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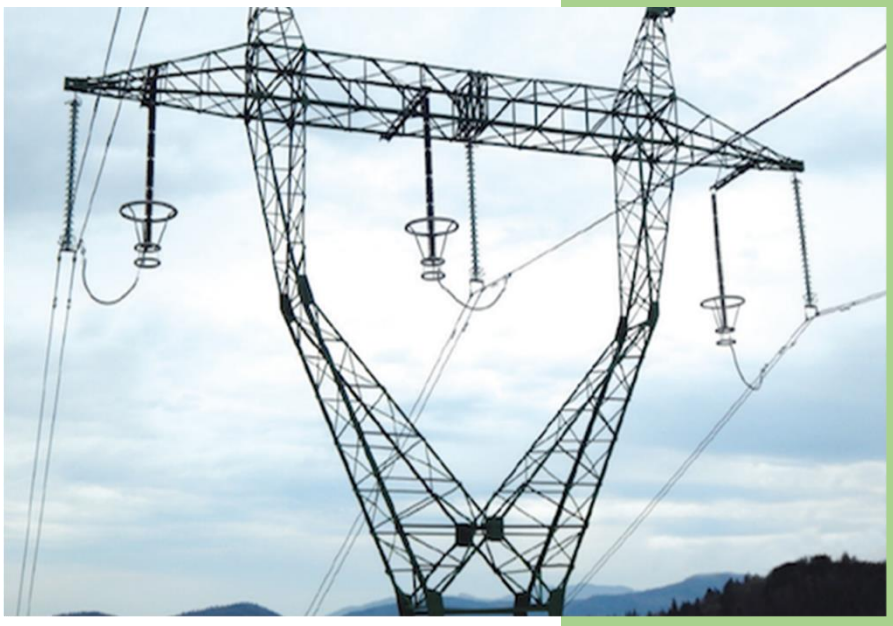
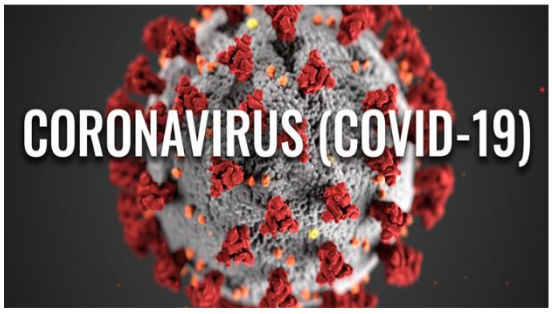
Resilient Indian Power System: Multiple challenges during 'COVID-19' pandemic outbreak and their mitigation





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Resilient Indian Power System : Multiple challenges during 'COVID-19' pandemic outbreak and their mitigation

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Abstract—Coronavirus Disease (COVID-19) is an infectious disease caused by a newly discovered Coronavirus and can spread from person to person through contacts. The Coronavirus stated to have been initiated sometime in the month of December 2020 from China and by around 11th of March 2020, it was declared to be a pandemic outbreak by World Health Organization (WHO), when it was found to have spread to more than 100 countries with large number of positive cases as well as deaths across the globe. Initially in India the spread of COVID-19 was not as serious as in other parts of the world, like in many countries in Europe, USA, South Korea and Iran. However, by middle of March 2020, the spread of Coronavirus assumed serious concerns in India also and in order to arrest the same and to ensure social distancing amongst the people, w.e.f. 25th March 2020, lockdown in whole of the India was imposed, initially for a period of 21 days upto 14th April 2020 and then was continued further till 3rd May 2020.

With the whole of India under lockdown, all the offices and industrial & commercial units, except the establishments which come under the category of essential services were closed, resulting into steep reduction in electricity consumption in the country. The result was large gap between demand and supply. This paper describes that under the lockdown period : a) in what manner and quantum the loss of the load in the Indian electricity grid was observed; b) how the balance between the severely curtailed load and the generation was achieved; c) how the must-run status of renewable generation was maintained, even under the stressed conditions in the grid; and d) what all specific steps were taken by the power system utilities to operate the grid with safety and security without any glitches under such difficult conditions, exacerbated with lockdown and social distancing. Large reduction in demand and hence the substantial surplus generation available in the grid, also caused lowering of the prices of the electricity traded under market and the paper also discusses that how the volumes and prices of the electricity traded under day ahead market in the power exchange moved.

Keywords—COVID-19 lockdown social distancing, safety, security, economy, peak demand, daily energy, renewable energy sources. cross border trade; day ahead market; solar generation; wind generation; 'must-run status', zero cost energy, grid balancing, flexing of thermal generation,

