guideline on electricity transmission system operation made it mandatory to identify contingency in the control area of each TSO. This helps in remedial actions to mitigate the impact of those contingencies. Based on this, the TSO can prepare an action plan.

4.2.2.3. Case Study-7: Common standard schemes for setting up of interconnected network under ENTSO

Article 17[162] "Control requirements" of the guideline on electricity transmission system operation mandates for a formal contract agreement between relevant TSO and the transmission-connected demand facility[8] owner or the transmission-connected distribution system operator to agree on the schemes and settings of different control devices of the transmission-connected demand facility or the transmission-connected distribution system relevant for system security. The agreement shall cover at least the following elements:

a) isolated (network) operation;

b) damping of oscillations;

c) disturbances to the transmission network;

d) automatic switching to emergency supply and restoration to normal topology; and

e) automatic circuit-breaker re-closure (on 1-phase faults).

[8]Demand Facility means a facility which consumes electrical energy and is connected at one or more connection points to the transmission or distribution system.

Also, the transmission-connected entities shall set the protection and control devices of its transmission-connected facility in compliance with the following priority ranking, organised in decreasing order of importance:

a) transmission network protection;

b) transmission-connected demand facility or transmission-connected distribution system protection;

c) frequency control (active power adjustment); and

d) power restriction.

Key takeaways: The above case study illustrates importance of common standard schemes for setting up of interconnected network and different control devices. These need to be bound by a contractual obligation for transmission connected users. This contractual binding motivates the connected users to take necessary steps for the protection of transmission system.

4.2.2.4. Case Study-8: Relevance assessment of transmission assets for outage coordination

Article 84 "Methodology for assessing the relevance of assets for outage coordination" of the guideline on electricity transmission system operation empowers TSOs to jointly develop a methodology for assessing relevance of assets for outage coordination. Relevance of Assets for Outage Management (RAOCM)[163] is a methodology that is based on Commission Regulation (EU) 2017/1485 (System Operation Regulation) and Commission Regulation (EU) 2015/1222 (Guideline on capacity allocation and congestion management-CACM). It lists down parameters which act as a yardstick to assess an asset, based on which an asset can be taken for outage. The parameters are:

a) Power flow identification influence threshold - 15% - 25%

b) Power flow filtering influence threshold - 3% - 5%

c) Voltage influence threshold - 0.03 pu - 0.05 pu

Following are the salient features of methodology for assessing the relevance of assets for outage coordination:

1. The methodology is applicable to all transmission systems, distribution systems and interconnections in the European Union and regional security coordinators. It is voluntary for transmission systems and distribution systems or parts of the transmission systems and distribution systems located in islands of member states of which the systems are not operated synchronously with Continental Europe (‘CE’), Great Britain (‘GB’), Nordic, Ireland and Northern Ireland (‘IE/NI’) or Baltic synchronous area.
2. The influence computation method has following characteristics:

(a) it can characterise influence of the absence of one network element, being a network element, a power generation module, a demand facility connected to a TSO or transmission connected DSO/CDSO[9] network on the power flow or voltage of another transmission network element;

(b) it is applicable on a year-ahead common grid model[10],

(c) the influence is characterised with respect to the relative or absolute value of power flow or voltage variation and the result is able to be compared against thresholds.

3. Calculation: Power flow influence factor is evaluated by computing two elementary factors: power flow identification influence factor and power flow filtering influence factor.

4. Network elements to which influence computation method shall be applied: TSOs are required to apply the influence computation methodology to compute power flow influence factor. It requires assessment of counter flow influence factors on network elements of control area. It includes power generating modules, demand facilities connected outside TSO's control area but connected to transmission network.

5. Requirement of coordination among TSOs: When a TSO applies the influence computation method, the TSO shall have the right to request the support of concerned TSOs to use dynamic studies to assess influence of the connectivity status or electrical values (such as voltages, power flows, rotor angle) of the network elements, power generating modules, and demand facilities located in transmission-connected DSOs/CDSOs networks connected to other TSOs.

6. Requirement to inform: Where one or more elements are identified as relevant to ensure secure operation of its transmission system, the TSO which performed dynamic studies and TSOs to which transmission-connected DSO/CDSO are connected to, shall inform their regulatory authorities and relevant RSC(s) of the elements identified with the reasoning supporting this result.

7. Standardization of threshold value so that the exercise yields standard results and not different results for different regions: Each TSO shall select threshold values inside the range of relevant asset thresholds that it shall use to determine its proposition of relevant assets.

8. Assets under consideration: Each TSO shall include in its proposition of relevant assets: (a) all transmission network elements connected outside its control area; (b) all network elements of a transmission-connected DSO/CDSO connected to another TSO's control area; (c) all network elements connecting the TSO's control area to another TSO's control area.

[9]Closed Distribution System Operator (CDSO)- Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market in electricity (recast). Empowers Member States to allow citizen energy communities to become distribution system operators either under the general regime or as 'closed distribution system operators. Once a citizen energy community is granted the status of a distribution system operator, it should be treated as, and be subject to the same obligations as, a distribution system operator.
[10]The Common Grid Model (CGM) is defined as a Union-wide data set agreed between various Transmission System Operators (TSOs) describing the main characteristic of the power system (generation, loads and grid topology) and rules for changing these characteristics during the capacity calculation process (Article 2(2) of the Regulation establishing a Guideline on Capacity Allocation and Congestion Management - the CACM Regulation (Regulation on market coupling)).

9. Frequency of conducting the exercise: All TSOs of each outage coordination region shall jointly re-assess the relevance of external network elements, power generating modules and demand facilities for outage coordination at least once every three years after the first assessment.

Key takeaways: The quality and efficient use of the interconnected system and resources is always given a higher priority. Therefore, it is necessary to standardize outage coordination, especially in synchronous connected area. It is important to identify critical assets for outage coordination. The Outage Coordination Region shall be considered equal to the Capacity Calculation Region[11] unless all concerned TSOs agree to merge two or more outage coordination regions into one unique outage coordination region. The above case study illustrates importance of principles of proportionality and non-discrimination; transparency; optimisation between the highest overall efficiency and lowest total costs for all parties involved to ensure network security and stability.

4.2.2.5. Case Study-9: Role of Frequency Leaders and Resynchronisation Leader maintaining grid reliability - An European Experience

Frequency Leader is a coordinating agency which helps in coordinating frequency management function. The TSOs of each synchronised region shall appoint a frequency leader. It comes into play after a severe grid disturbance has occurred (*frequency deviation higher than +/-200[12] mHz*[164]) lasting more than 15 minutes. In case of system split/islanding, the frequency leader shall be chosen within each synchronous area, based on the following criteria.

a) Previously implemented coordination for frequency management;
b) High amount of generation reserve that can be mobilised within a very few minutes (upward in case of under-frequency situation, downward in case of over-frequency situation), and a large free secondary reserve capability;
c) Capacity margin of tie lines (in export, in case of under-frequency situation, and in import, in case of over-frequency situation); and
d) Acquisition of frequency values at least of direct neighbouring grids, and if possible, of non-direct neighbouring grid that are parts of the same of the synchronous system by measurements (EAS, phone calls, conference calls, etc.)

Also, during system restoration[165], when a synchronous area is split in several synchronised regions or during system restoration, when a synchronous area is not split but the system frequency exceeds the frequency limits for the alert state. The TSOs of each synchronised region shall appoint a frequency leader.

As a default TSO with the highest K-factor[13] under operation (or referring to the most recent published value) within its load-frequency control (LFC) area will be appointed as the frequency leader. Besides this, the following criteria shall be considered:

[11] Capacity calculation regions are the geographic area in which coordinated capacity calculation is applied.
[12] The Continental European (CE) Power System -a large, synchronized area stretching from Spain to Turkey and from Poland to Netherlands; encompassing 25 countries- is experiencing a continuous system frequency deviation from the mean value of 50 Hz, and this since mid of January 2018.
[13]K-factor of an Load Frequency Control (LFC) area or LFC block means a value expressed in megawatts per hertz ('MW/Hz'), which is as close as practical to, or greater than the sum of the auto-control of generation, self-regulation of load and of the contribution of frequency containment reserve relative to the maximum steady-state frequency deviation

Resynchronisation Leader act as coordinating agency for frequency leaders during the resynchronisation process of two neighbouring areas and to execute the resynchronisation of two areas, based on the limits of its available means and those of each TSO respectively. In case of numerous splits, the areas are resynchronised stepwise. For split situations, the resynchronisation leader has to be selected for different synchronous areas (one leader for two areas) to resynchronise these areas. In case of numerous splits, the areas are resynchronised stepwise two by two, in a successive way. The resynchronization leader must coordinate the resynchronisation process. The resynchronization leader will have following capabilities (requirements):

- Have at least one substation under its responsibility with a "high capacity" line to reconnect both areas;
- Be able to acquire the values of both areas' frequencies (by EAS, by measurement or at least by phone);
- Be able to acquire the value of voltage of both substations of the point of connection (by measurement or at least by phone); and
- Be able to manage voltage deviation at least for the point of connection.

The resynchronisation leader fulfils the following actions:

a) It coordinates frequency leaders,

b) It chooses the substation for resynchronisation, which is one under its responsibility, and is equipped with PSD (parallel switching device)

c) It coordinates a quick reconnection of next lines between two already resynchronized islands (even outside its LFC area) after reconnection of the first one to strengthen rapidly the link between both the areas.

Key takeaways: From the above case study, we understand that ENTSO has formulated a coordination mechanism consisting of frequency leader and resynchronization leader. We understand the role of frequency and resynchronization leader inside an area in trouble with at least two TSOs, as far as the process of restoration is concerned, two separate tasks regarding the situations: one for frequency management of areas in trouble and one for the resynchronization process of areas are needed to be executed.

The objective of reliability guidelines is to formulate key practices and information on specific issues of reliability in high levels of Bulk Electricity Supply (BES). These guidelines establish recommendations, considerations, and industry best practices on particular topics for use by users, owners, and operators of the BES to help assess and ensure BES reliability.

4.2.2.6. Case Study-10: Tools/ Metrics for measuring effectiveness of primary frequency response

For performance assessment, Electric Reliability Council of Texas (ERCOT) interconnection is a single Balancing Authority (BA) that has developed metrics to evaluate governor response performance. Metrics namely Maximum governor dead band[14] setting of +/- 0.036 Hz[166] with a maximum droop setting[15] of 5% for all generating units are included in the Regional Reliability Standard BAL-001-TRE-1[167].

It provides performance metric calculations for initial Primary Frequency Response (PFR), sustained PFR, and limits on calculation of PFR performance. PFR uses a fixed time interval to determine initial governor response to a frequency event. Sustained PFR also establishes a fixed time interval; this time is used to determine if frequency response is being sustained through the stabilization period. High scores on both metrics indicate that frequency response is being sustained as desired. Low scores on both can indicate that frequency response is not being provided.

NERC also uses a similar tool to that of ERCOT, known as the Generator Resource Survey, to calculate governor PFR by using historical data or manually calculated values. This tool, which uses the NERC Regional Standard BAL-001- TRE-1 as a starting framework, evaluates an individual resource's ability to provide PFR during both the initial period and the sustained period. It evaluates resources for their ability to provide PFR much like the BAL-001-TRE-1 except for a few notable differences.

Key takeaways: This case study explains how ERCOT and NERC have developed a performance metric to evaluate effectiveness of the primary frequency response mechanism functions. The metric is based on governor dead band governor droop settings.

4.2.2.7. Case Study-11: Operating Reserve Management

Operating Reserve is the generating capacity available to the system operator within a short interval of time to meet demand in case a generator goes down or there is another disruption to the supply. Power systems must always provide some amount of operating reserve because the electric load tends to jump around randomly. Without operating reserve, the load would sometimes exceed the operating capacity of the system resulting in brownouts/ blackouts. Systems that include wind and solar power sources require additional operating reserve to guard against random decreases / increases in the renewable power supply.

Therefore, NERC's guidelines on operating reserve management[168] has suggested following measures:

- Regulating Reserve
- Contingency Reserve
- Frequency Responsive Reserve
- Capability to respond to large loss-of-load events
- Reserve Sharing Groups and Frequency Response Sharing Groups

Regulating Reserve objective is to ensure that the responsible entity has sufficient capacity to meet the performance requirements. While planning for regulating reserve, balancing authorities should take into account following:

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[14]The inclusion of the governor droop and dead band in dynamic models helps to reproduce the measured frequency response accurately and is a key aspect of model validation. Governor Dead Band is that for a given position of the governor control valves, an increase/decrease in speed can occur before the position of the valve changes. The governor dead-band can materially affect the system response.

[15]Droop speed control is a control mode used for AC electrical power generators, whereby the power output of a generator reduces as the line frequency increases. It is commonly used as the speed control mode of the governor of a prime mover driving a synchronous generator connected to an electrical grid.

- Connected entity's generation mix, type of load, the variability in both generation and load, and the probability of extreme influences such as weather;
- Types of resources and the portion of their capacity that can be made available for regulation;
- The responsible entity should incorporate into its regulating needs, consideration of contractual arrangements such as exports and imports. Changes to contractual arrangements should be assessed and accounted for in the responsible entity's ability to respond and meet the performance requirements;
- The responsible entity should evaluate its planned regulating reserve (based on changing system conditions, such as the current load, forecast errors, and generation mix) needs over the operating time horizon and gauge its ability to meet its regulating reserve needs on at least an hourly basis; and
- The responsible entity should plan and implement its ability to restore its regulating reserve as needed. This may include the ability to restore regulating reserve in either direction.

Contingency Reserve is made when a responsible entity experiences an event i.e., loss of supply or significant scheduling problems, which can cause frequency disturbances. In such situations it should be able to adjust its resources in such a manner so as to assure its Area Control Error (ACE)[16] recovers in accordance with the requirements of the applicable reliability standards. In order to meet the requirements of the NERC Reliability Standards, balancing authority need to identify Most Severe Single Contingency (MSSC)[17]. To determine MSSC base contingency reserve, many types of resources can be considered for use as contingency reserve, provided that they can be deployed within the appropriate timeframe. As technology and innovations occur, this list may continue to grow, but may include:

- Unloaded/loaded generation;
- Off-line generation;
- Demand resources;
- Energy Storage Devices; and
- Resources such as wind, solar, etc., provided any limitations are taken into account.

Frequency Responsive Reserve: An amount of reserve automatically responsive to locally-sensed frequency deviation. Planned frequency responsive reserve (day-ahead, day of and hour prior[18]) should be available in addition to planned regulating and contingency reserve. For a responsible entity experiencing a frequency deviation, frequency responsive reserve would be deployed to arrest frequency change and remain deployed until frequency is returned to its normal range. Although response is generally expected to come from on-line rotating machines, other resources (e.g., controllable load contracted for that purpose, certain energy storage devices, etc.) can provide initial and sustained response that would help to arrest frequency change and sustain frequency at an acceptable post event-level until frequency is returned within its normal range.

[16] Area Control Error (ACE): The instantaneous difference between net actual and scheduled interchange, taking into account the effects of frequency bias including a correction for meter error.
[17] Most Severe Single Contingency (MSSC): The Balancing Contingency Event, due to a single contingency identified using system models maintained within the Reserve Sharing Group (RSG) or a Balancing Authority's area that is not part of a Reserve Sharing Group, that would result in the greatest loss (measured in MW) of resource output used by the RSG or a Balancing Authority that is not participating as a member of a RSG at the time of the event to meet Firm Demand and export obligation (excluding export obligation for which Contingency Reserve obligations are being met by the sink Balancing Authority)
[18] Intraday transaction.

Capability to Respond to Large Loss-of-Load Events: System should be able to adjust its resources in such a manner so as to ensure its Area Control Error (ACE) recovers in accordance with applicable reliability standards, a responsible entity should identify options to respond to large loss-of-load events - that is, the ability to reduce resources or rapidly bring on additional load. In many cases, decommitment of resources is an option, but with this option comes the risk that the decommitted resource cannot be recommitted in a timely manner resulting in the exchange of a current solution for a future reliability problem. Planning can mitigate this problem.

Each responsible entity's planning for the possibility of a large loss-of-load event should include consideration of the following:

- its energy import and export schedules with other responsible entities;
- how large loss-of-load events could be affected by interruption of these schedules, taking into account the terms and conditions under which such energy schedules were arranged; and
- the available down range on resources which have been made available by the sale of non-firm energy which may disappear during a contingency or other disturbance.

Reserve Sharing Groups (RSG) are commercial arrangements among Balancing Authorities to better enable them to collectively meet the requirements of NERC reliability standards. The spreading of reserve across a larger geographically dispersed group can improve reliability and it provides for the opportunity to comply with the performance standards while at the same time economically supplying reserve. RSG is a group whose members consist of two or more Balancing Authorities that collectively maintain, allocate, and supply contingency reserve to enable each Balancing Authority within the group to recover from Balancing Contingency Events.

Frequency Response Sharing Group: NERC Standard BAL-003-2[169] allows Balancing Authorities (BAs) to meet their Frequency Response Obligations (FROs) by electing to form Frequency Response Sharing Groups (FRSGs). A Frequency Response Sharing Group (FRSG) is a group whose members consist of two or more Balancing Authorities that collectively maintain, allocate, and supply operating resources required to jointly meet the sum of the frequency response obligations of its members.

- Frequency response has many unique characteristics which makes an FRSG different from a RSG. The frequency response capability of individual generating units can change from moment to moment depending on operating point, mode of operation, type of unit, and type of control system.
- The agreement among the participating responsible entities for the FRSG should address the minimum reserve requirement for the group, the allocation of reserve among members, and reporting and record keeping for regulatory compliance.

Key takeaways: This case study illustrates practices for the management of an appropriate mix of operating reserve, as well as readiness to respond to loss of load events. It also provides guidance with respect to the management of Operating Reserve required to meet the NERC Reliability Standards.

4.2.2.8. Case Study-12: Planning for reactive power management

Reliability Guideline on Reactive Power Planning[170] provides utilities with guidance and direction related to the modeling, study, and placement of reactive power resources in support of robust voltage profiles. The strategies outlined here center around the need for static and dynamic reactive power resource planning and operational planning as described in relevant NERC Reliability Standards. Reactive power planning and voltage control can be separated by time frame to better understand system reactive capability requirements.

Time Frame A: *Steady State (Pre-Contingency)*

In steady-state operation, voltages are maintained within scheduled voltage ranges on the Bulk Power System (BPS), with individual elements (e.g., generators and dynamic reactive resources) maintaining a terminal voltage set point value. Manual readjustment of network elements is performed to maintain these schedules throughout the day as load and transfer levels change. Automatic devices also continuously operate to maintain their set points.

Time Frame B: *Transient State*

Following a system disturbance, transient voltage stability may be a concern and is studied using transient stability tools. In this time frame, the following considerations are made:

- Generator Automatic Voltage Regulator (AVR) excitation system response;
- AVR over-excitation and under-excitation limiters (where applicable) may come into effect, depending on design generator voltage protective relay settings;
- Generator turbine-governor controls, HVDC controls, and other fast-acting FACTS controls effects;
- Automatic transformers tap changing is not considered due to their slow controls and intentional time delays;
- Automated local or wide-area Remedial Action Schemes (RAS) (e.g., generator tripping, automatic load tripping, line tripping, and other automatic actions) are considered;
- Under-Voltage Load Shedding (UVLS) settings; and
- Dynamic load characteristics including the effects of induction motor loads.

Time Frame C: *Mid-Term Dynamics*

After the first swing transient voltage response, the system (if stable) will begin to dampen oscillations and return to a new steady-state condition. As the transient oscillations dampen out, the system is in a transitory state termed "mid-term dynamic." During this time frame, automated controls (e.g., fast switched shunt reactive devices) may be operating, dynamic resources are continually adjusting, and generator excitation systems are responding to maintain terminal voltage.

Time Frame D: *Long-Term Dynamics (Post-Contingency*)

Once the system has dynamically found a new equilibrium point following a contingency, post-contingency analysis is performed to assess voltage stability and security. This analysis includes the results of all automatic control devices that respond within this defined time frame (e.g., 3 mins). These include excitation systems maintaining voltage schedule, power factor, etc., governor response, Automatic Generation Control (AGC), and other continuous control devices, including Flexible AC Transmission System (FACTS).

Time Frame E: *Steady-State (Post-Contingency)*

The last time frame encompasses the applicable time associated with each entity's emergency ratings. This means that the system returns to within acceptable operating limits within this time frame following an event and therefore the analysis time frame ends at this point. All manual readjustments and automatic controls are considered within this time frame.

Reactive Power Assessment Techniques

There are various types of planning techniques for studying reactive power control and requirements for reliable operation of the Bulk Power System (BPS). Each type of planning technique and the situations where these analyses are useful are discussed below.

Contingency Analysis for BPS is planned and operated within its equipment's normal thermal ratings and system voltage limits for conditions where all scheduled elements are in service (normal condition). This "N-1" condition applies to both steady state and stability requirements. In addition to satisfactory performance for normal system conditions and for single contingencies, the system should be able to withstand some selected "N-2" contingencies when determining stability limitations and also extreme (more severe but less probable) disturbances without suffering voltage collapse, cascading, or instability.

QV Analysis provides the sensitivity of bus voltage with respect to injections of reactive power at a given bus location. The purpose of QV analysis is to determine how much reactive margin a particular bus has before voltage collapse would occur under pre- and post-contingency operating conditions. A system is defined as voltage stable if the V-Q sensitivity is positive for every bus and voltage unstable if V-Q sensitivity (reactive margin) is negative for any one bus. QV curves are generated by placing a dummy machine at the bus being analyzed.

PV Analysis is a key tool in computing transfer capability and operating limits for interfaces and transmission paths that are known to be limited by voltage stability. It provides the sensitivity of bus voltages with respect to increasing transfers of active power (MW) between a source and sink. PV analysis is the primary technique that provides the proximity to voltage collapse in terms of active power transfer. The analysis can be performed for pre-contingency or post-contingency conditions. This is a commonly used tool to understand operating limits with respect to voltage performance on the BPS.

Transient Stability Analysis includes clearing of a fault, voltage will swing back up and then swing down. On the swing back down following the clearing of a fault, avoiding excessively large transient voltage dips is important both from a power quality perspective and from a BPS reliability perspective. The swing should not be so large as to cause additional facilities to trip (load or generation). Also, the dip should not be so large as to cause a voltage collapse. Many factors influence how large the transient dip is, including pre-contingency MW transfer levels, MW load levels, pre-contingency voltage levels, and pre-contingency dynamic reactive reserve levels.

Key takeaways: This case study provides strategies and recommended practices for reactive power planning, reactive power management and voltage control in real-time. It accounts for operational aspects of maintaining reliable voltages and enough reactive power capability on the bulk power system (BPS). A combination of static and dynamic reactive power resources helps ensure grid voltages are planned and operated within predefined limits to maintain system reliability and transfer power reliably across the BPS during normal operations and following a disturbance.

Key lessons learnt from international experience are summarized as follows:

1. A robust mechanism for contingency management is important consisting of listing of contingencies, analysis of contingency situations and procedure for handling of contingencies. Identification of contingency in advance helps in taking remedial actions to mitigate the impact of those contingencies.

2. Assessment of transmission assets for outage planning is necessary for outage coordination. This is done to standardize the identification of relevant assets for outage coordination process organised per outage coordination regions. It promotes overall efficiency amongst parties involved to ensure network security and stability.

3. For primary frequency control, the Governor Dead band Setting without step response is to be implemented. The governor droop settings shall not be less than three percent or greater than five percent. Also, there should a mechanism for regular performance assessment to check, if governors are working properly by reviewing energy management system scan rate data.

4. Operational reserves are necessary which can cater to varied needs based on prevailing scenario of the power system. Regulating Reserve are for performance improvement, Contingency Reserve to protect system from adverse disturbance and Frequency Responsive Reserve are critical for control areas which are witnessing under or over frequencies. These all are essential in an interconnected grid.

5. It is critical to conduct scenario based reactive power planning. Increasing regional inter connection may expose the power system with various type of inductive load. Therefore, proper planning for reactive power management needs to be undertaken in an increasingly complex interconnected grid.

Based on the international experience highlighted above as well as from key lessons learnt from the international experience; minimum set of regulatory requirement/ ingredients are listed as follows:

1. **Regulatory requirement/ ingredient #2:** For promotion of cross-border trade, it is recommended to prepare detailed standards for those parameters which have direct correlation with grid discipline and grid reliability. These are as follows:

    a) Regulatory framework governing contingency planning for the system;

    b) Common standard scheme for setting up interconnected networks;

    c) Relevance assessment of transmission asset for outage planning;

    d) Development of performance metrics;

    e) Operating reserve management; and

    f) Reactive power management.

2. **Regulatory requirement/ ingredient #3:** In order to make the network more robust, it is recommended to form a committee of cross functional members specifically having role in grid frequency management like the frequency and resynchronization leaders in Europe.

4.2.3. Information and communication technology including cyber security:

The Transmission Systems Operators (TSOs) in an interconnected grid need to exchange information in real time. Normally the TSOs input a standardized set of information including regional grid frequency, cross-border exchange of power, scheduled injection and/or drawl etc. This seamless flow of information is enabled through Information and Communication Technology (ICT) tools such as a common TSO technology platform. Following case studies illustrates how information technology tools are leveraged by Transmission System Operators working in tandem as well as challenges in usage of technology for co-ordination.

4.2.3.1. Case Study-12: ENTSO-E's use of IT Tool for system protection and reliability

ENTSO-E has Steering Group IT/ Tools under the Systems Operation Committee (SOC) which provides technical and business oversight and guidance to the Systems Operation Committee to ensure that IT systems and projects that are required to fulfil business needs of SOC. Steering Group IT & Tools concentrates its efforts on the IT systems and Tools that are needed for pan-European coordination, harmonization and reporting. Applying both technical and business knowledge, it provides feedback, commentary and guidance to SOC on project and operational deliverables.

The Steering Group IT/ Tools has developed and maintained communication infrastructure and systems[171] including dedicated real-time data exchange communication network called Electronic Highway, and the ENTSO-E Awareness System which provides a real-time pan-European view on the state of transmission systems. The Emergency Operations Policy document of ENTSO-E clearly specifies that a tool named ENTSO-E Awareness System (EAS) - an IT tool for real-time data exchanges for pan-European use within ENTSO-E setup shall be used to increase the knowledge of the state of the system and accordingly, to launch alarms[172]. At present EirGrid (EirGrid plc is the state-owned electric power transmission operator in Ireland) and SONI (SONI is the independent Transmission System Operator for Northern Ireland) issue both local and wide area alerts. Local alerts are issued using the energy management system and are transmitted to centrally dispatched generators and demand side units. It is proposed that wide-area alerts are issued via the ENTSO-E Awareness System[173].

Key takeaways: The above case study illustrates effective usage of ICT for real-time data exchange and effective coordination among regional / cross-border TSOs.

4.2.3.2. Case Study-13: Cyber-attacks and cyber security

In March 2020, ENTSO-E announced that its IT network had been compromised in a cyber intrusion. In its press releases[174] ENTSO-E announced that "A risk assessment has been performed and contingency plans are now in place to reduce the risk and impact of any further attacks." In 2016, Russia hacked Ukraine's power grid using a malware. At 11:53 p.m. on 17 December 2016, the malware transmitted a staccato burst of pre-programmed commands to the substation, popping one circuit breaker after another until a strip of houses in and around western Kiev were plunged into darkness[175]. In December 2015, the European Parliament and the Council reached an agreement on the European Commission's proposed measures for security of Network and Information Systems (NIS Directive) and on the data protection reform. These measures established a modern and harmonised protection framework across the European Union (EU). In cyber security, three commonly accepted protection goals are defined, they are, confidentiality of data, integrity of data and availability of data. In the energy sector, the highest priority objective depends on the industry specific applications. For example, in generation and transmission, availability of data and integrity of data are the most important. Altered/ changed

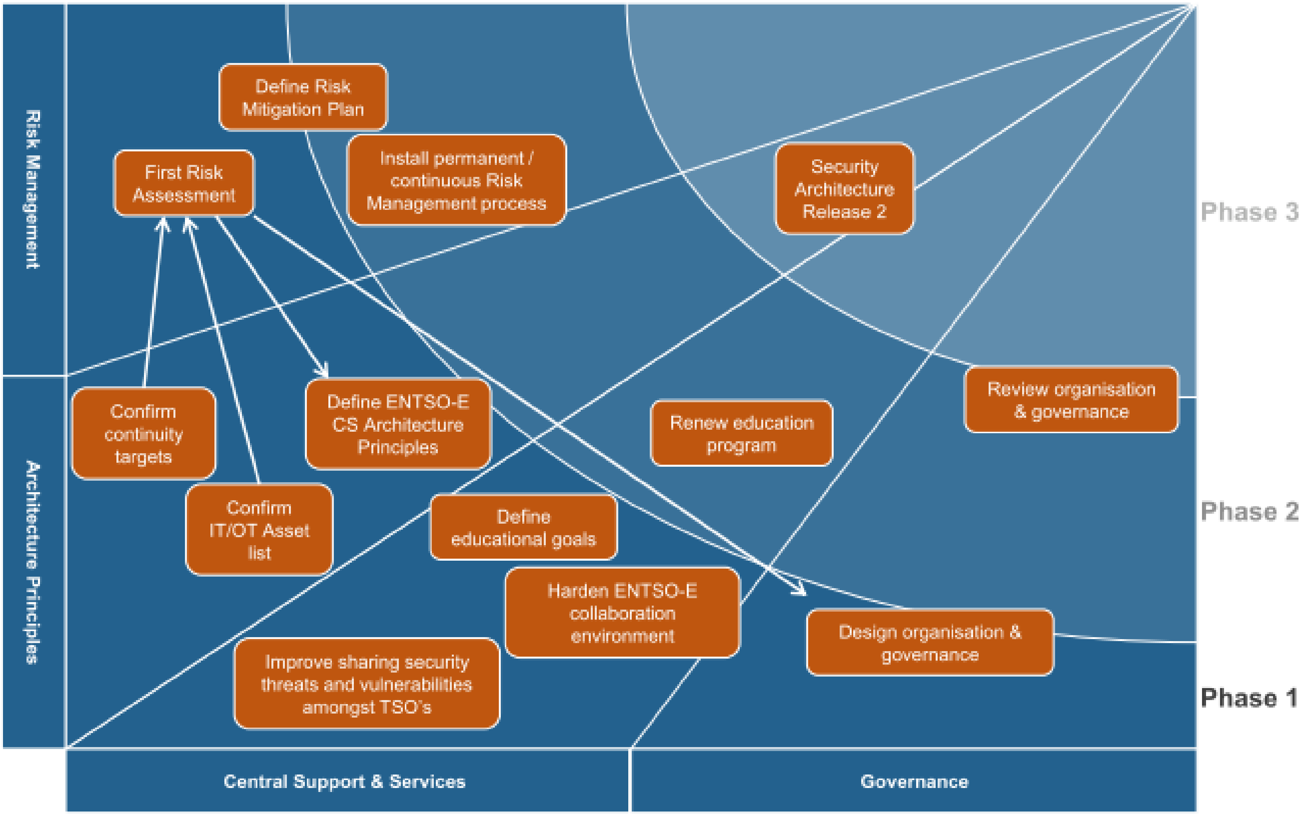

Figure 53: Phases of ENTSO-E's Cyber security roadmap

or delayed data could result in misconfiguration of a device that eventually could impact system reliability. For the advanced metering infrastructure, confidentiality of customer personal data is the most critical. The protection goals of computer security are preventing cyber acts that could directly or indirectly lead to unauthorized removal of nuclear or other radioactive material, potential blackouts or brownouts. Energy reliability at the European level relies on trans-European connectivity[176]. A failure in one energy system can have a potential cascading effect across regions. Another aspect in the interconnected energy grid is the 'weakest link' problem, i.e., due to the potential cascading impact across regions, network operators with a low maturity in cyber security bear a higher potential risk on causing a cascading blackout than operators with a high maturity in cyber security. The European Network for Cyber Security (ENCS) is a non-profit member organization that brings together critical infrastructure stake owners and security experts to deploy secure European critical energy grids and infrastructure. Founded in 2012, ENCS has dedicated researchers and test specialists who work with members and partners on applied research, defining technical security requirements, component and end-to-end testing, as well as education & training[177]. ENTSO-E is a member of ENCS. Currently, ENTSO-E is working on a [178]i) Cyber security by design for solutions and infrastructure; (ii) Secure physical network and 'middleware' layer; (iii) Shared awareness for all TSOs and Regional Security Coordinators (RSCs); and (iv) Pan-European Attack pattern anticipation.

As is clear from the above roadmap, ENTSO-E has stressed on creation of First Risk Assessment in phase 1 which is followed by installing permanent/ continuous risk management process in phase 2 with continual focus on organization and governance and training/ education. In future ENTSO-E has plans to incorporate detailed cyber security rules[179] as part of the Network Code.

Key takeaways: The above case study highlights need of cyber security as a part of the grid security and grid reliability.

4.2.3.3. Case Study-14: NERC's Electricity Information Sharing and Analysis Center (E-ISAC)

The Electricity Information Sharing and Analysis Center (E-ISAC)[180] gathers and analyzes security data, shares appropriate data with stakeholders, coordinates incident management, and communicates mitigation strategies with stakeholders. The E-ISAC, in collaboration with the Department of Energy (DOE) and the Electricity Subsector Coordinating Council (ESCC), serves as the primary security communications channel for the electric industry and enhances industry's ability to prepare for and respond to cyber and physical threats, vulnerabilities, and incidents. The E-ISAC is operated by NERC and is organizationally isolated from NERC's enforcement processes. The E-ISAC:

- Gathers, analyzes, and shares cyber and physical threat alerts, warnings, advisories, notices, and vulnerability assessments security information provided by members;
- Provides an electronic, secure capability for E-ISAC participants to exchange and share information on all threats to defend critical infrastructure;
- Coordinates incident management;
- Communicates mitigation strategies with stakeholders across sectors; and
- Serves as a central point of coordination and communication for members.

The E-ISAC continues to distribute information to its members and has posted communications and guidance from key government partners, several all-points bulletins, and other advisories on its portal. Industry is in a period of heightened cyber risk due to a large contingent of industry employees working remotely. There is also an increase in opportunistic actors attempting to take advantage of the situation. Members are encouraged to check in regularly to receive updates. The E-ISAC also continues to provide information regarding emerging cyber threats. These include malicious attacks on conferencing and remote access infrastructure intended to disrupt operations as well as disinformation and spear phishing campaigns attempting to harvest credentials and other information.

Key takeaways: The above case study highlights the need for seamless flow of information amongst the concerned stakeholders to maintain reliability of such a complex power system.

4.2.3.4. Case Study-15: Grid Security Exercise

NERC's Grid Security Exercise (GridEx)[181] is an opportunity for utilities to demonstrate how they would respond to and recover from simulated coordinated cyber and physical security threats and incidents, strengthen their crisis communications relationships, and provide input for lessons learnt. The exercise is conducted every two years. GridEx aims to:

- Exercise incident response plans;
- Expand local and regional response;

- Engage interdependent sectors;
- Improve communication;
- Gather lessons learned; and
- Engage senior leadership.

Key takeaways: This kind of exercise provided an opportunity for various stakeholders in the electricity sector to respond to simulated cyber and physical attacks that affect the reliable operation of the grid, fulfilling NERC's mission to assure the effective and efficient reduction of risks to the reliability and security of the BPS.

Following case study explore the recent developments in use of technology and challenges from South Asian Region perspective.

4.2.3.5. Case Study-16 Use of Technology and Issues in SAR context

India's National Transmission System Operator, Power System Operation Corporation (POSOCO) in its Corporate Plan[182] for 2017-18 expressed that "*With strong AC interconnections to Nepal and Bhutan also on the anvil, there is a strong need for further interaction with the system operators of neighbouring countries and information exchange as far as network model and real-time data is concerned. POSOCO is poised to undertake this task*". Promoting innovation and adoption of latest technology with cyber security is among the mission statement[183] of POSOCO. National Critical Information Infrastructure Protection Centre (NCIIPC) was created by Government of India under section 70 (A) of Information Technology Act, 2000. NCIIPC has published Guidelines for protection of critical Infrastructure (CII) and Framework for evaluation of Cyber Security[184]. Computer Emergency response Teams (CERT-In) under section 70 (B) of Information Technology Act, 2000. As per Rule 12(1) (a) of Information Technology Rules 2013, it is mandatory to report specific cyber security incidents to CERT-In. Further, CERC (Communication System for inter-State transmission of Electricity) Regulations, 2016 specifies that CEA shall formulate and notify technical standards, cyber security requirements, protocol for the communication system for Power Sector within the country including the grid integration with the grid of the neighboring countries. Clause 13 of this Regulations specifies that, communication infrastructure shall be planned, designed and executed to address the network security needs as per standard specified by CEA. Recently, Ministry of Digital Infrastructure and Information Security, Government of Sri Lanka together with Sri Lanka Computer Emergency Readiness Team | Co-ordination Centre (SL CERT|CC), proposed the draft of the National Cyber Security Bill, 2019 to the Sri Lankan Parliament for its actions[185]. The new Cybersecurity Bill proposes to establish a Cyber Security Agency to act as the executive governing body for cybersecurity in Sri Lanka and it will be responsible for the implementation of National Cybersecurity Strategy "including preparation and execution of operational strategies, policies, action plans, programs and projects." It will also be granted power to act as the central point of contact.

Thus, even though, the SAR region countries have expressed a strong desire for exchange of information regarding network model and real-time data as well as they are in process of developing cyber security framework. There is a lack of coordinated efforts in achieving a common goal.

Key lessons learnt from international experience are summarized as follows:

1. ICT-based tool for seamless exchange of network information and real-time data is an absolute necessity to increase the knowledge of the state of the system and accordingly raise alarm.

2. ICT-based tool may be developed by the regional TSO or Operational Committee looking after grid integration / unification of regional grids of domestic power system of a country or cross-border power grid interconnection.

3. In order to speak common language both in terms of use of ICT for exchange of real-time information as well as in terms of cyber security readiness coordinated and collaborative efforts are required.

4. Incorporating the common standards, for (i) use of ICT for exchange of real-time information; and (ii) cyber security protocol in the Grid Code / Regulations / Rules for the purpose of regional integration / unification of grids (both intra-national and inter-national) can help grant it a legal status and achieving its quick enforcement.

Based on the international experience highlighted above as well as from key lessons learnt from the international experience; minimum set of regulatory requirement/ ingredients are listed as follows:

1. **Regulatory requirement/ ingredient #4:** Steering Group / Committee consisting of experts from the regional countries specializing in information technology tools and cyber security shall be constituted that would provide overall guidance on development of standards / codes / specifications for the ICT tools and a framework for cyber security readiness.

2. **Regulatory requirement/ ingredient #5:** The Steering Group / Committee so constituted shall recommend suitable modifications in the country-wise Grid Code / Regulations / Rules to gradually adopt the suggested developed standards / codes / specifications for the ICT tools and a framework for cyber security readiness.

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5. Chapter 5: Identification of gaps

5.1. Identification of gaps

In chapter 2, an in-depth review of grid discipline and grid reliability aspects in the SAR was conducted whereas in chapter 3, assessment of level of implementation and compliance of identified measures was conducted. In this chapter, the gaps with respect to the following are identified:

1) sector framework and institutions;
2) regulations, rules, codes and standards; and
3) implementation and compliance of identified measures.

In the subsequent chapter, the regulatory interventions are identified based on country-wise gaps identified in this chapter. For identification of gaps following questionnaire is developed. The rationale for which is provided as follows:

5.2. Afghanistan

Sl. No.	Details	Identified gaps
1.	**General**	
1.1	The Energy Services Regulatory Department of the MEW works as a regulatory authority and is created under the Electricity Law. But it is not an independent body.	Absence of independent electricity regulator.
1.2	The Grid Code applicable for Afghanistan is not available in English language in the public domain	Grid Code not available in the public domain.
2.	**System Planning**	
2.1	Power Sector Master Plan is published by the Ministry of Energy and Water of Afghanistan. It covers system planning, strategies for contingency / bottleneck, RE integration, reactive power planning, economic analysis, etc.	Absence of standardized detailed manual on system planning - security of supply, strategies for contingency/bottleneck, RE integration, reactive power planning, cost benefit analysis (social/economic).
3.	**System construction and safety**	
3.1	Details about measures for system construction and safety to be followed are not available in the public domain.	Inadequate measures in system construction and safety.
4.	**Grid connection**	

Sl. No.	Details	Identified gaps
4.1	Details about procedure to be followed for grid connectivity are not available in the public domain.	Absence of detailed procedure for grid connectivity.
5.	**System protection, testing and commissioning**	
5.1	Details about procedure to be followed for grid connectivity are not available in the public domain.	Absence of standards system protections measures for ensuring grid discipline and grid reliability.
6.	**System operation**	
6.1	Details about ancillary service market in Afghanistan are not available in the public domain.	Absence of ancillary service market which is helpful in relieving congestion and minimising frequency fluctuations in the grid.
6.2	Details about standard operating procedure outlining operational planning, system security, demand management and outage management are not available in the public domain.	Absence of standardised operating procedure outlining operational planning, system security, demand management, outage management.
6.3	Details about imbalance settlement mechanism to handle real-time imbalance in the system are not available in the public domain.	Absence of imbalance settlement mechanism to handle real-time imbalance in the system.
7.	**Scheduling and despatch**	
7.1	Details about detailed framework followed in Afghanistan for CBET are not available in the public domain.	Absence of detailed framework for CBET.
8.	**Information and communications Technology**	
8.1	There is inadequate regulatory push to regularly assess adequacy of current technology to manage grid operations and recommend solutions for improving system operations, market operations, grid reliability and cyber security.	Inadequate regulatory push to regularly assess adequacy of current technology to manage grid operations and recommend more effective technology solutions
8.2	Details about cyber security standards for critical information infrastructure in Afghanistan are not available in the public domain.	Cyber security standards for critical information infrastructure are absent.
9.	**Monitoring and compliance**	
9.1	Details about Regulations mandating sector participants to publish information related to power system in the public domain are not available.	No clear mandate for sector participants to publish information related to power system in public domain.

Sl. No.	Details	Identified gaps
9.2	Reports providing details of performance indicators from grid discipline and grid reliability perspective are not available in the public domain.	Inadequate performance monitoring indicators

5.3. Bangladesh

Sl. No.	Details	Identified gaps
1.	**System Planning**	
1.1	Power System Master Plan is published by the Power Division of Ministry of Power, Energy and Mineral Resources of Bangladesh covering system planning, strategies for contingency / bottleneck, RE integration, reactive power planning and economic analysis. However, there is no manual to help develop the master plan.	Absence of Transmission Planning Manual.
2.	**System construction and safety**	
2.1	The Electricity Rules 1937 and revisions thereof govern the safety requirements for electrical installation, operation, and maintenance which covers electrical equipment and associated work practices employed by the electric utility, but there is no mechanism to effectively monitor the compliance of these standards.	Absence of regular monitoring of compliance to system construction and safety.
3	**Grid connection**	
3.1	Detailed procedure for users seeking interconnection is given in the Bangladesh Grid Code 2019., but there is no mechanism to effectively monitor the compliance of the same.	Absence of regular monitoring and compliance of conditions and procedures for providing grid connectivity to the user.
4.	**System protection, testing and commissioning**	
4.1	There is no information available in the public domain on System Protection Philosophy or protection audit plans.	Absence of System Protection Philosophy and third-party protection audits.
5.	**System operation**	
5.1	There is no imbalance settlement mechanism such as frequency-linked imbalance settlement mechanism for grid discipline and frequency control.	Absence of imbalance settlement mechanism to handle imbalance in the system.