I. INTRODUCTION

By middle of March 2020, the spread of Coronavirus became serious concerns in India. In order to arrest this, and to ensure social distancing amongst all the people, w.e.f. 25th March 2020, pan-India lockdown was proclaimed, initially for a period of 21 days and then was extended further for another 19 days. It was notified that under lockdown, all the offices, business and commercial establishments, educational institutions and industrial units etc., except the establishment/units which come under essential category, shall remain closed and people were advised to remain confined to their homes, except under emergency conditions like towards seeking medical help etc. The lockdown imposed in whole of the country to contain the Coronavirus pandemic outbreak, presented a unique challenge to the power system operators due to very large reduction in the demand in the electricity grid and that too for a sustained long period. In a power system, based on the natural load patterns, occurrence of certain variations in the demand during the day is a normal phenomenon. In a large grid like that of India, since these variations are spread over a wide area and due to diversity of demand and other factors, such variations are addressed seamlessly. However, during current period when the system demand was already on the lower side due to favorable weather conditions, in view of the lockdown to address the situation arising out of COVID-19, there was an abnormally large reduction in the electricity demand, causing an additional drop of around 25% in the demand all around, and that too for a sustained long duration. This threw typical challenges to the grid operators and the paper describes in detail, that what were the different challenges

under these conditions and how each of these were dealt in a suitable manner and also gives an insight about the robustness and the sound systems and principles, on which the electricity grid in India is operating. It also gives an opportunity to dwell upon the fact, that how the standard systems and procedures to handle similar situations, can be refined further, in order to meet such situations, if occur in future.

II. SPECIFIC CHALLENGES TO INDIAN ELECTRICTY GRID UNDER LOCKDOWN

Currently, Indian Electricity Grid has an installed capacity of 369 GW as on February, 2020[1] and the break-up of the installed capacity in the Indian electricity grid is shown below in the *Figure* 1 [1]. It can be observed that it is a predominantly thermal grid with smaller but growing share of renewable of power.

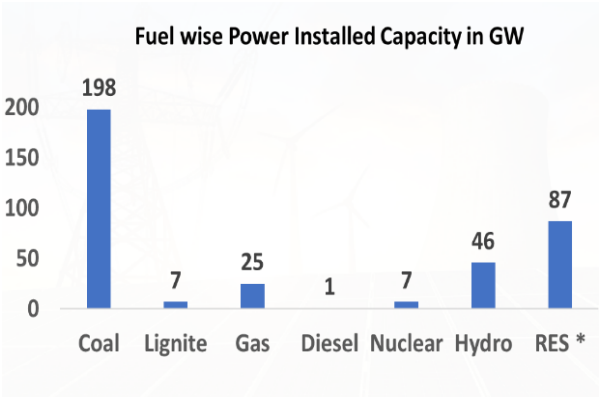

Figure 1 Fuel wise Power Installed Capacity in GW [1]

With the declaration of the lockdown, it was eminent that the demand in the grid would reduce and for that substantial generation will have to be identified for closing down/backing down. Under such conditions, the another important point which needs consideration is that due to closing of the offices and commercial establishments, the load curve also gets distorted to the extent that the load reduction is more during the day time, while during evening peak period due to continuing of the residential lighting load, the reduction in the demand may not be of equivalent quantum.

In addition to overall reduction and substantial changes of load profile, second challenge was to keep the must-run status of renewable power intact. Hence under the changed situation, envisaging the right demand curve, planning the generation level according to right mix of energy resources and maintaining the grid safety, security and economy were some of the main operational challenges and the need of the hour.

III. LARGE REDUCTION IN DEMAND IN THE INDIAN GRID DUE TO LOCKDOWN

Prior to lockdown, the peak demand met in the Indian electricity grid on a typical day, say 18th March 2020 (just one week before lockdown) was of the order of around 164.4 GW with the whole day energy in the range of around 3605 MU. Out of this, the contribution from Hydro was 315 MU (9%), from Wind & Solar (RE) was 251 MU (7%) and the balance (84%) was from thermal sources. However, with the lockdown there was a substantial reduction in the demand. The *Figure 2*[2] shows the comparison of the demand met in the Indian Grid on the day of lockdown, i.e. 25th March 2020 (lowermost curve) with that of 18th March 2020 (uppermost curve), i.e. precisely one week before. The other three (3) load curves in between, pertains to the days 22nd, 23rd and 24th March 2020 and these also have the reduced load due to the restrictions being imposed in the country w.e.f. 22nd March 2020 itself.

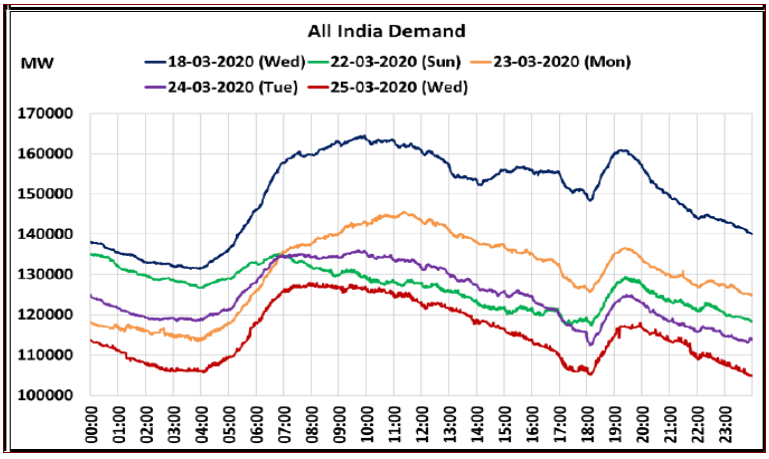

Figure 2All India Power Demand-Comparison of the demand met [2]

The *Figure 3* [3] shows the comparison of the Max Demand Met and Energy Met in the Indian Grid one week before the imposition of lockdown (18th-24th March) and one week after lockdown (25th-31st March 2020)[1].