Sl. No.	Details	Identified gaps
5.2	There is no market or commercial platform for grid users to provide ancillary services such as frequency control, spinning/ operating reserves, voltage control, black start capability etc.	Absence of ancillary service market which is helpful in relieving congestion and minimising frequency fluctuations in the grid.
5.3	The methodology for assessing the relevance of assets for outage coordination is not present.	Absence of a methodology for assessing the relevance of assets for outage coordination.
5.4	System operating standards are laid down in Bangladesh Electricity Grid Code Regulations, 2019. But there is no penalty/incentive provision for compliance of the same.	Absence of claw back mechanism/ penalty/ incentive provisions in the grid code regarding compliance to system operating standards.
6.	**Scheduling and despatch**	
6.1	The Bangladesh Grid Code 2019 ensures that the generating stations must declare available capacity to the SO during each hour of the day. However, there is no penalty mechanism for mis-declaration.	Absence of penalty mechanism for mis-declaration by the generating stations and inaccurate demand forecasting by distribution companies to ensure grid discipline and reliability.
6.2	There is no defined framework or a separate independent institution / committee / department in system operator for coordination of CBET in Bangladesh.	Absence of detailed framework for CBET.
7.	**Information and communications Technology**	
7.1	Cyber security related provisions are absent in Regulations/ Grid code of Bangladesh.	Cyber security standards for critical information infrastructure are absent.
8.	**Monitoring and compliance**	
8.1	The data published by Power Grid Company of Bangladesh (PGCB) on behalf of NLDC is limited to hourly generation and load shedding data. These grid performance indicators that provide an objective metric to monitor grid discipline and reliability are inadequate as they do not help in providing comprehensive coverage of status of grid reliability.	Inadequate performance monitoring indicators

5.4. Bhutan

Sl. No.	Description	Identified gaps
1.	**System Planning**	

Sl. No.	Description	Identified gaps
1.1	National Transmission Grid Master Plan published by the Department of Hydropower & Power Systems under the Ministry of Economic Affairs covers the system planning studies, contingency analysis, reactive power planning, energy security and the cost benefit analysis. However, there is no manual to help develop the master plan.	Absence of Transmission Planning Manual.
2.	**System construction and safety**	
2.1	BEA has established the safety principles for equipment maintenance under Operationalization of grid code regulations 2008 (published in November 2017). But these standards are not upgraded to International safety standards.	Inadequate measures in system construction and safety.
3.	**Grid connection**	
3.1	Detailed procedure for users seeking interconnection is given in the Bhutan Electricity Authority Grid Code Regulation 2008, but there is no mechanism to effectively monitor the compliance of the same.	Absence of regular monitoring and compliance of conditions and procedures for providing grid connectivity to the user.
4.	**System protection, testing and commissioning**	
4.1	There is no information available in the public domain on protection audit plans or implementation of the System Protection Philosophy.	Absence of System Protection Philosophy and third-party protection audits.
5.	**System operation**	
5.1	There is no imbalance settlement mechanism such as frequency-linked imbalance settlement mechanism for grid discipline and frequency control.	Absence of imbalance settlement mechanism to handle imbalance in the system.
5.2	There is no market or commercial platform for grid users to provide ancillary services such as frequency control, spinning/operating reserves, voltage control, black start capability etc.	Bhutan has not capitalised its hydro power resources by offering ancillary services to its neighbouring countries.
5.3	The methodology for assessing the relevance of assets for outage coordination is not present.	Absence of a methodology for assessing the relevance of assets for outage coordination.
5.4	System operating standards are laid down in Bhutan Electricity Authority Grid Code Regulation 2008. However, there is no penalty/incentive provision for compliance to the same.	Absence of claw back mechanism/ penalty/ incentive provisions in the grid code regarding compliance to system operating standards

Sl. No.	Description	Identified gaps
6.	**Scheduling and despatch**	
6.1	The Bhutan Grid Code ensures that the generating stations must declare the plant capabilities faithfully, i.e., according to their best assessment. But there is no penalty mechanism for mis-declaration by generating companies and for inaccurate forecast by distribution companies.	Absence of penalty mechanism for mis-declaration by the generating stations and inaccurate demand forecasting by distribution companies to ensure grid discipline and reliability
6.2	There is no defined framework or a separate independent institution / committee / department in system operator for coordination of CBET in Bhutan.	Absence of detailed framework for CBET.
7.	**Information and communications Technology**	
7.1	Cyber security related provisions are absent in Regulations/ Grid code of Bhutan.	Cyber security standards for critical information infrastructure are absent.
7.2	There is inadequate regulatory push to regularly assess adequacy of current technology to manage grid operations and recommend solutions for improving system operations, market operations, grid reliability and cyber security.	Inadequate regulatory push to regularly assess adequacy of current technology to manage grid operations and recommend more effective technology solutions
8.	**Monitoring and compliance**	
8.1	Bhutan Electricity Authority Grid Code Regulation, 2008, mandates Bhutan Power System Operator to prepare quarterly and annual reports assessing the performance of the transmission system and submit it to all licensees, Authority and the Ministry (annual reports to only the Ministry and Authority). However, there is no provision for making the information available in the public domain.	No clear mandate for sector participants to publish information related to power system in public domain.
8.2	Daily, quarterly and annual reports are published on the Bhutan Power System Operator website regarding major outages of feeder and equipment. However, these grid performance indicators that provide an objective metric to monitor grid discipline and reliability are inadequate as they do not help in providing comprehensive coverage of status of grid reliability.	Inadequate performance monitoring indicators.

5.5. India

Sl. No.	Description	Identified gaps
1.	**System Planning**	
1.1	Transmission system planning was guided by CEA manual on transmission planning criteria, 2013. CERC notified CERC (Planning, Coordination and Development of Economic and Efficient Inter-State Transmission System by Central Transmission Utility and other related matters) Regulation, 2018. The objective of this Regulation is to lay down the broad principles, procedures and processes to be followed for planning and development of an efficient, co-ordinated, reliable and economical system of inter-State transmission system (ISTS) for smooth flow of electricity from generating stations to the load centres and to promote transparency in the planning process.	The CERC (Planning, Coordination and Development of Economic and Efficient Inter-State Transmission System by Central Transmission Utility and other related matters) Regulation, 2018 lays down broad principles of power system planning. However, there is no detailed manual guiding the CTU for transmission planning in line with broad principles laid down by CERC in its Regulations.
2.	**System protection, testing and commissioning**	
2.1	No formalised standards at federal level as standards are set and monitored regionally by Regional Power Committees.	Regional power committee conducts system protection studies and lays down regional system protection standards.
3.	**System operation**	
3.1	Operating standards are slightly outdated relative to International standards, especially for outage management.	The current grid code operating procedure specifies yearly horizon for operational planning and determining relevance of assets for outage coordination. The time duration specified shall be short term (such as monthly, weekly, day ahead, intra-day)
3.2	There is currently no market mechanism for grid users to provide ancillary services such as frequency control, spinning/operating reserves, voltage control, black start capability etc.	The resilience of present Regulation for ancillary services is inadequate, efforts should be made to introduce to de-linking of payment from pool account and improving response time for secondary and tertiary services.
4.	**Scheduling and despatch**	
4.1	No standardized provisions currently exist for post-despatch analysis and compensating all generators that were compelled to run below normative parameters in the grid code.	Current Grid Code does not mandate conducting post-despatch analysis. Further, 4th Amendment to IEGC 2010 allows for compensation to Central Generating

Sl. No.	Description	Identified gaps
		Stations and Inter-State Generating Stations for compensation to generators forced to run below normative parameters (technical minimum). However, the same should be extended to all Generators forced to run below normative parameters due to transmission system constraints.
6.	**Monitoring and compliance**	
6.1	The grid performance indicators defined in existing regulations that provide an objective metric to monitor grid discipline and reliability are inadequate as they do not help in providing comprehensive coverage of status of grid reliability.	Inadequate performance monitoring indicators for integrated grid.

5.6. Maldives

Currently, Maldives has no transmission grid. Even cross border electricity trade has not been considered as a viable option for Maldives. Therefore, conducting a gap analysis was not plausible for Maldives. However, certain regulatory interventions are suggested in Section 6.3.5 based on the analysis from previous chapters.

5.7. Nepal

Sl. No.	Description	Identified gaps
1.	**Grid Code**	
1.1	The NEA Grid Code and other regulatory documents are not available in the public domain.	Grid Code not available in the public domain.
2.	**System Planning**	
2.1	Transmission System Development Plan, published by Rastriya Prasaran Grid Company Limited (RPGCL) covers planning of transmission system, reactive compensation planning, cost benefit analysis, contingency strategies, security of supply and RE integration. However, there is no manual to help develop the master plan.	Absence of standardized detailed manual on transmission planning - security of supply, strategies for contingency/bottleneck, RE integration, reactive power planning, cost benefit analysis (social/economic).
3.	**System construction and safety**	

Sl. No.	Description	Identified gaps
3.1	Electricity Regulation, 2050 (1993) and NEA Grid Code details the system construction and safety related provisions. However, there is no mechanism to effectively monitor the compliance of these provisions.	Inadequate measures in system construction and safety.
4.	**Grid connection**	
4.1	Detailed procedure is in place for users seeking interconnection in the NEA Grid Code 2005.However, there is no mechanism to effectively monitor compliance of the same.	Absence of regular monitoring and compliance of conditions and procedures for providing grid connectivity to the user.
5.	**System protection, testing and commissioning**	
5.1	There is no information available in the public domain on System Protection Philosophy or protection audit plans.	Absence of System Protection Philosophy and third-party protection audits.
6.	**System operation**	
6.1	There is no market or commercial platform for grid users to provide ancillary services such as frequency control, spinning/operating reserves, voltage control, black start capability etc.	Absence of ancillary services mechanism in the country.
6.2	Nepal Electricity Authority Grid Code, 2005 has the system operating standards but, the detailed standard operating procedures for operational planning, demand and outage management are not available.	Absence of standard operating procedure outlining operational planning, system security, demand management, outage management.
6.3	There is no imbalance settlement mechanism such as frequency-linked imbalance settlement mechanism for grid discipline and frequency control	Absence of imbalance settlement mechanism to handle imbalance in the system.
7.	**Scheduling and dispatch**	
7.1	There is no defined framework or a separate independent institution / committee / department in system operator for coordination of CBET in Nepal.	Absence of detailed framework for CBET.
7.2	There is no clause in the Grid Code or any Regulations to manage events related to mis-declaration of generation availability by generating stations. However, provisions regarding penalty for misdeclaration are present in individual PPA's signed between NEA and the licensee.	Absence of detailed penalty mechanism in Grid Code and the same should be in public domain. Currently, NEA does the function of Load Dispatch and therefore, it is able to enforce penalty against misdeclaration by generating plants by invoking

Sl. No.	Description	Identified gaps
		clauses in the individual PPAs. The clauses in PPAs may not be uniform and can be modified easily through amendment to PPAs. Absence of penalty mechanism for inaccurate demand forecasting by distribution companies to ensure grid discipline and grid reliability.
8.	**Information and communications Technology**	
8.1	Cyber security related provisions are absent in Regulations/ Grid code of Nepal.	Cyber security standards for critical information infrastructure are absent.
8.1	There is inadequate regulatory push to regularly assess adequacy of current technology to manage grid operations and recommend solutions for improving system operations, market operations, grid reliability and cyber security.	Inadequate regulatory push to regularly assess adequacy of current technology to manage grid operations and recommend more effective technology solutions
9.	**Monitoring and compliance**	
9.1	Critical information such as region-wise frequency and voltage deviations on a daily-basis, major outage events etc. are not available in the public domain.	No clear mandate for sector participants to publish information related to power system in public domain.
9.2	There are no performance indicators defined that provide an objective metric to monitor grid discipline and reliability.	Inadequate performance monitoring indicators.

5.8. Pakistan

Sl. No.	Description	Identified gaps
1.	**System protection, testing and commissioning**	
1.1	There is no information available in the public domain on System Protection Philosophy or protection audit plans.	Absence of System Protection Philosophy and third-party protection audits.
2.	**System operation**	
2.1	There is no imbalance settlement mechanism such as frequency-linked imbalance settlement mechanism for grid discipline and frequency control.	Absence of imbalance settlement mechanism.
2.2	There is no market or commercial platform for grid users to provide ancillary services such as frequency	Absence of a commercial mechanism/ market for providing ancillary services.

Sl. No.	Description	Identified gaps
	control, spinning/operating reserves, voltage control, black start capability etc.	
2.3	The methodology for assessing the relevance of assets for outage coordination is absent.	Absence of a methodology for assessing the relevance of assets for outage coordination.
3.	**Scheduling and despatch**	
3.1	There is no defined framework or a separate independent institution / committee / department in system operator for coordination of CBET in Pakistan	Absence of detailed framework for CBET.
4.	**Information and communications Technology**	
4.1	There is inadequate regulatory push to regularly assess adequacy of current technology to manage grid operations and recommend solutions for improving system operations, market operations, grid reliability and cyber security.	Inadequate regulatory push to regularly assess adequacy of current technology to manage grid operations and recommend more effective technology solutions
5.	**Monitoring and compliance**	
5.1	Critical information such as region-wise frequency and voltage deviations on a daily-basis, major outage events etc. are not available in the public domain.	No clear mandate for sector participants to publish information related to power system in the public domain.
5.2	National Electric Power Regulatory Authority (NEPRA) publishes annual performance evaluation reports for National Transmission & Despatch Company (NTDC). However, it is observed that monitoring is only done on annual basis with the last report published for 2017-18.	Absence of mechanisms to monitor performance standards of transmission licensee on a regular basis.
5.3	The grid performance indicators defined in existing regulations that provide an objective metric to monitor grid discipline and reliability are inadequate as they do not help in providing comprehensive coverage of status of grid reliability.	Inadequate performance monitoring indicators.

5.9. Sri Lanka

Sl. No.	Description	Identified gaps
1.	**System Planning**	
1.1	The long-term transmission development plan 2013-2022 covers the transmission system planning	No mechanism to ensure compliance to system planning standards.

Sl. No.	Description	Identified gaps
	standards. However, there is no mechanism to ensure that standards are being complied with.	
2.	**System protection, testing and commissioning**	
2.1	There is no information available in the public domain on System Protection Philosophy or protection audit plans.	Absence of System Protection Philosophy and third-party protection audits.
3.	**System operation**	
3.1	There is no imbalance settlement mechanism such as frequency-linked imbalance settlement mechanism for grid discipline and frequency control.	Absence of imbalance settlement mechanism to handle imbalance in the system.
3.2	There is no market or commercial platform for grid users to provide ancillary services such as frequency control, spinning/operating reserves, voltage control, black start capability etc.	Absence of a commercial mechanism/ market for providing ancillary services.
3.3	The methodology for assessing the relevance of assets for outage coordination is not present.	Absence of a methodology for assessing the relevance of assets for outage coordination.
4.	**Scheduling and despatch**	
4.1	Sri Lanka has no existing transmission line connection with neighbouring countries. However, Sri Lanka is planning to establish a transmission connectivity with India and there is no detailed framework or a separate independent institution / committee / department in system operator to manage CBET.	Absence of detailed framework for CBET
4.2	There is no clause in the Grid Code to manage events related to mis-declaration of generation availability by generating stations and inaccurate demand forecast by distribution companies.	Absence of penalty mechanism for mis-declaration by the generating stations and inaccurate demand forecasting by distribution companies to ensure grid discipline and reliability.
5.	**Information and communications Technology**	
5.1	There is inadequate regulatory push to regularly assess adequacy of current technology to manage grid operations and recommend solutions for improving system operations, market operations, grid reliability and cyber security.	Inadequate regulatory push to regularly assess adequacy of current technology to manage grid operations and recommend more effective technology solutions
6.	**Monitoring and compliance**	

Sl. No.	Description	Identified gaps
6.1	Critical information such as region-wise frequency and voltage deviations on a daily-basis, major outage events etc. are not available in the public domain.	No clear mandate for sector participants to publish information related to power system in public domain.
6.2	The grid performance indicators defined in existing regulations that provide an objective metric to monitor grid discipline and reliability are inadequate as they do not help in providing comprehensive coverage of status of grid reliability.	Inadequate performance monitoring indicators.

5.10. Summary of identified gaps in South Asia Region

In this section a summary matrix is created to summarise gaps identified from each SAR country.

Key need gaps identified during the study	Afghanistan	Bangladesh	Bhutan	India	Nepal	Pakistan	Sri Lanka
System Planning							
Absence of standardized detailed manual on system planning	●	●	●	◐	●	◐	◐
System Construction and Safety							
Inadequate measures in system construction and safety.	●	●	●	◐	●	◐	
Grid Connection							
Absence of detailed procedure for grid connectivity.	●						
System protection, testing and commissioning							
Absence of standard system protections measures for ensuring grid discipline and grid reliability.	●					●	●
System Operations							
Absence of ancillary service market which is helpful in relieving congestion and minimising frequency fluctuations in the grid.	●	●	●		●	●	●
Absence of standardised operating procedure outlining operational planning, system security, demand management, outage management.	●			◐	◐		
Absence of imbalance settlement mechanism to handle real-time imbalance in the system.	●	●	●		●	●	●
Scheduling and Despatch							
Absence of detailed framework for CBET	●	●	●	◐	●	●	●
Absence of provisions to promote declaration discipline	●	●	●		●		●
Absence of provisions for compensating Gencos for forced under performance	●			●			

◐ **Partial Gap**: Steps are taken but scope for further strengthening and advancement ● **Gap**: Steps to be taken to overcome identified need gaps

Key need gaps identified during the study	Afghanistan	Bangladesh	Bhutan	India	Nepal	Pakistan	Sri Lanka
Information and communications Technology							
Need for adoption of advance operation technology and ICT infrastructure for reliable operations.	●		●		●	●	●
Cyber security standards for critical information infrastructure are absent.	●	●	●	◐	●	●	●
Monitoring and Compliance							
Inadequate provision to publish information related to power system in public domain.	●		●		●	●	●
Inadequate performance monitoring indicators	●	●	●		●	●	●

◐ **Partial Gap**: Steps are taken but scope for further strengthening and advancement ● **Gap**: Steps to be taken to overcome identified need gaps

6. Chapter 6– Detailed set of Regulatory measures / Interventions and mechanism needed for enhancing grid discipline and grid reliability in SA Region and Roadmap

6.1. Introduction

In chapter 2, an in-depth review of grid discipline and grid reliability aspects in the SAR was conducted. In chapter 3, assessment of the level of implementation and compliances of identified measures was undertaken. Chapter 4 covered the international experiences and best practices on regulatory interventions for grid discipline and grid reliability. Based on these, gaps in the sector framework and institutions, as well as gaps in implementation and compliance of identified measures were identified in chapter 5. Building on these chapters, this chapter provides detailed set of regulatory measures/ intervention and mechanism needed for enhancing grid discipline and grid reliability and a roadmap to improve grid discipline and grid reliability in SAR countries.

Section 0 of this chapter covers suggested regional regulatory measures/ interventions. Section 6.3 of this chapter covers country-wise specific regulatory measures / interventions. Section 6.4 of this chapter covers suggested roadmap for carrying out country-wise specific regulatory measures/ interventions.

6.2. Suggested regional regulatory measures/ interventions for enhancing grid discipline and grid reliability

Various SAR countries have regulatory regimes at different maturity stages. The rules/ regulations/ Grid Codes of the SAR countries need to be harmonious across the interconnected countries, to ensure seamless power trade across the borders. Further, such harmonious regulatory framework across the interconnected countries can help achieve grid discipline and grid reliability across the borders. This section provides such minimum set of suggested regional regulatory measures/ interventions to be undertaken in the South Asian region countries for improving grid discipline, grid reliability and to achieve a seamless interconnectivity of grids.

6.2.1. Suggested regional regulatory measures/interventions

We have identified a set of seven suggested regional regulatory measures/ interventions in the South Asian region for improving grid discipline and grid reliability.

6.2.1.1. Regulatory interventions

#1 Regulatory measure/ intervention for system planning:

Regional regulatory framework shall specify transmission planning criteria for regional transmission planning. In the creation of very large, interconnected grid, there can be unpredictable power flows leading to overloading of transmission lines due to imbalance in load-generation equilibrium in different pockets of the grid in real time operation. Reliable transmission planning is basically a trade-off between the cost and the risk involved. There are no widely adopted uniform guidelines which determine the criteria for transmission planning vis-à-vis acceptable degree of adequacy and security. Practices in this regard vary from country to country. The common theme in various approaches for transmission system planning is "acceptable system performance".

A detailed transmission planning criterion, enables to achieve uniformity in system planning, reduction in network congestion, strategy for generation and load alternatives and renewable energy integration. The SAR planning criteria should consist of scope and philosophy for system planning, nominal voltage limits, power quality limits (harmonics), system reserve requirements, scope for special protection systems, system studies (short circuit, load flow, etc.) and evaluation of system over a ten-year horizon (time period could be modified as per needs).

For planning cross border interconnections, a nodal agency should be authorised to assess interconnection technical feasibility. Presently Joint Technical Teams (JTT) are formed to conduct feasibility studies, to evaluate quantum of power (envisaged) to be traded, identify feasibility of connection to specific power plant or regional grid and define operating voltage and loading for the interconnect.

#2 Regulatory measure/ intervention for system construction and safety:

Regional regulatory framework shall specify provisions related to system construction and safety for the interconnectors.

The SAR Regulator is recommended to mandate International standards for system construction and safety such as the National Electrical Safety Code (NESC) by Institute of Electrical and Electronics Engineers IEEE or Electrical safety standards prescribed by the Occupational Safety and Health Administration of the United States Department of Labour. The SAR Regulator is recommended to also entail establishment of nodal agency(ies) within six months, assigning stakeholder responsibilities for ensuring system safety and designate the responsibility to monitor compliance of safety standards to promote grid discipline and grid reliability. In the interim, till such standards are adopted by all the countries in SAR, the standards as mutually decided by the Joint Technical Committee(s) formed forco-ordination of CBET between the SAR countries shall be adopted and implemented to maintain grid reliability.

#3 Regulatory measure/ intervention for grid connection:

Regional regulatory framework shall lay down detailed procedure for grid connections for various grid users including renewable energy generators. For ensuring power system safety, it is important to standardise process for grid connectivity by defining test requirements for power system elements such asynchronous generators, non-synchronous generator and HVDC and FACTS devices.

The standardised process for connectivity to the grid shall specify the process flow, time limit for processing of connectivity applications, the roles and responsibilities of various stakeholders and shall establish a framework for accountability in a transparent manner.

The following minimum tests shall be carried out on respective power system elements:

Synchronous Generator: Real and reactive power capability assessment, reactive power control capability, model validation and verification test for the complete generator and excitation system, model validation and verification of turbine/governor and load control or active power/ frequency control functions, testing of governor performance and automatic generation control.

Non-Synchronous Generator (Solar/Wind): Real and reactive power capability for generator, power plant controller function test, frequency response test, fault ride through test.

HVDC/FACTS Devices: Damping capability of HVDC/FACTS Controller, frequency controller capability of HVDC Controller, Reactive Power Controller capability for HVDC/FACTS, validation of Voltage Dependent Current Order Limiter (VDCOL) characteristic for ensuring proper validation of HVDC performance, filter bank adequacy assessment based on present grid condition and validation of response by FACTS devices as per settings.

#4Regulatory measure/ intervention for system operations:

a) For the interconnections, the regional regulatory framework shall publish procedure for operational planning, system security, demand management, define key system performance indicators outage management and partial or complete grid disturbance, defining grid incidence and disturbance like events. The scope of JTT's should be widened from the current scope. JTTs apart from conducting technical and commercial feasibility define operating parameters for interconnections such as allowable voltage variation, outage planning and tripping recovery timeline etc.

b) Regulatory intervention to develop ancillary services market in each of the SAR country considering likelihood of increasing CBET in near future. To start with, hydro power rich countries like Afghanistan, Nepal and Bhutan can provide ancillary services under the supervision of regional system operator. However, in the long term (about 8-10 years) a market-based approach should be devised. The market based regulation for offering ancillary services shall outline eligibility of the participants, identification of nodal agency, roles and responsibilities of participating agencies and the nodal agency, procedure for scheduling, despatch and withdrawal of ancillary services, approach for energy accounting, harmonisation of reserve requirement for participating countries and provisions related to financial settlement. This market-based approach will help in tapping hydro potential for countries like Afghanistan, Nepal, Bhutan and India and also help other participating SAR countries to benefit from the shared ancillary resources to achieve grid reliability.

c) Regional regulatory framework shall introduce incentive/ penalty-based imbalance settlement mechanism considering the regional interconnections. To start with, it is recommended to the Regulator to make provision for quantum-based imbalance settlement mechanism. In this mechanism deviation quantum-based slabs should have fixed imbalance rates and imbalance penalty should be computed based on slab wise rates. Over a period of 3 to 5 years, after defining regional operational frequency band;

an frequency linked imbalance mechanism should be implemented. In this mechanism, imbalance rates need to be static/fixed for specific frequency slabs. Once SAR regional power market gets operationalised, further narrowing of operational frequency should be proposed and dynamic imbalance rates should be used which could be derived from regional market clearing price.

#5 Regulatory measure/ intervention for scheduling and despatch:

a) Regional regulatory framework shall specify penalty for mis-declaration by the generating companies and inaccurate demand forecasting by distribution companies for maintaining grid discipline in context of interconnections. In the interim, a higher margin may be allowed for misdeclaration, however, over time the margin allowed for misdeclaration shall be progressively reduced and the penalty amount be increased to enforce grid discipline in an interconnected grid.

b) Framework for co-ordination of CBET shall be developed and introduced in each of the SAR countries. The framework shall encompass defining designated authorities/nodal agencies for co-ordination of CBET, detailed procedure for scheduling and despatch to facilitate transactions, provisions related to real time deviations, approach for energy accounting and standardising metering arrangements, standardised reporting arrangements and mechanism for dispute redressal.

#6 Regulatory measure/ intervention for information and communications technology:

In order to improve grid discipline and grid reliability aspects, the respective country Regulators shall push for adoption of advanced technology including Information and Communication Technology (ICT) and operational technologies. The regional regulatory framework shall also specify cyber security related aspects to identify critical information infrastructure. It shall also define the measures to be undertaken to protect the critical information infrastructure and shall mandate periodic publishing of related information in the public domain.

To begin with, it is recommended to the Regulator to chalk out guidelines for introduction and implementation of centralised monitoring system. It should be ensured that control centre shall have centralised supervision and monitoring system. This centralised system should be integrated with entire network including standalone network elements. For communication system, communication technicalities for power system shall be standardised. This technical standard document should highlight applicability of communication systems like LDCs, transmission & distribution utilities. The communication system should be capable to provide integration with supervisory control and data acquisition system, wide area measurement system, video conferencing system and automatic meter reading, etc. The technical standards should lay down minimum performance requirement for each communication technologies (OPGW/PLCC/Cellular).

To ensure cyber security, an independent intervention should be made to outline protective measures. It should include measures related to information protection (including data storage), implementation of measures for protection of communication network, scope for training and change management, preparation of business continuity plans, etc.**# 7 Regulatory measure/ intervention for monitoring and compliance:**

a) In context of the interconnections, the regional regulatory framework shall lay down provision for periodic publishing of monitoring and compliance reports, system performance reports, third-party audit reports and other such important documents in the public domain.

b) Regional Regulatory framework shall define and mandate capturing uniform standardized information on grid performance indicators for effective reporting of status of grid reliability considering regional interconnections.

6.2.1.2. Institutional interventions

Role played by institutions in maintaining grid discipline and grid reliability:

For effective regional / cross-border unification / integration of grids, a regional regulatory institution is required. To strengthen regulations related to infrastructure sector in the region South Asia Forum for Infrastructure Regulation (SAFIR) was established in May 1999. SAFIR aims to provide a platform for experience sharing amongst the regulators of the region, to build regulatory decision-making and response capacity in South Asia, to facilitate regulatory process, to conduct training programmes to serve regulatory agencies and other stakeholders, to spur research on regulatory issues and to provide a databank of information relating to regulatory reform processes and experiences.

Also, SARI/ EI has proposed within SAFIR a group specifically focusing on Electricity Sector may be formed that will act as neutral, apolitical forum/ platform for regulators and experts to assemble, brainstorm, strategize and recommend specific steps to address the multiple barriers to CBET[19]. It is proposed that, the proposed regulatory agency has to work towards ensuring necessary alignments among the transmission network operators of the member countries to provide necessary open access to country's grid for bilateral and multilateral electricity exchange.

6.2.2. Explanatory notes

Sl. No.	Explanatory notes for suggested regulatory measures/ interventions
1.	**Imbalance Settlement Mechanism**
	Any power system needs to balance the generation and consumption of energy over multiple timeframes from seconds, hours, days and even years ahead. There is always deviation in actual generation from scheduled generation and actual drawal from scheduled drawal. There will always be differences between the contracted volumes and the actual metered volumes. Thus, to handle these differences (or imbalances) in real time, there is a need for imbalance handling mechanism. Imbalance settlement is one of the fundamental parts of the Balancing Markets. It represents the financial settlement mechanism with the goal of settling the costs incurred by the deviations from Balancing Responsible Parties[20]' (BRP) net positions (imbalances). BRP need to pay for any deviations from the scheduled net positions in negative direction and to receive financial compensation for any deviations from the scheduled net positions in positive direction if Imbalance price is positive and vice

[19]SARI/ EI, Integrated Research and Action for Development, Chapter 4 of Report on Regional Energy/ Electricity Regulatory Institutional Mechanism in South Asia: South Asia Forum of Electricity/ Energy Regulators (SAFER).
[20] Balance Responsible Parties (BRPs) are required to schedule the generation of their group, exchanges and forecast (schedule) their consumption issuing the schedule nomination for each dispatching period.

Sl. No.	Explanatory notes for suggested regulatory measures/ interventions
	versa if Imbalance price is negative. The deviations are calculated by comparing the scheduled market plan of the BRP with the actual realisation. The main goal of financial settlement is to ensure that BRP help maintain the system's balance in an economically efficient manner and to incentivise market participants in helping support the system balance. In the regulation, imbalance settlement is defined on a non-discriminatory, fair, objective, and transparent basis. To help with the increased share of renewables, imbalance prices should reflect the real time value of energy. Imbalance price for each imbalance settlement period is required for the financial value of imbalance settlement. Imbalance price is determined for each imbalance price area, for each imbalance settlement period and in each direction (positive and negative). The imbalance settlement period is defined as the time for which the imbalance is calculated and should be the same duration as "dispatch period". Based on metered values for each imbalance settlement period, the TSO charges/ pays BRPs/ Balancing Service Providers[21] (BSP) depending on the situation in the power grid and on market rules defined for the balancing area.

Case	Imbalance price is negative	Imbalance price is positive
Positive Imbalance	System operator pays to balance responsible parties	balance responsible party pays to System Operator
Negative Imbalance	balance responsible party pays to System Operator	System Operator pays to balance responsible parties

In the table above, the financial cash flow between TSO and BRP is presented regarding to the imbalance price and type of imbalance. Each TSO should determine the imbalance price in each direction in its imbalance areas for each settlement period. Within its scheduling area, each TSO should also calculate the allocated volume, imbalance adjustment and the imbalance for each BRP, for each imbalance settlement period and in each imbalance area. If imbalance has a positive sign, that indicates the BRP's surplus and if it has a negative sign, it indicates BRP's shortage Within its scheduling area, each TSO should calculate the allocated volume, imbalance adjustment and the imbalance for each BRP, for each imbalance settlement period and in each imbalance area.

2.	**Ancillary Services**
	Ancillary services are those functions performed by the equipment and people that generate, control, transmit, and distribute electricity to support the basic services of generating capacity, energy supply, and power delivery. Ancillary services help in maintaining proper flow and direction of electricity, address imbalances between supply and demand, and help the system recover after a power system event to ensure grid reliability. All these result in relieving congestion and minimising frequency fluctuations in the grid. In systems with significant variable renewable energy (RE) penetration,

[21] Balancing Service Providers are the Balancing Market Participants offering balancing services (ancillary services) in real time.

Sl. No.	Explanatory notes for suggested regulatory measures/ interventions
	additional ancillary services may be required to manage increased variability and uncertainty. Typically, these services can be classified into primary (response time of few seconds to 5 minutes), secondary (response time of 30 seconds to 15 minutes), fast tertiary (response time of 5 minutes to 30 minutes), slow tertiary (response time of 15 minutes to 50 minutes). Countries shall start with empowering national system operator to identify and arrange sources of ancillary services. To start with, it is recommended to the Regulator to conduct system studies based on which major categories of ancillary services could be proposed, e.g., load generation balancing service, network control ancillary services, system restart ancillary services. For further development and market-based model can be proposed, a separate product could be constituted for this purpose, comprising of sellers interested in participating in the ancillary services market.
3.	**System protection and safety**
	System protection deals with detecting instability in the power system and consequent control actions to restore operating point and/or prevent damage to equipment. Loss of system stability can lead to partial or complete system blackouts. To overcome these situations special protections schemes are tested and implemented (e.g., islanding schemes, automatic voltage regulators/ power system stabilizers for generating companies). Transmission operators shall start with implementing under-frequency relays, islanding systems, rate of change of frequency relays, reverse power flow relays, voltage surge relays, etc. As a next step, utilities shall implement Wide Area Measurement System (WAMS)and Phasor Measurement Unit (PMU) to determine phase angle difference which will help small signal stability monitoring, voltage and frequency stability monitoring, phase angle differences and can also trigger alarms on abnormal system conditions. For ensuring power system safety regulators shall standardise process for grid connectivity by defining test requirements for power system elements such as synchronous generators, non-synchronous generators, and HVDC and FACTS devices.
4.	**Transmission Planning Criteria**
	Objective of long-term transmission planning is to make the best network design decisions for today after considering possible future needs and generation resource expansion options or scenarios. A detailed transmission planning is essential to achieve economies of scale, reduction in network congestion, strategy for generation & load alternatives and renewable energy integration. It is recommended to the Regulator to empower transmission operators to prepare a transmission planning criterion. The planning manual shall consist of scope and planning philosophy, criteria for steady-state and transient-state behaviour, criteria for simulation and contingency studies and additional planning criteria and guidelines (e.g., reactive power compensation, criteria for wind and solar projects, guidelines for planning HVDC transmission system and voltage stability standards).

Sl. No.	Explanatory notes for suggested regulatory measures/ interventions
	Based on planning manual the transmission utility shall start preparing a long-term plan which shall be updated on regular basis.
5.	**Outage Management**
	Outages are known for high levels of risk, with a large potential for cost overruns. Improper planning of outages could result in declining power system performance, increase in unplanned shutdowns, unavailability of space for work schedule for planned outages, risk of damage to assets and asset life reduction. An effective outage planning results in reduced outage durations and improves reliability of the system. It is recommended to the Regulator to mandate implementation of IT tools for outage management and coordination by transmission operators/ system operators. Outage management system (OMS) identify outages and provide instant alerts. They also record the history of outages throughout the operations and provide real-time insight into the systems. OMS systems also provide customer assistance by alerting them about outages and status of repairs. OMS systems usually work in tandem with geographical information systems (GIS) and / or customer information systems (CIS).
6.	**Declaration Discipline**
	Intentional mis-declaration of available capacity or schedule by any generator in order to make an undue commercial gain through imbalance charges levied under imbalance settlement mechanism. Any intentional mis-declaration of available capacity to the LDCs for its own undue commercial gain or that of a generator is considered as gaming. To stop this practice of mis-declaration by generator, it is recommended to the Regulator to define penalty provisions, where the quantum of penalty per mis-declaration can be linked to daily fix charges or can devise any other market-driven framework.
7.	**Framework for coordination of CBET**
	With increasing regional integration, the regional cross border electricity trade is likely to increase. Therefore, it is recommended to the Regulator to devise regulatory measures to coordinate CBET in the region. It shall consist of institutional framework (i.e., roles and responsibilities for laying down detailed procedure, system planning, nodal agency for operation & settlement), methodology for tariff determination (standard bilateral contracts/ competitive bidding), metering arrangements & energy accounting, setting up of standard data and communication facilities and dispute settlement and resolution mechanism.
8.	**Regulatory interventions to improve transparency through disclosures**
	It is recommended to the Regulator to promote transparency in the sector by mandating utilities to publish system performance information in the public domain on a regular basis. Therefore, while drafting regulations/rules/code emphasis shall be given on (i) defining responsibility for monitoring & compliance of specific regulations and (ii) mandating disclosure of reports/ submissions in the public domain.

Sl. No.	Explanatory notes for suggested regulatory measures/ interventions
9.	**System Defence Plan/ Remedial Action Scheme**
	System Defence Plan/Remedial Action Scheme is the technical measures to be undertaken to prevent the propagation or deterioration of a disturbance in the transmission system, in order to avoid a wide area disturbance or blackout. System defence Plan may include, but are not limited to the following: - Start or stop/disconnection of generators - Demand/Load disconnection or Storage system disconnection - Instruction to grid connected users to change their Active and Reactive power outputs - Instruction to LDCs to change voltage regulator set-points on transformers on their grid - Ultra low frequency mode activation - HVDC Systems active and reactive power control - System Protection Schemes actions (including Automatic Low Frequency Demand Disconnection and On-Load Tap Changer Blocking Schemes) - Requesting maximum or minimum values of reactive power to significant grid users in coordination with LDCs - Assistance for Active Power - Control area allocated capacity curtailments
10.	**Post-despatch Analysis**
	The need for post event analysis in large power grids is very important as far as power system operations are concerned. Many incipient problems can be diagnosed in the root itself. The probable result of not doing the post-despatch analysis may have catastrophic effects on the power system. It shall consist of but are not limited to the followings: i) Analysis of frequency and voltage ii) Analysis of Grid Code violations and follow up with agencies iii) Analysis of Grid Events (GD/GI) iv) Evaluating primary response, viz. computation of Frequency Response Characteristics (FRC) of individual control areas v) Low Frequency Oscillations (LFO) monitoring and analysis vi) Detailed reports of grid disturbances/grid events vii) Simulation of events and learnings thereof viii) Event replay, lessons learnt and dissemination of same ix) Taking up shortcomings with stakeholder

6.3. Suggested country-wise specific regulatory measures / interventions

After summarizing the analysis of the SA region with respect to grid discipline and reliability, identification of gaps in sector framework, institutions, regulations, rules, codes, implementation, and compliance of identified measures and considering the relevant international experiences, the country-wise specific measures/interventions are given below. These measures/ interventions have been designed based on perspective of integration/unification of regional grids of domestic power system of a country, as well as cross-border power grid interconnection. The interventions have been classified based on the time frame required to accomplish them. The short-term interventions may take one year to three years' time, medium-term interventions may take four years to six years of time whereas long-term interventions may take more than six years of time to achieve success. This chapter also includes an indicative roadmap for carrying out these interventions.

6.3.1. Afghanistan

Sl. No.	Identified gaps	Suggested regulatory intervention
1.	**General**	
1.1	Absence of independent electricity regulator.	It is recommended to create an independent electricity regulator with a mandate to regulate sector participants (generation/ transmission/ distribution), to specify Grid Code having regard to Grid Standards, to specify and enforce the standards with respect to quality, continuity, and reliability of service by licensees and to discharge such other functions as may be assigned under the empowering act.
1.2	Grid Code not available in the public domain.	It is recommended to the regulator to publish its grid code in the public domain with relevant provisions related to system planning, system construction and safety, grid connection, system protection, testing & commissioning, scheduling, and despatch, information, and communications technology, monitoring, and compliance to promote grid discipline and grid reliability.
2.	**System Planning**	
2.1	Absence of standardized detailed manual on system planning - security of supply, strategies for contingency/bottleneck, RE integration, reactive power planning, cost benefit analysis (social/economic).	It is recommended to the Regulator to develop transmission planning criteria.
3.	**System construction and safety**	
3.1	Inadequate measures in system construction and safety.	It is recommended to the Regulator to define mechanism for strengthening of power system safety.
4.	**Grid connection**	

Sl. No.	Identified gaps	Suggested regulatory intervention
4.1	Absence of detailed procedure for grid connectivity.	It is recommended to the Regulator to specify a detailed procedure for grid connectivity and publish the same in public domain.
5.	**System protection, testing and commissioning**	
5.1	Absence of standards system protections measures for ensuring grid discipline and grid reliability.	It is recommended to the Regulator to specify system protection philosophy, protection schemes and guidelines for testing & commissioning.
6.	**System operation**	
6.1	Absence of ancillary service market which is helpful in relieving congestion and minimising frequency fluctuations in the grid.	Regulatory intervention to develop ancillary service market in the country.
6.2	Absence of standardised operating procedure outlining operational planning, system security, demand management, outage management.	It is recommended to the Regulator to publish standard operating procedures for operational planning, system security, demand management, define key system performance indicators outage management and partial or complete grid disturbance, defining grid incidence and disturbance like events.
6.3	Absence of imbalance settlement mechanism to handle real-time imbalance in the system.	It is recommended to the Regulator to introduce incentive / penalty-based imbalance settlement mechanism
7.	**Scheduling and despatch**	
7.1	Absence of detailed framework for CBET.	It is recommended to the Regulator to specify framework for co-ordination of CBET
8.	**Information and communications Technology**	
8.1	Inadequate regulatory push to regularly assess adequacy of current technology to manage grid operations and recommend more effective technology solutions	It is recommended to the Regulator to make necessary interventions for implementation of ICT infrastructure like communication facilities, operational technology systems (e.g., SCADA/EMS, WAMS/PMU) and cyber security to ensure grid discipline and grid reliability.
8.2	Cyber security standards for critical information infrastructure are absent.	It is recommended to the Regulator to specify cyber security code to identify critical information infrastructure. It shall also define the measures to be undertaken to protect critical information infrastructure and shall mandate periodic publishing of related information in the public domain.
9.	**Monitoring and compliance**	
9.1	No clear mandate for sector participants to publish information	It is recommended to the Regulator to lay down provision for periodic publishing of monitoring and compliance reports, system

Sl. No.	Identified gaps	Suggested regulatory intervention
	related to power system in public domain.	performance reports, third-party audit reports and other such important documents in the public domain.
9.2	Inadequate performance monitoring indicators	It is recommended to the Regulator to define and mandate capturing information on grid performance indicators for effective reporting of status of grid reliability