On the basis of the values shown in *Figure 3* [3] and comparing the averages of three days of the Max. Demand and Energy Met, prior to COVID-19 lockdown vis-a-vis post lockdown, the representative values of variations are shown in

[1] For analysis in this paper 18th-24th March is considered as pre lockdown period and 25th-31st March 2020 is considered as post lockdown period.

Figure 4 [4] below. As can be seen from Figure 4 [4], due to COVID–19 effects, there is a decline in the peak demand by a factor of 26.10 %, while the decline in Daily Energy met is by 25.48%. In fact, on a particular day, i.e. on 27th March 2020, the values of Demand Met have come down still lower, i.e. 115.2 GW in terms of Peak Demand and 2592 MU in terms of energy. However, to avoid such individual cases, where the demand may have been affected due to weather conditions also, the average values for the representative week/days have been evaluated, in order to present the values in a more realistic manner.

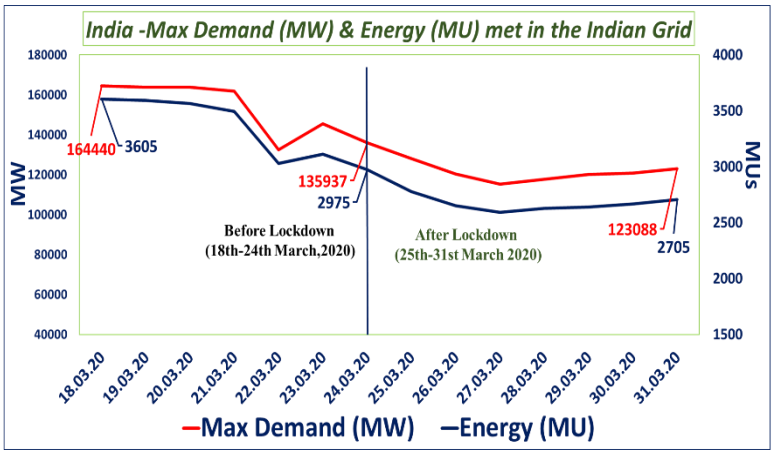

Figure 3 India -Max Demand (MW) & Energy (MU) met in Indian Grid [3]

In order to understand the change in the load pattern during this period, the All India Demand trends curves for a longer duration are shown in *Figure 5*[5] . First week in the figure (shown in blue color) is for the period 07.04.19 to 13.04.19 i.e. almost one year before the current period. The trends of all the 7 days in the week show normal load pattern with peak demand persisting in the range 155-170 GW. The second week in the figure (shown in green color) is for the period 22.03.20 to 28.03.20, i.e. the week during which the lockout as on 25.03.20, started. This clearly shows the sharp fall in the peak demand from 160 to 120 GW & below due to the effects of COVID-19.

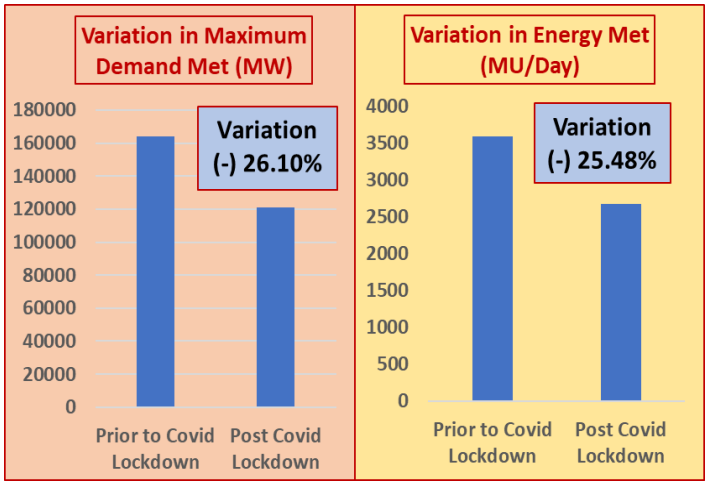

Figure 4 Variation in Demand met in Indian Grid [4]

The subsequent two weeks in the *Figure 5*[5], i.e from 29.03.20 to 11.04.20 shows the peak demand varying in the range of around 120 GW, substantiating that after the lockdown, the peak demand has more or less settled at a reduced level of around 40 GW (25%) less than the peak demand during the normal (pre COVID-19) period. The analysis of the variation in the daily energy figures (MU/Day) is also on the similar lines, substantiating that post COVID-19, there is an additional reduction in power consumption in the country by around 25% on consistent basis for weeks together, which is very high and unprecedented and affects the techno economic viability of the various components of the power system. *Figure 6* [6] shows the daily demand pattern in the All India Grid up to 16th April 2020, indicating a slight increase in the demand reaching up to 130 GW. This is however in view of the onset of summer period and increase in some weather beating load. However, looking into the pre COVID-19 level of demand, which was around 160 GW, the current level of demand is still on very low side.