6.3.2. Bangladesh

Sl. No.	Identified gaps	Suggested regulatory intervention
1.	**System Planning**	
1.1	Absence of Transmission Planning Manual	It is recommended to the Regulator to separately specify transmission system planning manual which outline planning scope and planning philosophy, criteria for simulation studies, steady-state and transient-state behaviour, reactive power compensation, criteria for renewable energy integration and guidelines for planning HVDC transmission system and voltage stability.
2.	**System construction and safety**	
2.1	Absence of regular monitoring of compliance to system construction and safety.	It is recommended to the Regulator to define the rules and procedure for monitoring compliance to system construction and safety regulations.
3.	**Grid connection**	
3.1	Absence of regular monitoring and compliance of conditions and procedures for providing grid connectivity to the user.	It is recommended to the Regulator to mandate the Transmission licensee to conduct advanced tests before connecting HVDC/ FACTS devices and also to publish details of compliance to conditions and procedures for establishing grid connections
4.	**System protection, testing and commissioning**	
4.1	Absence of System Protection Philosophy and third-party protection audits	It is recommended to the Regulator to define mechanism for strengthening of power system protection through white paper or consultation paper.
5.	**System operation**	
5.1	Absence of imbalance settlement mechanism to handle imbalance in the system.	It is recommended to the Regulator to introduce incentive / penalty-based imbalance settlement mechanism

Sl. No.	Identified gaps	Suggested regulatory intervention
5.2	Absence of ancillary service market which is helpful in relieving congestion and minimising frequency fluctuations in the grid.	It is recommended to the Regulator to introduce ancillary services (primary, secondary, and tertiary responses) for frequency Regulation and improved grid reliability.
5.3	Absence of a methodology for assessing the relevance of assets for outage coordination	It is recommended to the Regulator to introduce provision for assessing the relevance of assets for outage coordination to ensure minimum outages and better grid discipline and reliability
5.4	Absence of claw back mechanism/ penalty/ incentive provisions in the grid code regarding compliance to system operating standards	It is recommended to the Regulator to introduce claw back mechanism/ penalty provisions/ incentive provisions in the Grid code for ensuring compliance to system operating standards (e.g., system reliability indices and system availability standards) for grid connected users and transmission owner/utility.
6.	**Scheduling and despatch**	
6.1	Absence of penalty mechanism for mis-declaration by the generating stations and inaccurate demand forecasting by distribution companies to ensure grid discipline and reliability	It is recommended to the Regulator to specify penalty for mis-declaration by the generating companies and inaccurate demand forecasting by distribution companies
6.2	Absence of detailed framework for CBET.	It is recommended to the Regulator to specify framework for co-ordination of CBET.
7.	**Information and communications Technology**	
7.1	Cyber security standards for critical information infrastructure are absent.	It is recommended to the Regulator to specify cyber security code to identify critical information infrastructure. It shall also define the measures to be undertaken to protect the critical information infrastructure and shall mandate periodic publishing of related information in the public domain.
8.	**Monitoring and compliance**	
8.1	Inadequate performance monitoring indicators	It is recommended to the Regulator to define and mandate capturing information on grid performance indicators for effective reporting of status of grid reliability

6.3.3. Bhutan

Sl. No.	Identified gaps	Suggested regulatory intervention
1.	**System Planning**	

Sl. No.	Identified gaps	Suggested regulatory intervention
1.1	Absence of Transmission Planning Manual.	It is recommended to the Regulator to specify transmission planning criteria
2.	**System construction and safety**	
2.1	Inadequate measures in system construction and safety.	It is recommended to the Regulator to define mechanism for strengthening of power system safety.
3.	**Grid connection**	
3.1	Absence of regular monitoring and compliance of conditions and procedures for providing grid connectivity to the user.	It is recommended to the Regulator to mandate the Transmission licensee to conduct advanced tests before connecting HVDC/ FACTS devices and also to publish details of compliance to conditions and procedures for establishing grid connections
4.	**System protection, testing and commissioning**	
4.1	Absence of System Protection Philosophy and third-party protection audits	It is recommended to the Regulator to define mechanism for strengthening of power system protection.
5.	**System operation**	
5.1	Absence of imbalance settlement mechanism to handle imbalance in the system.	It is recommended to the Regulator to introduce incentive / penalty-based imbalance settlement mechanism
5.2	Bhutan has not capitalised its hydro power resources by offering ancillary services	It is recommended to the Regulator to introduce ancillary services (primary, secondary, and tertiary responses) for frequency regulation and improved grid reliability.
5.3	Absence of a methodology for assessing the relevance of assets for outage coordination	It is recommended to the Regulator to introduce provision for assessing the relevance of assets for outage coordination to ensure minimum outages and better grid discipline and reliability
5.4	Absence of claw back mechanism/ penalty/ incentive provisions in the grid code regarding compliance to system operating standards	It is recommended to the Regulator to introduce claw back mechanism/ penalty provisions/ incentive provisions in the Grid code for ensuring compliance to system operating standards (e.g., system reliability indices and system availability standards) for grid connected users and transmission owner/utility.
6.	**Scheduling and despatch**	
6.1	Absence of penalty mechanism for mis-declaration by the generating stations and inaccurate demand forecasting by distribution companies to ensure grid discipline and reliability	It is recommended to the Regulator to specify penalty for mis-declaration by the generating companies and inaccurate demand forecasting by distribution companies

Sl. No.	Identified gaps	Suggested regulatory intervention
6.2	Absence of detailed framework for CBET.	It is recommended to the Regulator to specify framework for co-ordination of CBET
7.	**Information and communications Technology**	
7.1	Cyber security standards for critical information infrastructure are absent.	It is recommended to the Regulator to specify cyber security code to identify critical information infrastructure. It shall also define the measures to be undertaken to protect the critical information infrastructure and shall mandate periodic publishing of related information in the public domain.
7.2	Inadequate regulatory push to regularly assess adequacy of current technology to manage grid operations and recommend more effective technology solutions	It is recommended to the Regulator to make necessary interventions for implementation of ICT infrastructure like communication facilities, operational technology systems (e.g., SCADA/EMS, WAMS/PMU) and cyber security to ensure grid discipline and grid reliability.
8.	**Monitoring and compliance**	
8.1	No clear mandate for sector participants to publish information related to power system in public domain.	It is recommended to the Regulator to lay down provision for periodic publishing of monitoring and compliance reports, system performance reports, third-party audit reports and other such important documents in the public domain.
8.2	Inadequate performance monitoring indicators	It is recommended to the Regulator to define and mandate capturing information on grid performance indicators for effective reporting of status of grid reliability

6.3.4. India

Sl. No.	Identified gaps	Suggested regulatory intervention
1.	**System Planning**	
1.1	The CERC Planning, Coordination and Development of Economic and Efficient Inter-State Transmission System by Central Transmission Utility and other related matters Regulation, 2018 laid down broad contour of power system planning for which there is need for a detailed manual to carry out	It is recommended to the Regulator to take necessary steps to expedite the processes of developing detailed transmission system planning manual on the basis of CERC (Planning, Coordination and Development of Economic and Efficient Inter-State Transmission System by Central Transmission Utility and other related matters) Regulation, 2018.

Sl. No.	Identified gaps	Suggested regulatory intervention
	techniques mandated under the regulation.	
2.	**System protection, testing and commissioning**	
2.1	Regional power committee conduct system protection studies and lays down regional system protection standards.	It is recommended to the Regulatory Commission to standardise protection plans, it shall also take necessary steps to introduce best practices like creation of system defence plan as a proactive step for system protection. Also, the protection plan shall be updated over a horizon of 3 to 5 years. (Review of IEGC, 2020 proposed by Expert Group has provisions for standardised Protection, Testing & Commissioning Code.)
3.	**System operation**	
3.1	The current grid code operating procedure specifies operational planning and determining relevance of assets for outage coordination on a yearly basis. The time duration specified shall be short term (such as monthly, weekly, day ahead, intra-day)	It is recommended to the Regulator to further strengthen procedures related to outage management.
3.2	The resilience of present Regulation for ancillary services is inadequate, efforts should be made to introduce to de-linking of payment from pool account and improving response time for secondary and tertiary services.	It is recommended to the Regulator to take necessary steps to make ancillary service market framework more resilient in the country. (The new draft ancillary services Regulation (dated 29th May 2021) has the provision but, the same is in draft stage and not yet notified.)
4.	**Scheduling and despatch**	
4.1	Current Grid Code does not mandate conducting post-despatch analysis. Further, 4th Amendment to IEGC 2010 allows for compensation to Central Generating Stations and Inter-State Generating Stations for compensation to generators forced to run below normative parameters	Recommendation to the Regulator to request through FoR that the State Regulators shall develop their own regulations/ rules on similar lines providing state-based generators compensation that are forced run below normative parameters due to transmission system constraints. The Capacity Building of Indian Load Despatch Centres (CABIL) by Forum of Regulator published in 2018, highlights the importance of conducting post-despatch analysis[22]. The report also provides guidance on conducting post-despatch analysis.

[22] CABIL Report, 2018 - *http://www.forumofregulators.gov.in/Data/Reports/FOR%20Report%20CABIL.pdf*

Sl. No.	Identified gaps	Suggested regulatory intervention
	(technical minimum). However, the same should be extended to all Generators forced to run below normative parameters due to transmission system constraints.	
5.1		
6.	**Monitoring and compliance**	
6.1	Inadequate performance monitoring indicators. Inclusion of performance indicators which shall define the smartness of the system through system observability, system controllability, transparency in data access and sharing between relevant stakeholders, asset management and markets and customer inclusion.	It is recommended to the Regulator to define and mandate capturing information on advance grid performance indicators for effective reporting of status of grid reliability.

6.3.5. Maldives

Currently, Maldives has no transmission grid. The physical dispersion of the islands makes it virtually impossible to connect the entire country on a single grid. Due to its geographic location, surrounded by ocean, with nearly 1000 kms to the nearest mainland, even cross border electricity trade has not been considered as a viable option for Maldives. The Ministry of Environment and Energy report 'Greater Malé Region Renewable Energy Integration Plan' and the USAID report 'Maldives Submarine Cable Interconnection Pre-feasibility Study' give a detailed analysis of options for undersea electrical interconnections in Greater Malé. Both studies clearly show that interconnections would support significant increases in renewable energy deployment. Large-scale renewable energy deployment in Greater Malé will require the islands of Malé, Villingili, Thilafushi, Gulhifalhu and Hulhumalé/ Hulhulé to be interconnected using undersea electrical cables.

Considering the possible future inter connections in Maldives, we suggest that capacity building for drafting regulations covering the following shall be initiated to ensure grid discipline and reliability:

- System Planning
- System Construction and Safety
- Grid Connection

- System operation
- System protection, testing and commissioning
- Scheduling and Despatch
- Information and Communication technology
- Monitoring and Compliance

6.3.6. Nepal

Sl. No.	Identified gaps	Suggested regulatory intervention
1.	**Grid Code**	
1.1	Grid Code not available in the public domain.	It is recommended to the Regulator to make necessary effort to develop its grid code.
2.	**System Planning**	
2.1	Absence of standardized detailed manual on transmission planning - security of supply, strategies for contingency/bottleneck, RE integration, reactive power planning, cost benefit analysis (social/economic).	It is recommended to the Regulator to develop transmission planning criterion.
3.	**System construction and safety**	
3.1	Inadequate measures in system construction and safety.	It is recommended to the Regulator to define mechanism for strengthening of power system safety.
4.	**Grid connection**	
4.1	Absence of regular monitoring and compliance of conditions and procedures for providing grid connectivity to the user.	It is recommended to the Regulator to mandate the Transmission licensee to conduct advanced tests before connecting HVDC/ FACTS devices and also to publish details of compliance to conditions and procedures for establishing grid connections.
5.	**System protection, testing and commissioning**	
5.1	Absence of System Protection Philosophy and third-party protection audits	It is recommended to the Regulator to specify system protection philosophy, protection schemes and guidelines for testing & commissioning.
6.	**System operation**	
6.1	Absence of ancillary services mechanism in the country.	Regulatory intervention to develop ancillary service market in the country.
6.2	Absence of standard operating procedure outlining operational	It is recommended to the Regulator to publish procedure for operational planning, system security, demand management, define

Sl. No.	Identified gaps	Suggested regulatory intervention
	planning, system security, demand management, outage management.	key system performance indicators outage management and partial or complete grid disturbance, defining grid incidence and disturbance like events.
6.3	Absence of imbalance settlement mechanism to handle imbalance in the system.	It is recommended to the Regulator to introduce incentive / penalty-based imbalance settlement mechanism
7.	**Scheduling and dispatch**	
7.1	Absence of detailed framework for CBET.	It is recommended to the Regulator to specify framework for co-ordination of CBET.
7.2	Absence of penalty mechanism for mis-declaration by the generating stations in the Grid Code and inaccurate demand forecasting by distribution companies to ensure grid discipline and reliability	It is recommended to the Regulator to specify in the Grid code/ Regulations penalty for mis-declaration by the generating companies and inaccurate demand forecasting by distribution companies..
8.	**Information and communications Technology**	
8.1	Cyber security standards for critical information infrastructure are absent.	It is recommended to the Regulator to specify cyber security code to identify critical information infrastructure. It shall also define the measures to be undertaken to protect critical information infrastructure and shall mandate periodic publishing of related information in the public domain.
8.2	Inadequate regulatory push to regularly assess adequacy of current technology to manage grid operations and recommend more effective technology solutions	It is recommended to the Regulator to make necessary interventions for implementation of ICT infrastructure like communication facilities, operational technology systems (e.g., SCADA/EMS, WAMS/PMU) and cyber security to ensure grid discipline and grid reliability.
9.	**Monitoring and compliance**	
9.1	No clear mandate for sector participants to publish information related to power system in public domain.	It is recommended to the Regulator to lay down provision for periodic publishing of monitoring and compliance reports, system performance reports, third-party audit reports and other such important documents in the public domain.
9.2	Inadequate performance monitoring indicators	It is recommended to the Regulator to define and mandate capturing information on grid performance indicators for effective reporting of status of grid reliability

6.3.7. Pakistan

Sl. No.	Identified gaps	Suggested regulatory intervention
1.	**System protection, testing and commissioning**	
1.1	Absence of System Protection Philosophy and third-party protection audits	It is recommended to the Regulator to define mechanism for strengthening of power system protection through white paper or consultation paper.
2.	**System operation**	
2.1	Absence of imbalance settlement mechanism.	It is recommended to the Regulator to introduce incentive / penalty-based imbalance settlement mechanism.
2.2	Absence of a commercial mechanism/ market for providing ancillary services.	It is recommended to the Regulator to introduce ancillary services (primary, secondary, and tertiary responses) for frequency regulation and improved grid reliability.
2.3	Absence of a methodology for assessing the relevance of assets for outage coordination	It is recommended to the Regulator to introduce provision for assessing the relevance of assets for outage coordination to ensure minimum outages and better grid discipline and reliability.
3.	**Scheduling and despatch**	
3.1	Absence of detailed framework for CBET.	It is recommended to the Regulator to specify framework for co-ordination of CBET.
4.	**Information and communications Technology**	
4.1	Inadequate regulatory push to regularly assess adequacy of current technology to manage grid operations and recommend more effective technology solutions	It is recommended to the Regulator to encourage adoption of technology solutions for improving system operations, market operations, grid reliability and cyber security.
5.	**Monitoring and compliance**	
5.1	No clear mandate for sector participants to publish information related to power system in the public domain.	It is recommended to the Regulator to lay down provision for periodic publishing of system planning reports, monitoring and compliance reports, system performance reports, third-party audit reports and other such important documents in the public domain.
5.2	Absence of mechanisms to monitor performance standards of transmission licensee.	Introduction of incentive/ penalty mechanism for improving transmission system availability.
5.3	Inadequate performance monitoring indicators.	It is recommended to the Regulator to define and mandate capturing information on grid performance indicators for effective reporting of status of grid reliability.

6.3.8. Sri Lanka

Sl. No.	Identified gaps	Suggested regulatory intervention
1.	**System Planning**	
1.1	No mechanism to ensure compliance to system planning standards.	It is recommended to the Regulator to introduce penalty provisions for non-compliance to system planning standards.
2.	**System protection, testing and commissioning**	
2.1	Absence of System Protection Philosophy and third-party protection audits.	It is recommended to the Regulator to define mechanism for strengthening of power system protection through white paper or consultation paper.
3.	**System operation**	
3.1	Absence of imbalance settlement mechanism to handle imbalance in the system.	It is recommended to the Regulator to introduce incentive/ penalty-based imbalance settlement mechanism.
3.2	Absence of a commercial mechanism/ market for providing ancillary services.	It is recommended to the Regulator to introduce ancillary services (primary, secondary, and tertiary responses) for frequency regulation and improved grid reliability
3.3	Absence of a methodology for assessing the relevance of assets for outage coordination.	It is recommended to the Regulator to introduce provision for assessing the relevance of assets for outage coordination to ensure minimum outages and better grid discipline and reliability
4.	**Scheduling and despatch**	
4.1	Absence of detailed framework for CBET	It is recommended to the Regulator to specify framework for co-ordination of CBET
4.2	Absence of penalty mechanism for mis-declaration by the generating stations and inaccurate demand forecasting by distribution companies to ensure grid discipline and reliability.	It is recommended to the Regulator to specify penalty for mis-declaration by the generating companies and inaccurate demand forecasting by distribution companies.
5.	**Information and communications Technology**	
5.1	Inadequate regulatory push to regularly assess adequacy of current technology to manage grid operations and recommend more effective technology solutions	It is recommended to the Regulator to encourage adoption of technology solutions for improving system operations, market operations, grid reliability and cyber security.
6.	**Monitoring and compliance**	

Sl. No.	Identified gaps	Suggested regulatory intervention
6.1	No clear mandate for sector participants to publish information related to power system in public domain.	It is recommended to the Regulator to mandate periodic publishing of system planning reports, monitoring and compliance reports, system performance reports, third-party audit reports and other such important documents in the public domain.
6.2	Inadequate performance monitoring indicators.	It is recommended to the Regulator to define and mandate capturing information on grid performance indicators for effective reporting of status of grid reliability.

6.4. Suggested country-wise roadmap for undertaking specific regulatory measures/ interventions:

Country-wise roadmap for undertaking above specified regulatory measures/ interventions is as follows:

6.4.1. Afghanistan

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
1.	**General**			
1.1	It is recommended to create an independent electricity regulator with a mandate to regulate sector participants (generation/ transmission/ distribution), to specify Grid Code having regard to Grid Standards, to specify and enforce the standards with respect to quality, continuity, and reliability of service by licensees and to discharge such other functions as may be assigned under the empowering act.	Legislative measure shall be taken for creation of an independent electricity regulator for the country.	-	-
1.2	It is suggested that regulator to publish its grid code in the public domain with relevant provisions related to system planning, system construction and safety, grid connection, system protection, testing & commissioning, scheduling, and despatch, information, and communications technology, monitoring, and compliance to promote grid discipline and grid reliability.	1) It is recommended to the Regulator to initiate process for drafting grid code. 2) After following a consultative process the grid code shall be finalised and notified in the public domain.	-	-
2.	**System Planning**			
2.1	It is recommended to the Regulator to develop transmission planning criteria.	It is recommended to the Regulator to develop grid code with provisions related to system planning like contingency criteria, system planning studies, voltage & frequency variation limits to promote grid discipline and grid reliability.	A working paper shall be floated for discussion on transmission planning criteria.	It is recommended to the Regulator to draft and notify transmission planning criteria that shall be prepared to create a unified interstate/province electricity transmission system.
3.	**System construction and safety**			

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
3.1	It is recommended to the Regulator to define mechanism for strengthening of power system safety.	It is recommended to the Regulator to develop grid code with provisions related to system construction and safety like standards for general safety requirements and Designate the responsibility to monitor compliance to promote grid discipline and grid reliability.	It is recommended to the Regulator to conduct a study on International best practices and propose approaches to be adopted for strengthening system safety.	1) It is recommended to the Regulator to define safety standards and make necessary provisions for their compliance. 2) The regulatory shall make provisions to conduct independent third-party safety audits annually
4.	**Grid connection**			
4.1	It is recommended to the Regulator to specify a detailed procedure for grid connectivity and publish the same in public domain.	It is recommended to the Regulator to develop grid code with provisions related to grid connection like conditions and process to get connected to the grid (incl. renewable energy generators) to promote grid discipline and grid reliability.	It is recommended to the Regulator to publish white paper outlining needs for standardising grid connectivity procedure, model agreements and technical standards prior to providing access.	It is recommended to the Regulator to lay down detailed procedure for grid connections for various grid users including renewable energy generators.
5.	**System protection, testing and commissioning**			
5.1	It is recommended to the Regulator to specify system protection philosophy, protection schemes and guidelines for testing & commissioning.	It is recommended to the Regulator to develop grid code with provisions related to system protection, testing and commissioning to ensure grid discipline and grid reliability.	It is recommended to the Regulator to conduct a study on identification and implementation of system protection schemes.	1) It is recommended to the Regulator to develop system protection philosophy, defining protection schemes and guidelines for testing & commissioning. 2) It is recommended to the Regulator to mandate

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
				conducting independent third-party safety audits annually.
6.	**System operation**			
6.1	Regulatory intervention to develop ancillary service market in the country.	It is recommended to the Regulator to develop grid code with provisions related to management of frequency response by providing ancillary services to ensure grid discipline and grid reliability.	Considering the fact that Afghanistan has 23,000 MW of hydropower potential, and the current emphasis is on development of hydropower in the near future. It is recommended to the Regulator to conduct a study on introduction of ancillary services.	It is recommended to the Regulator to explore establishing market-based ancillary services.
6.2	It is recommended to the Regulator to publish standard operating procedures for operational planning, system security, demand management, define key system performance indicators outage management and partial or complete grid disturbance, defining grid incidence and disturbance like events.	It is recommended to the Regulator to develop grid code with provisions related to system operation to ensure grid discipline and grid reliability.	It is recommended to the Regulator to publish detailed operating procedures outlining operational planning, system security, demand management, methodology for relevance of assets for outage coordination and partial or complete grid disturbance handling, monitoring of phase angle difference.	
6.3	It is recommended to the Regulator to introduce incentive / penalty-based imbalance settlement mechanism	It is recommended to the Regulator to develop grid code with provisions related to imbalance settlement mechanism to ensure grid discipline and grid reliability.	It is recommended to the Regulator to publish a white paper/ consultation paper on progressive narrowing of normal frequency operating range, its implications and suggested roadmap.	1) A consultation paper/ white paper shall be published on Introduction of incentive/ penalty-based imbalance settlement mechanism in Afghanistan. 2) It is recommended to the Regulator to finalise Regulations for Imbalance Settlement Mechanism after

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
				comprehensive stakeholder consultations. 3) Rules and procedure for implementation of the incentive/ penalty-based mechanism shall be issued.
7.	**Scheduling and despatch**			
7.1	It is recommended to the Regulator to specify framework for co-ordination of CBET	It is recommended to the Regulator to develop grid code with provisions related to coordination of CBET to ensure grid discipline and grid reliability.	A comprehensive study shall be undertaken to understand the role played by various stakeholders for CBET in Afghanistan, leading to specific recommendations for building framework.	It is recommended to the Regulator to draft specific Regulation defining the framework for coordination of CBET. This shall consist of identified roles and responsibilities of various stakeholders, standard contracts for export and import of power, grid safety related provisions for CBET.
8.	**Information and communications Technology**			
8.1	It is recommended to the Regulator to make necessary interventions for implementation of ICT infrastructure like communication facilities, operational technology systems (e.g., SCADA/EMS, WAMS/PMU) and cyber security to ensure grid discipline and grid reliability.	It is recommended to the Regulator to develop grid code which emphasise on implementation of advance operation technologies and ICT infrastructure for better operation of the grid.	A comprehensive study shall be undertaken to prepare roadmap for adoption of advanced ICT technologies and operation technology systems	It is recommended to the Regulator to mandate use of advanced ICT technologies and operational technology systems by concerned stakeholders.
8.2	It is recommended to the Regulator to specify cyber security code to identify critical information infrastructure. It shall also define the	It is recommended to the Regulator to develop grid code with key provisions of cyber	It is recommended to the Regulator to publish a consultation paper/ white paper	It is recommended to the Regulator to publish cyber security standards which

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
	measures to be undertaken to protect critical information infrastructure and shall mandate periodic publishing of related information in the public domain.	security framework for protection of critical information infrastructure.	on requirement of regulatory intervention for development of cyber security code to protect critical information infrastructure.	encompass standards for various communication technologies, identification of data transfer protocols, measures for information protection, provision for cyber audits and capacity building.
9.	**Monitoring and compliance**			
9.1	It is recommended to the Regulator to lay down provision for periodic publishing of monitoring and compliance reports, system performance reports, third-party audit reports and other such important documents in the public domain.	It is recommended to the Regulator to develop grid code which mandates on publishing of monitoring and compliance reports, system performance reports in public domain.	1) It is recommended to the Regulator to mandate periodic publishing of various monitoring and compliance reports. 2) Regulator may explore imposing penalties for non-compliance i.e., non-disclosure in the public domain.	
9.2	It is recommended to the Regulator to define and mandate capturing information on grid performance indicators for effective reporting of status of grid reliability	1) It is recommended to the Regulator to define following performance indicators of grid reliability: - Frequency Deviation Index, - Voltage Deviation Index, - Available Transfer Capability, - Contingency Violation, - Grid Disturbances along with details of tripping, Outage duration, generation loss, load loss and energy unserved, - Grid Incidences along with details of tripping, Outage duration, generation loss, load loss and energy unserved, - Frequency Response. 2) It is recommended to the Regulator to mandate regular reporting of the performance indicators in the public domain.		-

6.4.2. Bangladesh

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
1.	**System Planning**			
1.1	It is recommended to the Regulator to specify transmission planning criteria.	A working paper shall be floated for discussion on transmission planning criteria.	Based on findings of discussion, draft amendments to the Grid code shall be prepared for deliberations and finalisation.	Appropriate amendments to Grid code shall be made to operationalize transmission planning criteria.
2.	**System construction and safety**			
2.1	It is recommended to the Regulator to define the rules and procedure for monitoring compliance to system construction and safety regulations.	Annual Safety audits are currently undertaken by PGCB internally. It is suggested that the grid code shall mandate conducting independent third-party safety audits biennially and publishing the findings of such third-party audits in the public domain.	1) It is suggested that the regulator to mandate conducting independent third-party safety audits once a year and internal audits once every quarter. 2) It is recommended to the Regulator to monitor the compliance of the above-mentioned provisions.	
3.	**Grid connection**			
3.1	It is recommended to the Regulator to mandate the Transmission licensee to conduct advanced tests before connecting HVDC/ FACTS devices and also to publish details of compliance to conditions and procedures for establishing grid connections	Regulatory intervention for introduction of advance tests for HVDC/ FACTs devices prior to grid connectivity into the grid code before allowing grid connection to ensure grid reliability.	It is recommended to the Regulator to direct the Transmission licensee to provide information of connection applications processed on monthly and yearly basis to the Regulator with reasons of rejection if applicable. This shall also include reports on compliance of tests conducted by the conventional and non-conventional energy sources before establishing connections with the Transmission system.	
4.	**System protection, testing and commissioning**			
4.1	It is recommended to the Regulator to define mechanism for strengthening of power system	BERC shall mandate Transmission System	1) The System Protection Working group/ committee at NLDC shall frame appropriate standard specifications for Protection	

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
	protection through white paper or consultation paper.	Operator(s) to define the protection system philosophy.	Systems. 2) The Grid code shall mandate conducting independent third-party protection audits biennially. The Grid code shall mandate publishing findings of third-party audits in the public domain.	
5.	**System operation**			
5.1	It is recommended to the Regulator to introduce incentive / penalty-based imbalance settlement mechanism	A consultation paper/ white paper shall be published on Introduction of incentive/ penalty-based imbalance settlement mechanism in Bangladesh.	1) It is recommended to the Regulator to finalise Regulations for Imbalance Settlement Mechanism after comprehensive stakeholder consultations. 2) It is recommended to the Regulator to issue Rules and procedure for implementation of the incentive/ penalty-based mechanism.	
5.2	It is recommended to the Regulator to introduce ancillary services (primary, secondary, and tertiary responses) for frequency Regulation and improved grid reliability.	A consultation paper/ white paper on introduction of ancillary services in Bangladesh's power sector shall be prepared and deliberated.	Specific Regulations on ancillary services (covering primary and tertiary) shall be framed and implemented.	Regulations on ancillary services shall introduce secondary response through AGC and market-based price discovery of ancillary services.
5.3	It is recommended to the Regulator to introduce provision for assessing the relevance of assets for outage coordination to ensure minimum outages and better grid discipline and reliability	A consultation paper/ white paper on introduction of methodology for assessing the relevance of assets for outage coordination in Bangladesh's power sector shall be prepared and deliberated.	BERC shall finalise the methodology for assessing the relevance of assets for outage coordination and the same shall be implemented in the long term	
5.4	It is recommended to the Regulator to introduce claw back mechanism/ penalty provisions/ incentive provisions in the Grid code for ensuring compliance to system operating standards (e.g., system reliability indices and system availability standards) for grid connected users and transmission owner/utility.	A consultation paper/ white paper on introduction of claw back mechanism/ penalty provisions/ incentive provisions in the Grid code for ensuring compliance to system operating	Specific regulations on claw back mechanism/ penalty provisions/ incentive provisions in the Grid code for ensuring compliance to system operating standards (e.g., system	The penalty/incentive provisions for the transmission licensee(s) shall be made stringent with time to ensure better grid discipline and grid reliability.

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
		standards for grid connected users and transmission owner/utility shall be prepared and deliberated.	reliability indices and system availability standards) for grid connected users and transmission owner/utility shall be framed and implemented.	
6.	**Scheduling and despatch**			
6.1	It is recommended to the Regulator to specify penalty for mis-declaration by the generating companies and inaccurate demand forecasting by distribution companies	BERC shall initiate regulatory consultations (through working paper/ draft proposal) to understand implications of introducing penalty mechanism for mis-declaration by the generating companies and distribution companies in Bangladesh.	BERC shall finalise Regulations imposing penalties for mis-declaration of available capacity by the Generating Companies and mis-declaration of drawal by Distribution companies, based on comprehensive stakeholder consultations.	
6.2	It is recommended to the Regulator to specify framework for co-ordination of CBET.	A comprehensive study shall be undertaken to understand the role played by various stakeholders for CBET in Bangladesh, leading to specific recommendations for building framework.	BERC shall draft specific Regulation defining the framework for coordination of CBET. This shall consist of identified roles and responsibilities of various stakeholders, standard contracts for export and import of power, grid safety related provisions for CBET.	With increase in CBET with the neighbouring countries of Bangladesh, the complexities of CBET are likely to increase. It is suggested that a separate specialized department within PGCB shall be formed to coordinate CBET effectively.
7.	**Information and communications Technology**			
7.1	It is recommended to the Regulator to specify cyber security code to identify critical information infrastructure. It shall also define the	BERC shall publish a consultation paper/ white paper on requirement of regulatory	It is recommended to the Regulator to publish cyber security standards which encompass standards for various communication technologies, identification of data transfer protocols, measures for	

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
	measures to be undertaken to protect the critical information infrastructure and shall mandate periodic publishing of related information in the public domain.	intervention for development of cyber security code to protect the critical information infrastructure security.	information protection, provision for cyber audits and capacity building.	
8.	**Monitoring and compliance**			
8.1	It is recommended to the Regulator to lay down provision for periodic publishing of monitoring and compliance reports, system performance reports, third-party audit reports and other such important documents in the public domain.	The Grid code shall be amended to mandate periodic publishing of various monitoring and compliance reports.		The Regulator may explore imposing penalties for non-compliance i.e., non-disclosure in the public domain.
8.2	It is recommended to the Regulator to define and mandate capturing information on grid performance indicators for effective reporting of status of grid reliability	1) It is recommended to the Regulator to define following performance indicators of grid reliability: - Frequency Deviation Index, - Voltage Deviation Index, - Available Transfer Capability, - Contingency Violation, - Frequency Response, - Grid Disturbances along with details of tripping, Outage duration, generation loss, load loss and energy unserved, - Grid Incidences along with details of tripping, Outage duration, generation loss, load loss and energy unserved, - Estimated Energy Not Supplied (EENS). 2) It is recommended to the Regulator to mandate regular reporting of the performance indicators in the public domain.		-

6.4.3. Bhutan

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
1.	**System Planning**			
1.1	It is recommended to the Regulator to specify transmission planning criteria	A working paper shall be floated for discussion on transmission planning criteria.	Based on findings of discussion, draft amendments to the Grid code shall be prepared for deliberations and finalisation.	Appropriate amendments to Grid code shall be made to operationalize transmission planning criteria.
2.	**System construction and safety**			
2.1	It is recommended to the Regulator to define mechanism for strengthening of power system safety.	It is recommended to the Regulator to conduct a study on international best practices and propose approaches to be adopted for strengthening system safety.	1) Transmission system operator shall comply with International safety standards. (e.g., OHSAS 18001) 2) It is recommended to the Regulator to mandate to conduct independent third-party safety audits annually	
3.	**Grid connection**			
3.1	It is recommended to the Regulator to mandate the Transmission licensee to conduct advanced tests before connecting HVDC/ FACTS devices and also to publish details of compliance to conditions and procedures for establishing grid connections	Regulatory intervention for introduction of advance tests for HVDC/ FACTs devices prior to grid connectivity into the grid code before allowing grid connection to ensure grid reliability.	It is recommended to the Regulator to direct the Transmission licensee to provide information of connection applications processed on monthly and yearly basis to the Regulator with reasons of rejection if applicable. This shall also include reports on compliance of tests conducted by the conventional and non-conventional energy sources before establishing connections with the Transmission system.	
4.	**System protection, testing and commissioning**			
4.1	It is recommended to the Regulator to define mechanism for strengthening of power system protection.	BEA shall mandate Transmission System Operator(s) to define the protection system philosophy.	1) The System Protection Working group/ committee at Bhutan NLDC shall frame appropriate standard specifications for Protection Systems. 2) The Grid code shall mandate conducting independent third-	

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
			party protection audits biennially. The Grid code shall mandate publishing findings of third-party audits in the public domain.	
5.	**System operation**			
5.1	It is recommended to the Regulator to introduce incentive / penalty-based imbalance settlement mechanism	A consultation paper/ white paper shall be published on Introduction of incentive/ penalty-based imbalance settlement mechanism in Bhutan.	1) It is recommended to the Regulator to finalise Regulations for Imbalance Settlement Mechanism after comprehensive stakeholder consultations. 2) It is recommended to the Regulator to issue Rules and procedure for implementation of the incentive/ penalty-based mechanism.	
5.2	It is recommended to the Regulator to introduce ancillary services (primary, secondary, and tertiary responses) for frequency regulation and improved grid reliability.	A consultation paper/ white paper on introduction of ancillary services in Bhutan's power sector shall be prepared and deliberated.	Specific regulations on ancillary services (covering primary and tertiary) shall be framed and implemented.	Regulations on ancillary services shall introduce secondary response through AGC and market-based price discovery of ancillary services.
5.3	It is recommended to the Regulator to introduce provision for assessing the relevance of assets for outage coordination to ensure minimum outages and better grid discipline and reliability	A consultation paper/ white paper on introduction of methodology for assessing the relevance of assets for outage coordination in Bhutan's power sector shall be prepared and deliberated.	BEA shall finalise the methodology for assessing the relevance of assets for outage coordination and the same shall be implemented in the long term	
5.4	It is recommended to the Regulator to introduce claw back mechanism/ penalty provisions/ incentive provisions in the Grid code for ensuring compliance to system operating standards (e.g., system reliability indices and system availability standards) for grid connected users and transmission owner/utility.	A consultation paper/ white paper on introduction of claw back mechanism/ penalty provisions/ incentive provisions in the Grid code for ensuring compliance to system operating standards for grid connected users and transmission	Specific regulations on claw back mechanism/ penalty provisions/ incentive provisions in the Grid code for ensuring compliance to system operating standards (e.g., system reliability indices and system availability standards) for grid connected	The penalty/incentive provisions for the transmission licensee(s) shall be made stringent with time to ensure better grid discipline and grid reliability.

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
		owner/utility shall be prepared and deliberated.	users and transmission owner/utility shall be framed and implemented.	
6.	**Scheduling and despatch**			
6.1	It is recommended to the Regulator to specify penalty for mis-declaration by the generating companies and inaccurate demand forecasting by distribution companies	It is recommended to the Regulator to initiate regulatory consultations (through working paper/ draft proposal) to understand implications of introducing penalty mechanism for mis-declaration by the generating companies and distribution companies in Bhutan.	BEA shall finalise Regulations imposing penalties for mis-declaration of available capacity by the Generating Companies and mis-declaration of drawal by Distribution companies, based on comprehensive stakeholder consultations.	
6.2	It is recommended to the Regulator to specify framework for co-ordination of CBET	A comprehensive study shall be undertaken to understand the role played by various stakeholders for CBET in Bhutan, leading to specific recommendations for building framework.	BEA shall draft specific Regulation defining the framework for coordination of CBET. This shall consist of identified roles and responsibilities of various stakeholders, standard contracts for export and import of power, grid safety related provisions for CBET.	With increase in CBET with the neighboring countries of Bhutan, the complexities of CBET are likely to increase. It is suggested that a separate specialized department within BPSO shall be formed to coordinate CBET effectively.
7.	**Information and communications Technology**			
7.1	It is recommended to the Regulator to specify cyber security code to identify critical information infrastructure. It shall also define the measures to be undertaken to protect the critical information infrastructure and shall mandate	BEA shall publish consultation paper/ white paper on requirement of regulatory intervention for development of	It is recommended to the Regulator to publish cyber security standards which encompass standards for various communication technologies, identification of data transfer protocols, measures for	

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
	periodic publishing of related information in the public domain.	cyber security code to protect the critical information infrastructure security.	information protection, provision for cyber audits and capacity building.	
7.2	It is recommended to the Regulator to make necessary interventions for implementation of ICT infrastructure like communication facilities, operational technology systems (e.g., SCADA/EMS, WAMS/PMU) and cyber security to ensure grid discipline and grid reliability.	A comprehensive study shall be undertaken to conduct cost benefit analysis for implementation of advance ICT technologies and operation technology systems	It is recommended to the Regulator to mandate use of advance ICT technologies and operation technology systems by concerned stakeholders	
8.	**Monitoring and compliance**			
8.1	It is recommended to the Regulator to lay down provision for periodic publishing of monitoring and compliance reports, system performance reports, third-party audit reports and other such important documents in the public domain.	The Grid code shall be amended to mandate periodic publishing of various monitoring and compliance reports.		The Regulator may explore imposing penalties for non-compliance i.e., non-disclosure in the public domain.
8.2	It is recommended to the Regulator to define and mandate capturing information on grid performance indicators for effective reporting of status of grid reliability	1) It is recommended to the Regulator to define following performance indicators of grid reliability: - Available Transfer Capability, - Contingency Violation, - Frequency Response, - Grid Disturbances along with details of tripping, Outage duration, generation loss, load loss and energy unserved, - Grid Incidences along with details of tripping, Outage duration, generation loss, load loss and energy unserved, - Estimated Energy Not Supplied (EENS) 2) It is recommended to the Regulator to mandate regular reporting of the performance indicators in the public domain.		-

6.4.4. India

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
1.	**System Planning**			
1.1	It is recommended to the Regulator to take necessary steps to expedite the processes of developing detailed transmission system planning manual on the basis of CERC Planning, Coordination and Development of Economic and Efficient Inter-State Transmission System by Central Transmission Utility and other related matters Regulation, 2018.	1) It is recommended to the Regulator to notify a detailed manual for transmission system planning after stakeholder consultation. 2) CEA's national electricity plan shall asses requirement of energy storage systems for demand response measures (after conducting feasibility studies). Further, the transmission plan shall also consider measurable benefit of the new interconnection to the society as a whole.		
2.	**System protection, testing and commissioning**			
2.1	Regulatory intervention shall be made to standardise protection plans, it shall also take necessary steps to introduce best practices like creation of system defense plan as a proactive step for system protection. Also, the protection plan shall be updated over a horizon of 3 to 5 years.	1) It is recommended to the Regulator to have a common protection philosophy for grid users at national level. It will help in proper coordination of protection system in order to isolate the faulty equipment and avoid unintended operation of protection system. It will also help in creating a repository of	It is recommended to the Regulator to define a clear mandate for NPC/RPCs in coordination with SO (NLDC/RLDC/SLDC) to prepare system defence plan, considering following elements: (a) The operational security limits set out as per operating standards,	It is recommended to the Regulator to specify penalty/ claw back for non-compliance to system defence planning on NPC/ RPCs.

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
		protection system settings and events. 2) Currently, there are no uniform standards at Federal level for conducting regular protection audits. The standards are set and monitored regionally by RPCs. The grid code shall mandate regular protection audit plans for internal and third-party audits. As per report of the Expert Group for review of IEGC. The proposed IEGC 2020 provides for annual self-audit and third party audit of each sub-station once every 5 years or earlier as advised by the RPC.	(b) The behaviour and capabilities of load and generation within the synchronous area, (c) The specific needs of the high priority significant grid users and, (d) The characteristics of its transmission system. The system defence plan shall contain following: (a) The conditions under which the system defence plan is activated; (b) The system defence plan instructions to be issued by the transmission operator; (c) The measures subject to real-time consultation or coordination with the identified parties; (d) A list of the measures to be implemented by the transmission operator on its installations; (e) A list of the measures to be implemented by SLDCs; (f) A list of high priority significant grid users and the terms and conditions for their disconnection;	

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
			(g) The implementation deadlines for each measure listed in the system defence plan	
3.	**System operation**			
3.1	The current grid code specifies operating procedure for determining relevance of assets for outage coordination on a yearly basis. The time duration specified shall be short term (such as monthly, weekly, day ahead, intra-day)	1) It is recommended to Regulator to mandate regional stakeholders (RPCs/SLDCs) to conduct operational planning studies in different time horizons, viz., Yearly, Monthly, Weekly, Day-ahead, and intra-day. The above suggestion has also been included in the Expert Committee Report on Review of IEGC. 2) It is recommended to the Regulator to develop a methodology for determining relevance of assets for outage coordination. The methodology shall specify the institutional capacity building required and define responsibilities of various entities involved.	It is recommended to the Regulator to mandate conducting activities related to demand forecasting based on advance prediction models and conducting studies for relevance of asset for outage based on past trend to infuse best practices into the sector.	
3.2	It is recommended to the Regulator to take necessary steps to make ancillary service market framework more resilient in the country.	1) Consultation paper/ white paper shall be published outlining methodology for accurately assessing primary, the response time of secondary and tertiary reserves shall be refined	It is recommended to the Regulator to devise a framework to modify payments provisions of Ancillary Services (regulations services) a commercial mechanism shall be	Efforts shall be made to introduce energy storage systems and fast transient frequency support using controlled inertial response from wind turbines.

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
		by amending the Grid code. 2) Regulations on ancillary services shall introduce secondary response through AGC and market-based price discovery of ancillary services.	developed to cover commercial settlement of other resources such as Demand Response, Energy Storage.	
4.	**Scheduling and Despatch**			
4.1	It is recommended to the Regulator to introduce provisions related to post-despatch analysis and compensating generators that were compelled to run below normative parameters in the grid code. The Capacity Building of Indian Load Despatch Centres (CABIL) by Forum of Regulator published in 2018, highlights the importance of conducting post-despatch analysis.	Consultation paper/ white paper shall be published outlining framework for conducting post-despatch analysis. CERC may request through FoR that the State Regulators shall develop their own regulations/ rules on similar lines providing state-based generators compensation that are forced run below normative parameters due to transmission system constraints.		
5.1				
6.	**Monitoring and compliance**			
6.1	It is recommended to the Regulator to define and mandate capturing information on advance grid performance indicators for effective reporting of status of grid reliability.	1) It is recommended to the Regulator to define following performance indicators of grid reliability:	-	-

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
		- Voltage Deviation Index[23]- Frequency Deviation Index[24] - Area Control Error (ACE)[25] - Estimated Energy Not Supplied (EENS)[26] - Performance by technology type during EEA (Energy Emergency Alerts)[27] - Demand and RE Forecast[28] - Timely dissemination of information for the stakeholder's operational satisfaction or concern[29] 2) It is recommended to the Regulator to mandate regular reporting of the new performance indicators in the public domain.		