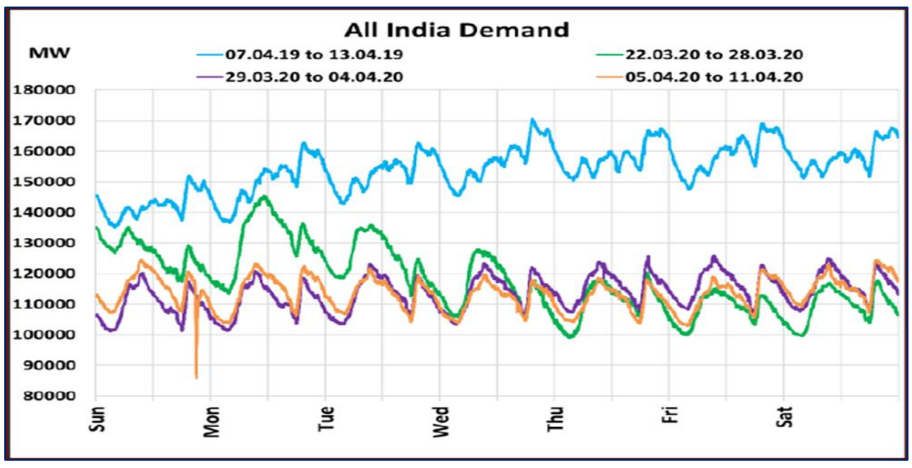

Figure 5 All India Demand trends curves for a longer duration [5]

IV. MAINTAINING MUST-RUN STATUS OF RENEWABLE GENERATION

As indicated earlier, out of the total installed capacity of 369 GW in India as on February 2020 [1] , the capacity pertaining to hydro generation is 45 GW (12.4%) and total other renewable capacity is 86.3 GW

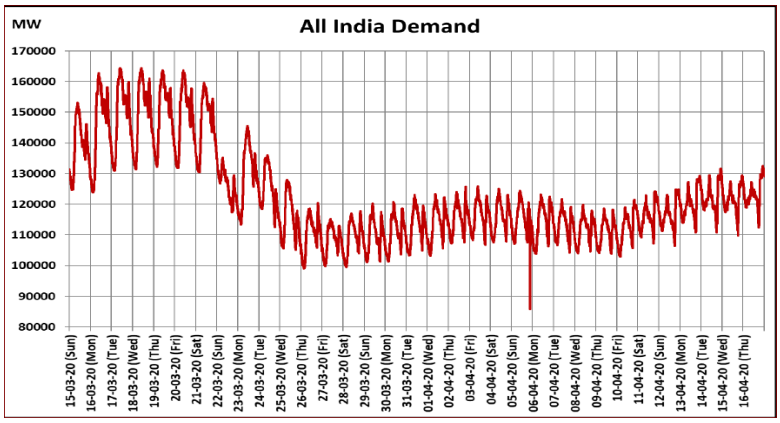

Figure 6 daily demand pattern in the All India Grid up to 16th April 2020 [6]

(23.48%). Out of renewable, the components of wind and solar are 37.6 GW (10.2%) and 34 GW (9.3%) respectively. The break-up of renewable capacity is a shown in the *Figure 7* [7] .The comparison of the operation of the various forms of generation, viz. renewable and thermal, to substantiate that how the challenge of preserving the must-run status of renewable generation during this period was met is given in the following paras:

Hydro Generation:

In case of hydro generation, a part of it being reservoir based, was religiously used by the utilities and grid operators to meet the peaking demand and the other hydro capacity falling under run of the river capacity, was also used without any restrictions, being zero cost energy. The details of hydro generation in the Indian grid and comparison of average generation, prior to the COVID-19 lockdown and post lockdown are shown in the *Figure 8* [8] . It can be seen from *Figure 8* [8], that due to COVID–19 effects, there is no reduction in the generation at Hydro Plants, rather there is an enhancement by (+) 3.84%, which could be there because of change in inflows. From this it can be inferred that due to COVID-19 lockdown, there was literally no loss/spillage of zero cost hydro energy.

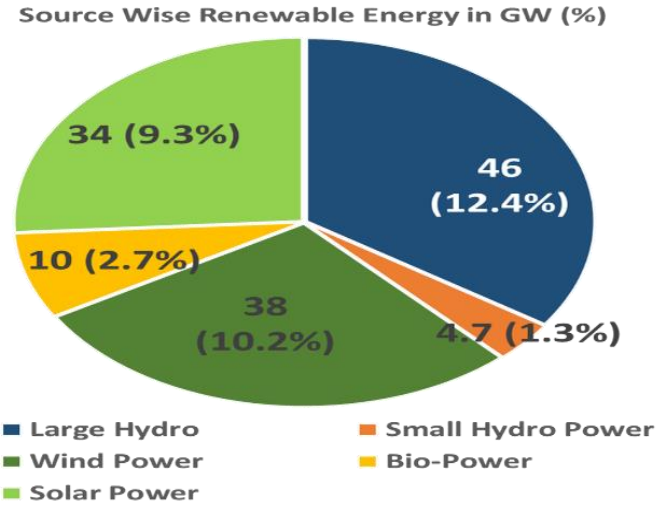

Figure 7 India- Source Wise Renewable Energy in GW (%) [7]

Wind Generation:

Wind generation in the Indian Electricity Grid is considered under 'must-run' category which means that this shall not be subjected to merit order dispatch and the System operator shall make all efforts to evacuate the available wind power. The details of wind generation in the Indian grid and comparison of average generation, prior to the COVID-19 lockdown and post lockdown are shown in *Figure 9* [8]. It can be seen in the *Figure 9* [8] that between the periods prior to COVID-19 lockdown and post lockdown, there is no reduction in the generation at Wind Plants, rather there is an enhancement by (+) 25.75%. Since the generation from wind is seasonal in nature and it starts building up at this point of time, i.e. around the month of March, the enhancement of generation at wind plants is natural. This