[23] **VDI (Voltage Deviation Index) :** It is % of time the voltage remained out of permissible range defined by the Regulator or standards and technical authority at all 400 kV and above sub-stations.

[24] **FDI (Frequency Deviation Index) :** It is % of time the frequency remained out of permissible limits defined by the Regulator or standards and technical authority.

[25] **ACE (Area Control Error):** ACE may be monitored along with deviations. ACE supervision and response time for ACE should be within permissible limits defined by the technical authority or regulator.

[26] **ENS (Energy not Supplied):** It is an estimation of the energy not supplied to final customers due to incidents in the transmission network.

[27] **Performance by technology Type during EEA (Energy Emergency Alerts):** The performance by technology type during the EEA provides information on aggregate performance of technologies by measuring the total five-minute intervals when an alert is present and how generators, by technology type, performed. The performance factor of a technology type measures the total MWs generated from a technology type during an EEA as a percentage of the economic maximum of all MWs for that technology type.

[28] **Demand and RE Forecast:** Forecasting demand and renewable resources scheduling has provided system operators greater flexibility in taking appropriate and judicious decisions during the course of operation. Accuracy of transmission system demand forecasts shared with the market participants helps to aid the system's operational planning to be far more accurate. Demand forecasting is a key input for preparation of schedules and for accuracy of transmission system's demand shared with the market participants. E.g.: reporting grid events as per Standards, operational communications, and feedback to transmission utility, publishing annual compendium, updated documentation and procedures to be published, etc.

[29] Timely dissemination of information : This helps in implementation of business applications to help in fast dissemination of information and decision making in the organization. Declaration of ATC / TTC capacities and timely dissemination of such information shall be a key measure of effectiveness for stakeholder satisfaction with the effectiveness of further programs / processes.

6.4.5. Nepal

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
1.	**Grid Code**			
1.1	It is recommended to the Regulator to make necessary effort to develop its grid code.	It is suggested that country shall publish its grid code in the public domain with relevant provisions related to system planning, system construction and safety, grid connection, system protection, testing &commissioning, scheduling, and dispatch, information and communications technology, monitoring, and compliance to promote grid discipline and grid reliability.	-	-
2.	**System Planning**			
2.1	It is recommended to the Regulator to develop transmission planning criterion.	A working paper shall be floated for discussion on transmission planning criteria. Based on findings transmission planning framework shall be formulated.	It is recommended to the Regulator to draft and notify transmission planning criteria that shall be prepared to create a unified interstate/province electricity transmission system.	
3.	**System construction and safety**			
3.1	It is recommended to the Regulator to define mechanism for strengthening of power system safety.	It is recommended to the Regulator to conduct a study on international best practices and propose approach for adoption of	1) It is recommended to the Regulator to define safety standards and make necessary provisions for their compliance. 2) The regulatory shall make provisions to conduct independent third-party safety audits annually	

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
		international safety standards and procedures.		
4.	**Grid connection**			
4.1	It is recommended to the Regulator to specify a detailed procedure for grid connectivity and publish the same in public domain.	It is recommended to the Regulator to lay down detailed procedure for grid connections for various grid users including renewable energy generators.		Regulatory intervention for introduction of advance tests for HVDC/ FACTs devices prior to grid connectivity into the grid code before allowing grid connection to ensure grid reliability.
5.	**System protection, testing and commissioning**			
5.1	It is recommended to the Regulator to specify system protection philosophy, protection schemes and guidelines for testing & commissioning.	Regulatory intervention to develop system protection philosophy, defining protection schemes and guidelines for testing & commissioning.	It is recommended to the Regulator to make provisions to conduct independent third-party safety audits annually. Penalty provisions for non-compliance to the system protection, testing and commissioning standards shall be introduced.	
6.	**System operation**			
6.1	Regulatory intervention to develop ancillary service market in the country.	The Government of Nepal has envisaged developing 15 GW of electricity in next 10 years and total installed capacity requirement is estimates at ~42 GW (High Scenario)/~29 GW (Reference Scenario)/~19 GW (Business-as-usual) by year 2040.	A market-based operation shall be established for providing ancillary services in the country. This can also be co-optimised with the energy market. A co-optimised energy and ancillary services markets have flexibility to allow for that generation capacity to be assigned either for the production of energy or provision of ancillary services or both and thus benefits both the generators and the power system.	

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
		Therefore, it is suggested that regulations shall be developed for creating ancillary services which can be an additional revenue stream for hydro generators making the hydro generation business more financially viable. This would also help in attracting private investments in the sector. [**Source**: Water and Energy Commission Secretariat, Electricity Demand Forecast Report (2015-2040) https://www.wecs.gov.np/storage/listies/October2020/electricity-demand-forecast-report-2014-2040.pdf]		
6.2	It is recommended to the Regulator to publish procedure for operational planning, system security, demand management, define key system performance indicators outage management and partial or complete grid disturbance, defining grid incidence and disturbance like events.	It is recommended to the Regulator to introduce system performance indicators like dependability index, security index, reliability index, voltage and frequency indices, percentage (%) of times ATC was violated and percentage (%) of times (N-1) Criteria was violated. It shall also mandate publishing recommendation(s) and action(s) taken report in the public domain	It is recommended to the Regulator to publish detailed operational procedure outlining operational planning, system security, demand management, methodology for relevance of assets for outage coordination and partial or complete grid disturbance handling, monitoring of phase angle difference.	

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
		for the improvement of performance indicators.		
6.3	It is recommended to the Regulator to introduce incentive / penalty-based imbalance settlement mechanism	A consultation paper/ white paper shall be published on Introduction of incentive/ penalty-based imbalance settlement mechanism in Nepal.	1) It is recommended to the Regulator to finalise Regulations for Imbalance Settlement Mechanism after comprehensive stakeholder consultations. 2) Rules and procedure for implementation of the incentive/ penalty-based mechanism shall be issued.	
7.	**Scheduling and dispatch**			
7.1	It is recommended to the Regulator to specify framework for co-ordination of CBET.	A comprehensive study shall be undertaken to understand the role played by various stakeholders for CBET in Nepal, leading to specific recommendations for building framework.	It is recommended to the Regulator to draft specific Regulation defining the framework for coordination of CBET. This shall consist of identified roles and responsibilities of various stakeholders, standard contracts for export and import of power, grid safety related provisions for CBET.	-
7.2	It is recommended to the Regulator to specify penalty for mis-declaration by the generating companies and inaccurate demand forecasting by distribution companies	It is recommended to the Regulator to initiate regulatory consultations (through working paper/ draft proposal) to understand implications of introducing penalty mechanism for mis-declaration by the generating companies and distribution companies in Nepal.	It is recommended to the Regulator to finalise Regulations imposing penalties for mis-declaration of available capacity by the Generating Companies and mis-declaration of drawal by Distribution companies, based on comprehensive stakeholder consultations.	
8.	**Information and communications Technology**			

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
8.1	It is recommended to the Regulator to specify cyber security code to identify critical information infrastructure. It shall also define the measures to be undertaken to protect critical information infrastructure and shall mandate periodic publishing of related information in the public domain.	NEA shall publish a consultation paper/ white paper on requirement of regulatory intervention for development of cyber security code to protect the critical information infrastructure.	It is recommended to the Regulator to publish cyber security standards which encompass standards for various communication technologies, identification of data transfer protocols, measures for information protection, provision for cyber audits and capacity building.	
8.2	It is recommended to the Regulator to make necessary interventions for implementation of ICT infrastructure like communication facilities, operational technology systems (e.g., SCADA/EMS, WAMS/PMU) and cyber security to ensure grid discipline and grid reliability.	A comprehensive study shall be undertaken to conduct cost benefit analysis for implementation of advance ICT technologies and operation technology systems	Regulatory shall mandate use of advance ICT technologies and operation technology systems by concerned stakeholders	
9.	**Monitoring and compliance**			
9.1	It is recommended to the Regulator to lay down provision for periodic publishing of monitoring and compliance reports, system performance reports, third-party audit reports and other such important documents in the public domain.	1) It is recommended to the Regulator to mandate periodic publishing of various monitoring and compliance reports. 2) Regulator may explore imposing penalties for non-compliance i.e., non-disclosure in the public domain.		-
9.2	It is recommended to the Regulator to define and mandate capturing information on grid performance indicators for effective reporting of status of grid reliability	1) It is recommended to the Regulator to define following performance indicators of grid reliability: - Frequency Deviation Index, - Voltage Deviation Index, - Available Transfer Capability, - Contingency Violation, - Grid Disturbances along with details of tripping, Outage duration, generation loss, load loss and energy unserved, - Grid Incidences along with details of tripping, Outage duration, generation loss, load loss and energy unserved,		-

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
		- Frequency Response, and - Estimated Energy Not Supplied (EENS). 2) It is recommended to the Regulator to mandate regular reporting of the performance indicators in the public domain.		

6.4.6. Pakistan

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
1.	**System protection, testing and commissioning**			
1.1	It is recommended to the Regulator to define mechanism for strengthening of power system protection through white paper or consultation paper.	NEPRA shall mandate Transmission System Operator(s) to define the protection system philosophy.	The Grid code shall mandate conducting independent third-party protection audits biennially and publishing findings of third-party audits in the public domain.	
2.	**System operation**			
2.1	It is recommended to the Regulator to introduce incentive / penalty-based imbalance settlement mechanism.	A consultation paper/ white paper shall be published on introduction of incentive/ penalty-based imbalance settlement mechanism in Pakistan.	1) NEPRA shall finalise Regulations for Imbalance Settlement Mechanism after comprehensive stakeholder consultations. 2) Rules and procedure for implementation of the incentive/ penalty-based mechanism shall be issued.	
2.2	It is recommended to the Regulator to introduce ancillary services (primary, secondary, and tertiary responses) for frequency regulation and improved grid reliability.	A consultation paper/ white paper on introduction of ancillary services in Pakistan's power sector shall be prepared and deliberated.	Specific Regulations on ancillary services (covering primary and tertiary) shall be framed and implemented.	Regulations on ancillary services shall introduce secondary response through AGC and market-based price discovery of ancillary services.

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
2.3	It is recommended to the Regulator to introduce provision for assessing the relevance of assets for outage coordination to ensure minimum outages and better grid discipline and reliability.	A consultation paper/ white paper on introduction of methodology for assessing the relevance of assets for outage coordination in Pakistan's power sector shall be prepared and deliberated.	NEPRA shall finalise the methodology for assessing the relevance of assets for outage coordination and the same shall be implemented in the long term.	
3.	**Scheduling and despatch**			
3.1	It is recommended to the Regulator to specify framework for co-ordination of CBET.	A comprehensive study shall be undertaken to understand the role played by various stakeholders for CBET in Pakistan, leading to specific recommendations for building the framework.	NEPRA shall draft specific Regulation defining the framework for coordination of CBET. This shall consist of identified roles and responsibilities of various stakeholders, standard contracts for export and import of power, grid safety related provisions for CBET.	As the volume of CBET with the neighbouring countries is expected to increase significantly, the complexities of CBET are likely to increase in the future. A separate specialized department shall be formed within the System Operator to coordinate CBET related operations effectively.
4.	**Information and communications Technology**			
4.1	It is recommended to the Regulator to encourage adoption of technology solutions for improving system operations, market operations, grid reliability and cyber security.	A consultation paper/ white paper on regulatory push for adoption of technology solutions for improving system operations, market operations, grid reliability and cyber security shall be prepared for consultation.	NEPRA shall mandate phased adoption of Technology solutions for improving system operations, market operations, grid reliability and cyber security	
5.	**Monitoring and compliance**			

<table>
<tr><th>Sl. No.</th><th>Suggested regulatory intervention</th><th>Short-term
(up to 3 years)</th><th>Medium-term
(3 to 6 years)</th><th>Long-term
(beyond 6 years)</th></tr>
<tr><td>5.1</td><td>It is recommended to the Regulator to lay down provision for periodic publishing of system planning reports, monitoring and compliance reports, system performance reports, third-party audit reports and other such important documents in the public domain.</td><td>The grid code shall specify the roles and responsibility for publishing information/ reports regarding grid discipline and reliability.</td><td>NEPRA shall direct NTDC to conduct grid discipline and grid reliability related studies on a regular basis and publish information/ reports in the public domain.</td><td>-</td></tr>
<tr><td>5.2</td><td>Introduction of incentive/ penalty mechanism for improving transmission system availability.</td><td>Regulations shall be developed for claw back mechanism or penalty provisions for the transmission licensee(s) in the event of transmission system outage due to poor performance, congestion, bottleneck, and other limitations.</td><td>-</td><td>-</td></tr>
<tr><td>5.3</td><td>It is recommended to the Regulator to define and mandate capturing information on grid performance indicators for effective reporting of status of grid reliability.</td><td colspan="2">1) It is recommended to the Regulator to define following performance indicators of grid reliability:
- Frequency Deviation Index
- Voltage Deviation Index
- Available Transfer Capability
- Contingency Violation
- Grid Disturbances along with details of tripping, Outage duration, generation loss, load loss and energy unserved,
- Grid Incidences along with details of tripping, Outage duration, generation loss, load loss and energy unserved,
- Frequency Response, and
- Estimated Energy Not Supplied (EENS).
2) It is recommended to the Regulator to mandate regular reporting of the performance indicators in the public domain.</td><td>-</td></tr>
</table>

6.4.7. Sri Lanka

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
1.	**System Planning**			
1.1	It is recommended to the Regulator to introduce penalty provisions for non-compliance to system planning standards.	It is recommended to the Regulator to Penalty provisions to be introduced for non-compliance of system planning standards such as contingency criteria, power system studies, voltage and frequency variation limits and transient stability limits	-	-
2.	**System protection, testing and commissioning**			
2.1	It is recommended to the Regulator to define mechanism for strengthening of power system protection through white paper or consultation paper.	PUCSL shall mandate Transmission System Operator to define the protection system philosophy.	The Grid code shall mandate conducting independent third-party protection audits biennially and publishing findings of third-party audits in the public domain.	
3.	**System operation**			
3.1	It is recommended to the Regulator to introduce incentive/ penalty-based imbalance settlement mechanism.	A consultation paper/ white paper shall be published on introduction of incentive/ penalty-based imbalance settlement mechanism in Sri Lanka.	1) PUCSL shall finalise Regulations for Imbalance Settlement Mechanism after comprehensive stakeholder consultations. 2) Rules and procedure for implementation of the incentive/ penalty-based mechanism shall be issued.	
3.2	It is recommended to the Regulator to introduce ancillary services (primary, secondary, and tertiary responses) for frequency regulation and improved grid reliability	A consultation paper/ white paper on introduction of ancillary services in Sri Lanka's	Specific Regulations on ancillary services (covering primary and tertiary) shall be framed and implemented.	Regulations on ancillary services shall introduce secondary response through

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
		power sector shall be prepared and deliberated.		AGC and market-based price discovery of ancillary services.
3.3	It is recommended to the Regulator to introduce provision for assessing the relevance of assets for outage coordination to ensure minimum outages and better grid discipline and reliability	A consultation paper/ white paper on introduction of methodology for assessing the relevance of assets for outage coordination in Sri Lanka's power sector shall be prepared and deliberated.	1) PUCSL shall draft methodology for assessing the relevance of assets for outage coordination. 2) PUCSL shall finalise and notify the methodology for assessing the relevance of assets for outage coordination.	
4.	**Scheduling and despatch**			
4.1	It is recommended to the Regulator to specify framework for co-ordination of CBET	-	A comprehensive study shall be undertaken to understand the role played by various stakeholders for CBET in Sri Lanka, leading to specific recommendations for building framework.	- PUCSL shall draft specific Regulation defining the framework for coordination of CBET. This shall consist of identified roles and responsibilities of various stakeholders, standard contracts for export and import of power, grid safety related provisions for CBET - With the commencement of CBET with the neighbouring countries (viz. India and Maldives), the complexities of CBET are likely to increase in future. Therefore, it is suggested that a separate specialized department shall be formed within CEB to coordinate CBET effectively

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
4.2	It is recommended to the Regulator to specify penalty for mis-declaration by the generating companies and inaccurate demand forecasting by distribution companies.	PUCSL shall initiate regulatory consultations (through working paper/ draft proposal) to understand implications of introducing penalty mechanism for mis-declaration by the generating companies and distribution companies in Sri Lanka.	PUCSL shall finalise regulations imposing penalties for mis-declaration of available capacity by the Generating Companies and mis-declaration of drawal by Distribution companies, based on comprehensive stakeholder consultations.	
5.	**Information and communications Technology**			
5.1	It is recommended to the Regulator to encourage adoption of technology solutions for improving system operations, market operations, grid reliability and cyber security.	A consultation paper/ white paper on regulatory push for adoption of technology solutions for improving system operations, market operations, grid reliability and cyber security shall be prepared for consultation.	PUCSL shall mandate phased adoption of Technology solutions for improving system operations, market operations, grid reliability and cyber security.	
6.	**Monitoring and compliance**			
6.1	It is recommended to the Regulator to mandate periodic publishing of system planning reports, monitoring and compliance reports, system performance reports, third-party audit reports and other such important documents in the public domain.	The grid code shall specify the role and responsibility for publishing information/ reports regarding grid discipline and reliability and mandate publishing the reports in the public domain.	It is recommended to the Regulator to monitor compliance to the mandatory provisions and impose penalties for non-compliance.	-
6.2	It is recommended to the Regulator to define and mandate capturing information on grid	1) It is recommended to the Regulator to define following performance indicators of grid reliability: - Voltage Deviation Index		-

Sl. No.	Suggested regulatory intervention	Short-term (up to 3 years)	Medium-term (3 to 6 years)	Long-term (beyond 6 years)
	performance indicators for effective reporting of status of grid reliability.	- Frequency Deviation Index - Available Transfer Capability - Contingency Violation, - Grid Disturbances along with details of tripping, Outage duration, generation loss, load loss and energy unserved, - Grid Incidences along with details of tripping, Outage duration, generation loss, load loss and energy unserved, and - Frequency Response. 2) It is recommended to the Regulator to mandate regular reporting of the performance indicators in the public domain.		

7. Chapter 7 - Suggested specific technical capacity building measures

In chapter 5, country-wise gaps in the regulatory framework and institutions, as well as gaps in implementation and compliance of identified measures have been identified. Further in chapter 6, country-wise suggestions on regulatory measures/ interventions along with roadmap for improving grid discipline and grid reliability, have been provided. To undertake the suggested regulatory measures/ interventions, country-wise capacity building needs have been identified. Following is a list of specific technical capacity building measures that need to be undertaken for enhancing better understanding on the issues related Grid discipline and grid reliability and are mapped to the SAR countries.

7.1. List of country-wise suggested specific technical capacity building measures

Legend: Y - Required; N - Not Required

#	Relevant Audience	Training Name	Afghanistan	Bangladesh	Bhutan	India	Maldives	Nepal	Pakistan	Sri Lanka
1	Regulators	**Introduction to Grid Discipline and Reliability** This shall cover the definitions, rationale for pursuing this area, case studies to demonstrate benefits and opportunity cost, status of GDR aspects in respective country, etc.	Y	Y	Y	Y	Y	Y	Y	Y
2	Regulators	**Capacity Building on Development of Grid Code** Development of grid code	Y	N	Y	N	Considering the possible future inter-connections	Y	N	N

#	Relevant Audience	Training Name	Afghanistan	Bangladesh	Bhutan	India	Maldives	Nepal	Pakistan	Sri Lanka
		covering need for the grid code, minimum requirement for system planning, system construction & safety, grid connection, system protections, system operations, scheduling & despatch, ICT including cyber security and monitoring & compliance to ensure grid discipline and reliability.					in Maldives, we suggest that capacity building for drafting regulations be initiated to ensure grid discipline and reliability			
3	Regulators/ Technical Authority for electricity standards/ Transmission operator	**Capacity Building on Development of System Planning Manual and Long-term Transmission Plan** Process for development of a system planning manual and transmission plan (forecast) for at least next five years. Session should focus on planning process, data requirement, planning criteria (e.g., managing N-1/ N-1-1 contingency), advance technical studies (power flow studies, fault analysis, steady state, and transient stability	Y	Y	Y	N	Y	Y	N	N

#	Relevant Audience	Training Name	Afghanistan	Bangladesh	Bhutan	India	Maldives	Nepal	Pakistan	Sri Lanka
		studies), reserve margin assessment, reactive power assessment, prerequisites for smooth integration of variable renewable energy with the grid, etc.								
4	Regulators	**Formulation of Penalty/Incentive provisions for promoting Grid Discipline** Regulatory interventions for introducing commercial penalty / incentive provisions to promote grid discipline. Case studies can be shown indicting benefits harnessed by such countries wherever such mechanism was present. The session should also cover the roadmap for gradual implementation of such mechanism in terms of coverage of grid users and extent (intensity) of penalty / incentive.	Y	Y	Y	N	Can be allotted when basic transmission system is developed	Y	Y	Y
5	Technical Authority for electricity	**Training Programme on International Best Practices in**	No Once	Y	Y	Y	Can be allotted when basic	Y	Y	Y

#	Relevant Audience	Training Name	Afghanistan	Bangladesh	Bhutan	India	Maldives	Nepal	Pakistan	Sri Lanka
	standards/ Transmission operator	**Transmission System Planning** Enabling system planning working group with international best practices in the field of transmission system planning. The session shall comprise of practices adopted to ensure better utilisation of existing infrastructure by assessing existing interconnector capacity made available to the market in real-time.	Afghanistan develops it manual for transmission planning and start, advance training on international best practices could be delivered.				transmission system is developed			
6	Regulators/ Technical Authority for electricity standards/ Transmission operator	**Strengthening standards for system safety and grid connection.** The objective is to enable concerned stakeholders to develop and comply with standards and procedures based on international practices.	Y	N	Y	Y	Can be allotted when basic transmission system is developed	Y	Y	Y
7	Regulators	**System Protection-Best Practices and Enforcement Regulations** Regulatory intervention for enforcing system protection standards like	Y	Y	Y	Y	N	Y	Y	Y

#	Relevant Audience	Training Name	Afghanistan	Bangladesh	Bhutan	India	Maldives	Nepal	Pakistan	Sri Lanka
		islanding schemes, relay setting, demand management and risk related to variable renewable energy. It should also focus on creating system defence plan and best practices related to system protection globally.								
8	Regulators	**Balancing the Grid-Ancillary services** Regulatory intervention for introduction of balancing services/ ancillary services. It should consist of framework adopted by SAR countries to develop an ancillary services market and other strategy adopted by non-SAR countries to manage load-generation balance in real-time (e.g., frequency response by generators, demand response by consumers, etc.).	Y	Y	Y	Y	Can be allotted when basic transmission system is developed	Y	Y	Y
9	Regulators/ Technical Authority for electricity standards/	**Strengthening of Outage Management** Strengthening of outage management related activities. It should	Y	Y	Y	No Advance training encompassing	Can be allotted when basic transmission	Y	Y	Y

#	Relevant Audience	Training Name	Afghanistan	Bangladesh	Bhutan	India	Maldives	Nepal	Pakistan	Sri Lanka
	Transmission operator	include framework for conducting operational planning studies that include planned outage assessment, special scenario assessment, system protection scheme assessment and inter-regional, intra-regional, inter-state, intra-state total transfer capability / available transfer capability assessment in short-term and near real-time. It should also highlight benefits of conducting studies to identify relevance of assets for outage coordination.				best practices in outage management.	system is developed			
10	Regulators	**Information and Communications Technology - Best Practices and Implementation** Implementation of ICT infrastructure for enabling power system. This should include familiarisation to present day OT systems (SCADA/EMS, WAMS/PMU, real-time	Y	Y	Y	Y	Y	Y	Y	Y

#	Relevant Audience	Training Name	Afghanistan	Bangladesh	Bhutan	India	Maldives	Nepal	Pakistan	Sri Lanka
		dynamic line rating), IT system for automating system operation and market operation business functions (scheduling, accounting, trading, settlement, etc.) and international standards by International Electrotechnical Commission (IEC)/ International Organization for Standardization (ISO) for ICT infrastructure.								
11	Regulators	**Capacity Building on Regulatory framework for Cyber Security** Formalising cyber security code. The training shall cover importance of cyber security, national level framework (if any), roles & responsibility of concerned stakeholders, framework for creating an electronic security perimeter, methodology for incident reporting & response planning, re-	Y	Y	Y	Y	Y	Y	Y	Y

#	Relevant Audience	Training Name	Afghanistan	Bangladesh	Bhutan	India	Maldives	Nepal	Pakistan	Sri Lanka
		configuration requirement of vulnerability assessment of legacy systems, standardizing protocol for communicating with control centers and supply chain related risk management.								
12	Regulators/ Transmission operator	**Capacity Building on Assessment of Investments in GDR** Capacity building on framework / mechanism for regulator to evaluate and approve investments proposed by the TSO / ISO to improve grid discipline and reliability. This framework should establish linkage between outcomes (i.e., improvement in key indicators depicting grid discipline and reliability) and input (i.e., corresponding investments).	Y	Y	Y	N	Y	Y	Y	Y
13	Regulators/ Transmission operator	**Capacity Building for Disclosure of GDR related Information to General Public** Capacity building on	Y	Y	Y	Y	Y	Y	Y	Y

#	Relevant Audience	Training Name	Afghanistan	Bangladesh	Bhutan	India	Maldives	Nepal	Pakistan	Sri Lanka
		framework / mechanism for regulator and TSO / ISO to disseminate information about GDR aspects to general public (e.g., running a campaign on initiatives / investments by the government / regulator to provide 24x7 reliable and quality power to citizens)								
14	Transmission operator/ System operator	**Power system simulation exercise** Biennial power system simulator exercises to demonstrate how they would respond to and recover from simulated coordinated cyber and physical security threats and incidents, strengthen their crisis communications relationships, and provide input for lessons learned. It helps in strengthening of emergency response plans, building strategies to overcome system vulnerabilities, and strengthening of standards operating procedures for	Y	Y	Y	Y	Can be allotted when basic transmission system is developed	Y	Y	Y

#	Relevant Audience	Training Name	Afghanistan	Bangladesh	Bhutan	India	Maldives	Nepal	Pakistan	Sri Lanka
		communications with control centre.								

7.2. Details of specific technical capacity building measures:

The Details of the specific technical capacity building measures are described as given below:

7.2.1. Introduction to Grid Discipline and Reliability

Following the importance of maintaining Grid Discipline and Reliability in the power system, it is imperative to introduce the same to the regulators of the power system. The objective of this capacity building measure is to introduce the concept of grid discipline and grid reliability, familiarize the regulators on ways to achieve GDR, its benefits and opportunity costs.

The capacity building measure shall consist of workshops, training material and webinars covering following topics:

1. Definitions of grid discipline, grid reliability and related common terminologies.
2. Importance of maintaining grid discipline and reliability in the power system network.
3. Technical parameters defining grid discipline and reliability, ways to measure and monitor them.
4. Various measures to be taken in order to achieve grid discipline and reliability in the power system.
5. Case studies covering the SAR countries and other countries demonstrating the benefits of implementing measures for GDR and corresponding opportunity costs.

7.2.2. Capacity building on development of grid code

The Grid Code works as the sole regulations governing the functioning of the Electric Grid. The objective of this capacity building measure is to support in development of the Grid Code which is to be followed by various participants to plan, develop, maintain, and operate power system in the country in a secure, economic, reliable, resilient, and efficient manner.

The capacity building measure shall consist of workshops, training material and webinars covering the following topics:

1. Need for development of Grid Code as the regulations that lays down the rules, guidelines, and standards to be followed by various stakeholders in the power system.
2. Common structure of the Grid Code and the elements of Grid code such as system planning, grid connection, scheduling & despatch, system protection, ICT & cyber security, monitoring, and compliance, etc.
3. System planning: Requirements for system planning, process of system planning and regulations enabling the same.
4. System construction & safety: Safety precautions to be undertaken during system construction, installation, operation, and maintenance of the power system
5. Grid Connection:

- Process to be followed for grid connection,
- Details of connection requirements for conventional and non-conventional generators and different types of consumers,
- Testing and commissioning guidelines to be followed before declaration of commercial operation.

6. System protection: Special protection schemes to be planned and implemented by the system operator and regulations for protection audit plans.
7. System operation:
- Technical standards & norms required for system operations such as outage planning, demand management, system security to be provided by the system operator and grid recovery procedures.
- Mechanisms for providing ancillary services, commercial mechanisms such as imbalance settlement mechanism for grid discipline and frequency control, etc. shall also be included.
8. Scheduling & despatch:
- Detailed requirement, procedure and timelines for scheduling and despatch process,
- Scheduling for renewable energy sources,
- Scheduling and despatch for inter-regional and cross-border transactions.
9. ICT & cyber security: Communication facilities required for facilitating necessary communication, data exchange and supervision/control of the grid between all the users of the grid and the system operator. Regulations pertaining to cyber security of the system shall also be included.
10. Monitoring & compliance: Periodic monitoring and compliance of all the rules, regulations and guidelines and need for mandatory third-party safety and protection audits to ensure effective grid discipline and grid reliability.

7.2.3. Capacity building on development of system planning manual and long-term transmission plan

Standardized system planning manual is needed to effectively develop and update the long-term transmission plan that functions as the strategic document for decision making in the power system. The objective of this capacity building measure is to facilitate development of a system planning manual and prepare a long-term transmission plan.

The capacity building measure shall consist of workshops, training material and webinars covering the following topics:

1. Need for system planning, documenting system planning manual and long-term transmission plan for maintaining GDR in the power system.
2. Detailed steps to be followed in the planning process of long-term transmission plan.
3. Prerequisites / data requirement for preparation of long-term transmission plan such as analysis of implementation of the previous long-term plan.
4. Planning criteria to be considered.
5. Advanced technical studies (e.g., power flow studies, fault analysis, steady state, and transient stability studies) to be conducted for transmission planning.
6. Reactive power and reserve margin assessment.
7. Minimum requirement for smooth integration of variable renewable energy with the grid.
8. Development and periodic updating of system planning manual.

7.2.4. Formulation of penalty/incentive provisions for promoting grid discipline

The performance-based penalty and incentive mechanisms helps in encouraging improvements in the quality of supply provided to the grid users and also promotes grid discipline. The objective of this capacity building measure is to enable the regulators to develop penalty/incentive mechanisms for promoting grid discipline in the power system.

The capacity building measure shall consist of workshops, training material and webinars covering the following topics:

1. Definitions of grid discipline and related common terminologies and importance of Grid discipline in the Power system.
2. Enforcement of grid discipline through regulatory mechanism with suitable examples from different countries.
3. Different models of Incentive/penalty mechanisms with detailed pros and cons for the same.
4. Practical experiences/ case studies on incorporation of penalty/incentive-based regulations.
5. Case studies indicating benefits harnessed by countries wherever such mechanism is present.
6. Road map for gradual implementation of penalty/incentive mechanisms including coverage of grid users and extent (intensity) of penalty/incentive.

7.2.5. Training program on international best practices in transmission system planning

The international best practices in transmission system planning shall help in ensuring effective utilization of the power infrastructure. The objective of this capacity building measure is to enable the regulator, system operator and other stakeholders in understanding, adopting, and implementing the international best practices in transmission system planning.

The capacity building measure shall consist of workshops, training material and webinars covering the following topics:

1. Introduction to system planning and long-term transmission plan in the power system.
2. Need for adopting international best practices in transmission system planning.
3. International best practices in transmission system planning - policies and technical aspects such as system studies, design, engineering, etc.
4. International best practices in economic and financial analysis for transmission system planning in order to understand the feasibility and opportunity cost of the same.
5. International best practices in environmental and social impact management in transmission system planning.
6. International best practices in quality assurance in system planning.
7. International case studies indicating improved utilisation of existing infrastructure and enhanced grid reliability through improvements in transmission system planning.

7.2.6. Strengthening standards for system safety and grid connection

The objective of this capacity building measure is to enable concerned stakeholders in developing and complying with standards and procedures for system safety and grid connection based on international best practices.

The capacity building measure shall consist of workshops, training material and webinars covering the following topics:

1. System safety
   a. Importance of system safety rules.
   b. Minimum safety standards required for substations/switchyards which cover the following topics:
      - Safe access to substations (while entering, departing, escorting personnel, etc.)
      - Working in substations and switchyards (general, Low Voltage (LV), High Voltage (HV) including HV apparatus testing, HV Gas Insulated Switchgear etc.)
   c. Minimum safety standards required for overhead lines and equipment with particular focus on working with HV transmission lines and cables.
   d. Minimum safety standards required for working with radio frequency transmitting communication apparatus.
   e. Moving beyond minimum safety standards - focus on best practices and rigorous standards employed internationally.
2. Grid connection
   a. Importance of clear, detailed, and standardised grid interconnection rules/procedures for generators, bulk power consumers, etc.
   b. Standard procedural requirements for grid users seeking interconnection which cover the following topics:
      - Nodal agency for granting interconnection requests,
      - Procedures and timeline for filing of application,
      - Standard format for the application form,
      - Application fee, and
      - Tests required for conventional and non-conventional energy sources prior to trial run for declaration of commercial operation, etc.
   c. Technical requirements to be fulfilled for connectivity to the grid, such as requirements related to:
      - reactive power compensation,
      - data and communication facilities,
      - system recording instruments,
      - safety responsibilities,
      - cyber security.
   d. Standard format for the Connection Agreement.

7.2.7. System protection - best practices and enforcement regulations

The objective of this capacity building measure is to design a system to minimize faults such as short circuiting and tripping, and to have the necessary infrastructure in place to mitigate, isolate, analyze and resolve system faults immediately when they occur.

The capacity building measure shall consist of workshops, training material and webinars covering the following topics:

1. Importance of a robust protection philosophy in maintaining grid reliability.
2. Establishing nodal agency(ies) and assigning stakeholder responsibilities in system protection.
3. Drafting a protection philosophy which covers the following topics:

- Design criteria,
- Line, cable, and substation protection,
- Reliability criteria,
- Protective relay settings and coordination,
- Protective relay maintenance and testing,
- Disturbance monitoring, recording, and reporting,
- Penalties for non-compliance, and
- Scope and frequency of protection audits.

4. International best practices to be implemented over medium-term and long-term time horizons.

7.2.8. Balancing the grid - ancillary services

The objectives of this capacity building measure are to: (i) understand importance of balancing the grid in terms of demand and supply in real-time through various interventions; (ii) develop and implement regulations and mechanisms for implementing the same

The capacity building measure shall consist of workshops, training material and webinars covering the following topics:

1. Understanding phenomena of demand-supply balancing in real-time and its impact on frequency and other grid parameters.
2. Understanding various types of ancillary (balancing) services and options to procure ancillary services.
3. Pricing of ancillary services in a non-market environment; treatment of the costs of ancillary services; Mechanisms for market-based procurement of ancillary services.
4. Allocation of balancing costs from both pre-contracted and uncontracted reserves as well as the use of implicit balancing.
5. Calculations and settlement of energy imbalance and other financial clearings.
6. Regulatory treatment of imbalance settlement surpluses and deficits.
7. Regulatory monitoring of implementation and impact of ancillary services.
8. Feasibility of implementing ancillary services are regional level.

9. Improving cross border infrastructure for optimized use of ancillary services / reserves.
10. Relevant case studies from South Asia and elsewhere.

7.2.9. Strengthening of outage management

Outages in the power system network results in direct or indirect losses in the system and severely reduce the efficiency. The objective of this capacity building measure is to design an outage management plan to effectively manage planned, forced and emergency outages which will result in lower frequency of outages, lower duration of outages and safe restoration of power to the grid.

The capacity building measure shall consist of workshops, training material and webinars covering the following topics:

1. Benefits of disciplined outage management.
2. Importance of accurate load forecasting in outage management.
3. Assignment of responsibilities to various stakeholders at regional and national level such as:

- load forecasting,
- preparation of outage management plans,
- review and finalisation of outage management plans, and
- monitoring of implementation.

4. Outage planning process to prepare and finalize the monthly/ quarterly/ annual outage management plans.
5. Procedures for planned outages, forced outages and emergency outages
6. Restoration plan and procedures after partial / total blackout.
7. Monitoring of reportable system events and reporting procedures for such events.
8. Relevance of assets for outage coordination.
9. International best practices on outage management to be implemented over medium-term and long-term time horizons.

7.2.10. Information and communications technology - best practices and implementation

With the developing power system, efficient communicationand data exchange has become inevitable. The objective of this capacity building measure is to familiarize power system operators and regulators with emerging information and communication technologies in power system domain.

The capacity building measure shall consist of workshops, training material and webinars covering the following topics:

1. Introduction: Power sector scenario of South Asian countries, level of maturity of SAR in terms of ICT implementations.
2. Role/importance of implementing ICT in power system (focusing on generic problem persistent in power sector and available ICT options).
3. Familiarization with present day ICT systems:

- OT Systems (SCADA, WAMS/PMU, AMI): Basic overview about technologies critical components and their benefits.
- Communication Systems (VSAT/OFC/PLC): Brief introduction to communication technologies and their benefits, introduction to communication protocols.
- IT Systems (Energy management system/ SO business automation applications): Brief introduction to IT systems, details of modules and features, benefits of IT systems to SO.

4. Risk associated to implementing ICT related to cyber security, overview of cyber security and its role in power systems, steps taken to secure critical ICT infra, case study of recent past cyber-attacks to power systems, brief overview to international ICT standards (IEC/ISO), highlight advanced cyber security solutions, outline key ingredients for cyber security manual for power systems.
5. Case studies of a few international system operators highlighting the following:
   - Brief description about new technologies
   - Steps taken by stakeholders to implementation of new technologies
   - Benefits harnessed by utilities.

7.2.11. Capacity building on regulatory framework for cyber security

When it comes to helping transmission utilities set targets, regulators should ensure that key areas pertaining to cyber security are addressed. The specific measures include planning for response in case of cyber-attacks and putting in place proper governance structure that ensures a robust cyber security framework. The aim is to ensure that utilities have designated people and procedures to respond in a comprehensive, focused, and well-planned manner to serious events.

The capacity building measure shall consist of workshops, training material and webinars covering the following topics:

1. Planning: Importance of planning for responses to cyber-attacks and cyber threats posed to the grid so that the responses are not haphazard, reactive, or fragmented. Key elements of planning, process of planning by utilities, compliance, and monitoring.
2. Standards: Introduction to prevailing standards in cyber security, awareness of best practices and compliance with obligations.
3. Reporting: Importance of transparency and information sharing for effective coordination among the utilities and stakeholders to cyber threat preparedness.
4. Procurement: Procurement of key IT assets shall be done considering cyber security as important parameter. This is important from systemic and interdependency-aware thinking point of view.
5. Personnel and policies: Integration of risk management across the utilities, including role-based access control, IT policy, etc.
6. Risk management: A security perspective that addresses security over compliance, i.e., being proactive instead of reactive.
7. Governance: Importance of having a proper governance framework. Reporting and transparency create accountability for performance.

8. Systems and operations: Integrating cyber security as part of systems and operations. The plans should have a feedback look (Plan à Do à Check à Act à Plan) and should not just be a one-time checkbox.

7.2.12. Capacity building on assessment of investments in GDR

Assessment of investment for infrastructure projects focuses on techno-economic and financial viability of the project. This consists of assessment of fixed and recurring direct costs, opportunity costs, tangible and intangible benefits, net present value, payback period, return on investment, etc. It is difficult to measure the benefits and quantify the return on investments required for strengthening grid discipline and grid reliability (for example: prevented revenue loss due to avoided outages). The objective of this training therefore is to build capacity on assessment of investments in grid discipline and grid reliability requiring special approach / techniques to measure and quantify the benefits of investments.

The capacity building measure shall consist of workshops, training material and webinars covering the following topics:

1. Basics of time value of money, interest rates, cash flow analysis, financial statements
2. Best practices for assessment of fixed and recurring direct costs, opportunity costs, tangible and intangible benefits, net present value, payback period, return on investment, etc. for the power sector projects
3. Determining return on investments, which shall cover the basics of determining cost of capital with common methodologies such as Capital Asset Pricing Model (CAPM)
4. Calculation of a discount rate which takes into consideration additional benefits of grid discipline and reliability that are harder to quantify. For example: cost savings from reduced frequency of supply outages and lower cost of maintenance and repairs
5. Project characteristics, risk analysis, and risk management which discusses the following:
    - Different stages of a project
    - Risk involved in each project stage
    - Risk management, with specific focus on risk allocation through contract agreements
6. Funding a project which includes:
    - Specific focus on Public private partnerships (PPP) and different levels of private participation
    - Various funding options in debt and equity
7. Estimating project cash flows, payback period, return on investment, etc.
8. Relevant case studies focusing on investments related to GDR infrastructure

7.2.13. Capacity building for disclosure of GDR related information to general public

The general public being on the major stakeholders of the power system, it is extremely vital to keep them aware and updated on the developments of the power system. The objective of this capacity building measure is to strengthen framework / mechanism for regulator and TSO / ISO to disseminate information about GDR aspects among general public.

The capacity building measure shall consist of workshops, training material and webinars covering the following topics:

1. Transparency - what it means and why it matters?
2. Regulatory tools for achieving transparency (Regulations that support - periodic information disclosures in the public domain, public consultations, speaking orders etc.)
3. GDR specific disclosures and their impact (e.g., will such disclosure improve general public's willingness to pay more for better quality of supply?)
4. Case studies covering impact of progressive transparency on improvement in grid discipline and grid reliability.
5. Regulatory toolkit for promoting transparency.
6. Framework for measuring impact of transparency on improvement of regulatory effectiveness in the area of GDR.

7.2.14. Power system simulation exercise

The objective of this capacity building measure is to provide concerned stakeholders an opportunity to exercise emergency response and recovery plans in response to simulated cyber and physical security attacks and other contingencies affecting power system. The goal of this exercise is to enhance operational response capabilities of utility staff.

The capacity building measure shall consist of workshops, training material and webinars covering the following topics:

1. Identification of exercise scenario and supporting tools with a team of industry subject matter experts.
2. Customize the scenario to meet their own learning and training objectives. Each customized scenario should remain reasonably consistent with the overall flow of the exercise.
3. Exercise knowledge partner shall conduct web-based information sessions to provide organizations with updates on the planning process, scenario design, planning material, and exercise tools
4. At the conclusion of the exercise, participating organizations will be asked to respond to an after-action survey. The summary will help develop observations and recommendations for a lesson learned report.
5. The final outcome of the exercise shall be decided based on following objectives: -
   - Level of implementation of incident response plans,
   - Assessment of impact on local and regional utilities,
   - Coordination with interdependent sectors,
   - Level of communication: Assessment of information flow to concerned stakeholders.

**********************End of report**********************