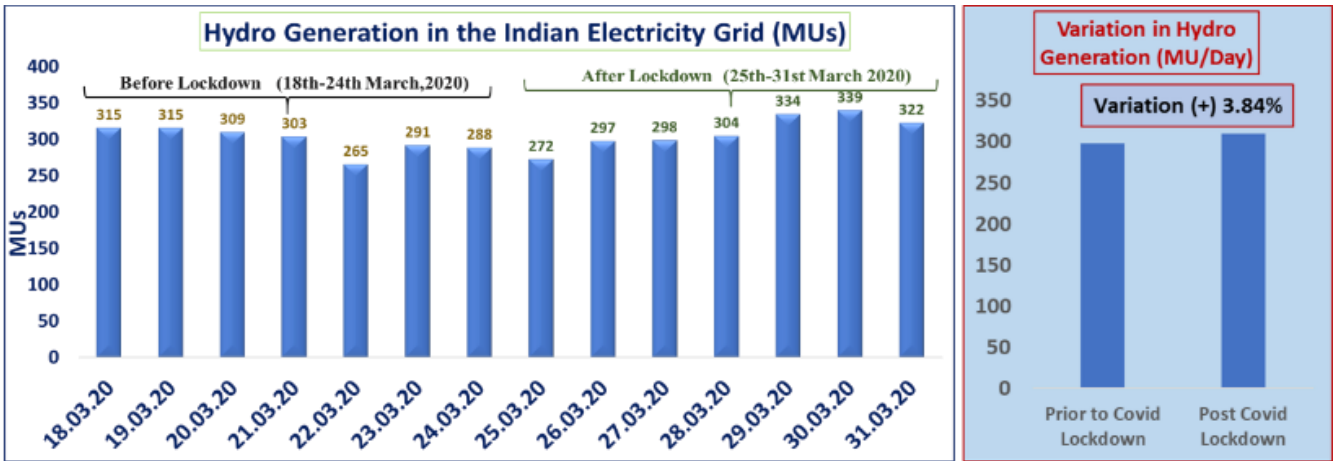

Figure 8 Hydro generation in the Indian grid & comparison of average generation- prior and Post COVID-19 lockdown [8]

however also substantiates that due to COVID-19 lockdown, there was primarily no backing down of the wind generation and its must-run status has been maintained.

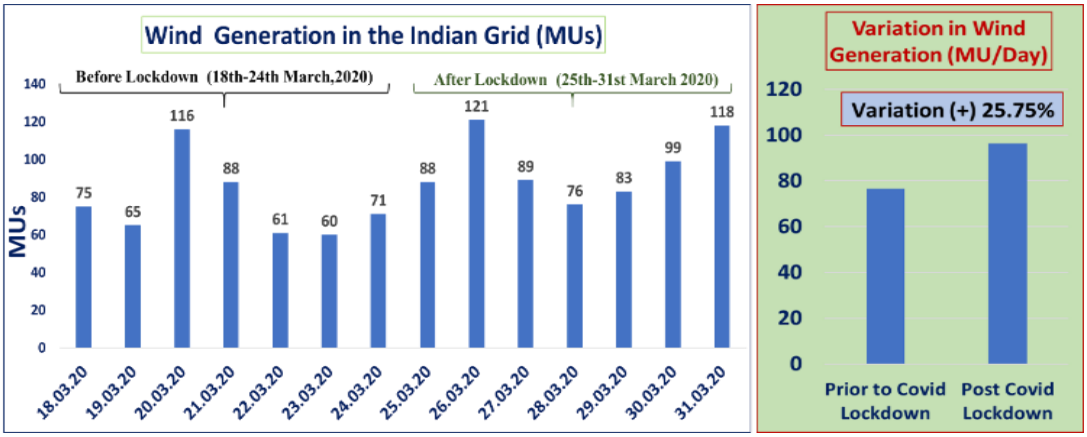

Figure 9 Wind generation in the Indian grid & comparison of average generation- prior & Post COVID-19 lockdown [8]

Solar Generation: In the Indian Electricity Grid, like Wind generation, the generation from Solar, also falls under 'must-run' category and it is envisaged that the System operator shall make all efforts to evacuate all the available solar generation also. The details of the solar generation in the Indian grid and comparison of average generation, prior to the COVID-19 lockdown and post lockdown are shown in the *Figure 10* [8] . It can be seen from *Figure 10* [8] that the average level of generation from solar plants during the period prior to COVID-19 lockdown and post lockdown is just 1.65%, which is insignificant. This small reduction in the solar generation post lockdown period can be attributed to the weather conditions and hence it can be inferred that due to COVID-19 lockdown, there was primarily no backing down of the solar generation also and along with wind, the solar generation must-run status was also maintained.

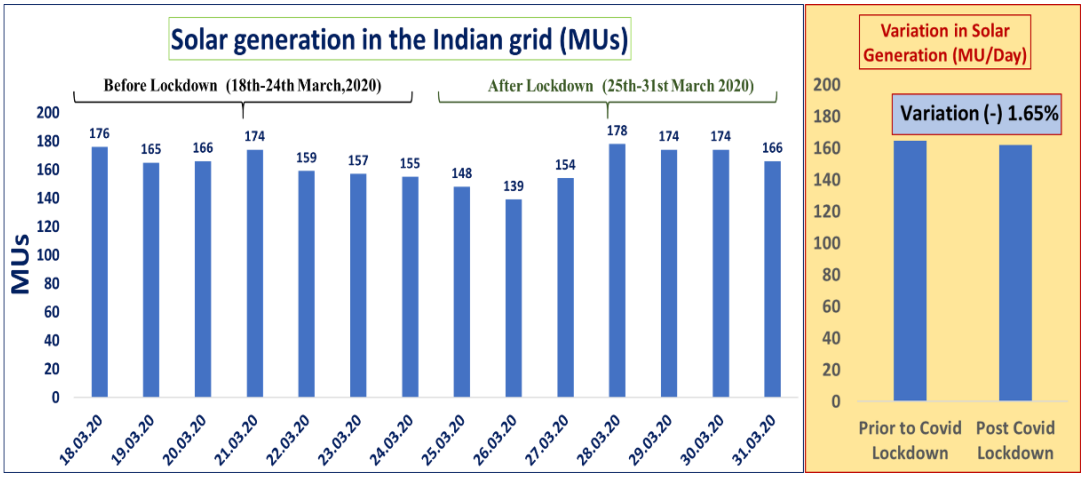

Figure 10 Solar generation in the Indian grid & comparison of average generation- prior and Post COVID-19 lockdown [8]

Thermal Generation: In the Indian Electricity Grid, currently out of the total installed capacity of 369 GW as on February 2020[1], the capacity of thermal generation (consisting of Coal, Lignite, Gas and diesel) is 230 GW, which converts to a share in the range of around 62.30 %. In terms of energy, the thermal generation constitutes the major share in the range of around 80%. The main fuel component in the thermal generation is coal, constituting a share of around 86%. With more and more RE capacity addition to the grid, thermal generation is being used as the main source towards flexing of the generation and grid balancing. In general, during the months of March and April in any year, the

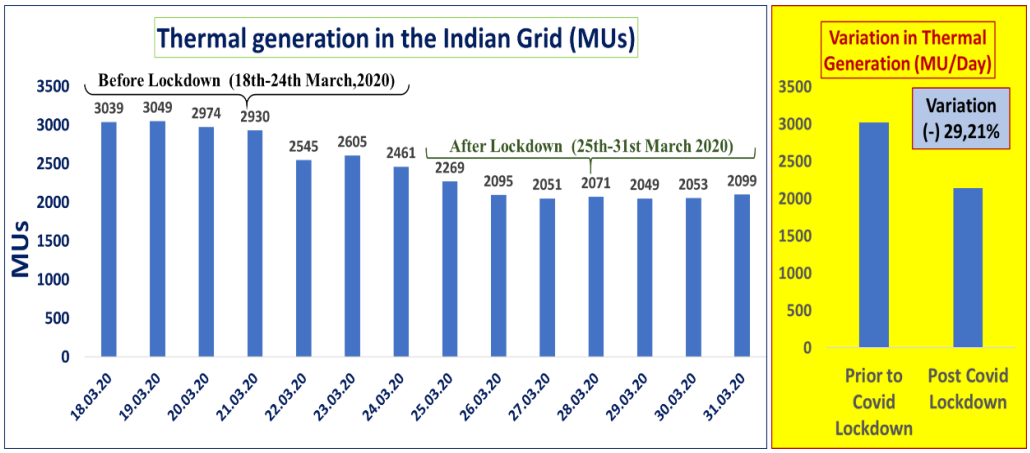

Figure 11 Thermal generation in the Indian grid & comparison of average generation- prior& Post COVID-19 lockdown [8]

demands are invariably on the lower side due to favorable weather conditions and to address the same the thermal generation in the grid was already operating at reduced level. However, to meet the situation of reduction in load, arisen due COVID-19 lockdown, very large quantum of additional reduction in the generation at thermal generating stations was proclaimed. The details and comparison of average thermal generation in the Indian grid, prior to the COVID-19 lockdown and post lockdown are shown above in *Figure 11* [8] Comparison of these values substantiate, that between the periods prior to COVID-19 lockdown and post lockdown, there is a substantial reduction in the generation level at Thermal Plants and in terms of daily average energy it goes as high as (-) 29.2%.

The above analysis shows that even under such typical situations, involving very high quantum of load crash, by flexing/backing down the thermal generation to high values, the need to back down other forms of renewable generation, mainly wind, solar and hydro, which have must-run status was averted and rendering saving towards carbon emission.

VI. EFFECTS ON THE ELECTRICITY MARKET (PX) VOLUMES & PRICES

Indian Electricity Grid has a number of products in its electricity market, which includes trades during long term period (more than 7 years), medium term period (1 to 3 years) and short-term period (up to 3 months). In addition to these there is another very popular product in the market, known as Day Ahead Market under Power Exchange (PX) and the price discovery for these trades is being carried out in a transparent manner by inviting double side bidding both from buyers and sellers. The daily price discovered under PX market is being used for settling the deviation mechanism also amongst the different players in the market and total volume transacted under PX varies in the range of around 4.16% [9] of the total electricity consumption in Indian electricity grid and during the year 2018-19 it was in the range of 53.52 Billion Units [10]. Subsequent to COVID-19 lockdown there was crash in demand in the Indian electricity grid, resulting into surplus conditions.

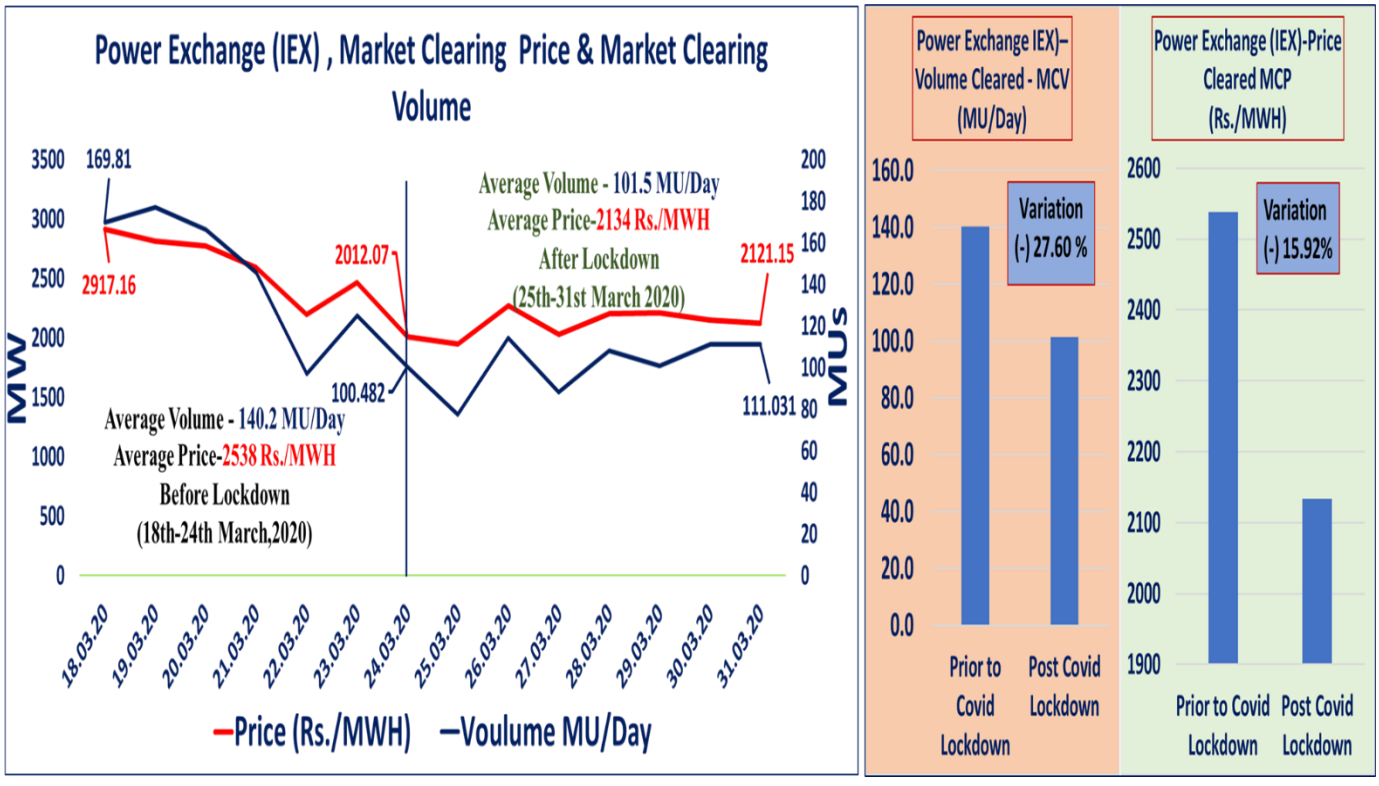

Figure 12 Power Exchange: Market Clearing Volume & Market Clearing Price (MCP) & average drop in MCV and MCP during Pre and Post COVID-19 lockdown [11]

Figure 12 [11] above shows the volume of electricity traded (Market Clearing Volume –MCV) in the PX and the discovered Market Clearing Price (MCP) and average drop MCV and MCP during the periods just prior to COVID-19 lockdown (18th-24th March 2020) and post COVID-19 lockdown (25th-31st March 2020). As shown in the *Figure 12* [11] post COVID-19 lockdown, the Avg. drop in the Market Clear Volume was from 140.2 MU/Day to 101.5 MU/Day, i.e. a drop of 27.6% and the Avg. drop in Market Clearing Price was from Rs. 2538/MWH to Rs. 2134/MWH, i.e. a drop of around 16%. The drop in the market

clearing volume and prices under surplus situation is a testimony towards the sound principles on which electricity market in India is operating. At the same time, market products of this nature also render valuable avenues and a healthy platform to meet such the contingency conditions in the grid.

VIII. MANAGING CONTINUITY OF CONTROL CENTRE OPERATIONS

In addition to all the above functions mentioned related to the grid operation, another most important function rendered was towards ensuring continuity of Load Dispatch Centre (LDC) operations, particularly, round the clock operations of the control centers. By strictly following the, social distancing protocols amongst the operating personnel and through sanitization and upkeep of the work area, the premises of the control centers were maintained safe and secure and operative on round the clock basis. All other logistics support were also ensured for the smooth operation of the control centers and the functions which were not real time and off grid in nature, were converted in the category of 'Work from Home' in order to minimize the personnel interaction in the control centers.

Further, in order to have the coordinated approach amongst the operators of different LDCs, viz. NLDC, RLDCs and SLDCs, urgent meetings and interactions were held amongst the members of the control centers through Forum of Load Despatchers (FOLD). In the interactions, agreement towards quick and ready support from one control area to another, in case of any criticality was arrived at and it was agreed to have regular interactions through Con-calls/Video Conferencing to resolve any outstanding issues. It was also agreed to carry out of periodic drills and exercises so as to keep the system in readiness to meet any eventuality.

Another important pro-active decision towards maintaining continuity of control center operations was to keep in readiness and operation the back-up control center, so that in the event the main control center premises are infected and needs to be sanitized and quarantined, the operations are switched over to the back-up control center without any interruption.

IX CONCLUSIONS

As a result of the lockdown to address the effects of Coronavirus pandemic outbreak, Indian electricity grid faced high quantum of load reduction and that too for a sustained long period. In general the months of March and April are considered as low demand months in any year, due to favorable weather conditions and against the peak demand of around 184 GW already met in the grid during the year 2019-20 [12], the peak demand prevailing during the current period was in the range of around 164 GW only. Under these relatively low demand conditions prevailing in the grid, due to lockdown, there was additional load crash of the order of around 40 GW during the peak period. Further in respect of daily energy consumption also, there was an additional loss of around 900 GWH of energy, which constitutes around 25% of the normal consumption in the electricity grid. During this period, a number of challenges were faced by the operators in the Indian electricity grid and they were mitigated with success. Some of the main challenges include i) to continuously balance the load generation in real time under all these conditions; ii) to find out the ways and means to protect the must-run status of renewable generation, by dispatching them in full, even at the cost of closing down/backing down of thermal generation to maximum possible extent; iii to ensure the continuity of the operation of the load dispatch centers and other control centers on round the clock basis, even under adverse physical conditions with restrictions on free movement. Under such situations, the demonstration of safe and secure operation of the Indian grid, support to the renewable generation to carry out full dispatch without any restrictions is certainly a remarkable feature and resilience shown by the Indian electricity grid to meet such challenges.

This incident of 'COVID-19' mandated that, under lockdowns/restrictions the movement of the personnel and other services were severely restricted in the affected places. It is therefore important that to meet such situations, all necessary steps are initiated to ensure continuity of load dispatch center operations, saving the operating personnel from getting infected by human-to-human contact and also maintaining the logistic support for the Control Centers in good shape. Under such conditions the reliability of the grid is also to be continuously assessed and close coordination and cooperation is to be maintained amongst the different

Control Centers, in order to meet any contingency with minimum effects. The focus of our analysis of course is limited with respect to grid operations only and it was observed that the operation of the power situation in the different parts of the grid was satisfactory.

The event also renders a good insight how the similar situations can be handled in future. We may use this as an opportunity to make a detailed policy paper based on the comprehensive and holistic impact assessment of such a situation. In the policy paper we can also address that how the disasters like COVID-19, which is a unique experience related with the human health, involving lockdowns and separations in the larger areas and for longer times, can be tackled with further confidence and satisfaction. The main point of thrust in the policy paper has to be, that under such conditions, how the electricity grid operations and continuance of electricity supply can be maintained with safety, security, reliability and economy.

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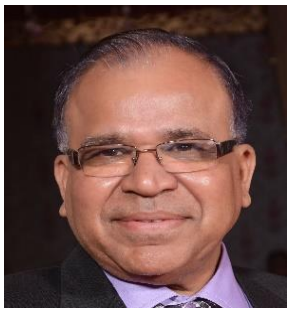
About the Authors



Mr. V K Agrawal is currently working as Technical Director at Integrated Research and Action for Development (IRADe) and working on SARI/EI Project. Mr. Agrawal has around 40 years of experience in the power sector. For a considerable period out of this, while working in POSOCO (Power System Operation Corporation Ltd.), he has served as Grid Operator in India in various senior capacities and relinquished the charge there in the year 2015, at the position of Executive Director.

Mr. Rajiv Ratna Panda currently works as Head-Technical, at Integrated Research and Action for Development (IRADe). Mr. Panda, engineer, management, research and development professional over a decade of rich & diverse experience and expertise in energy and power sector of South Asia , South East , Asia Pacific , Europe , USA Markets in the area of Grid Integration, power trade , regional power markets , policy, regulatory, legal, technical & planning aspects, subsidy Reform, Climate Change, Cross-Border Energy Trade (CBET), Investment Policy, Open Access, regional transmission planning and operation.

Dr. Jyoti Parikh is the Executive Director since the inception of IRADe in 2002. Dr. Parikh is the former member of the Prime Minister's Council on Climate Change – India and is a recipient of Nobel Peace Prize awarded to IPCC authors in 2007. Dr. Parikh has made valuable contribution in environment & climate change issues of the developing countries. Dr. Parikh served as the Senior Professor at Indira Gandhi Institute of Development Research (IGIDR), Mumbai, and was the Acting Director of IGIDR during 1997-98.

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