Learning from the COVID-19 experience - a framework for a resilient regional electricity grid for Bangladesh, Bhutan, Nepal and India.

Energy Insight

Dr Jyoti Parikh, Mr Vinod Kumar Agrawal, Mr Rajiv Ratna Panda, Mr Vinay Kumar Saini and Dr Jasleen Bhatti

November 2020

Abbreviations

BBIN	Bangladesh, Bhutan, India and Nepal
COVID-19	Coronavirus disease 2019
FOLD	Forum of Load Dispatchers of India
GWh/day	Gigawatt hours/day
HVDC	High Voltage Direct Current
LDC	Load Dispatch Centre
MW	Mega Watt
POSOCO	Power System Operation Corporation Limited

1. Introduction

During the last week of March 2020, all four BBIN countries in South Asia (Bangladesh, Bhutan, India, and Nepal) imposed major restrictions and began unprecedented lockdowns in order to fight the spread of the COVID-19 pandemic. To maintain social distancing and avert the spread of the virus through personal contact, all industries, offices, commercial and business establishments, and public places were closed down and people advised to stay in their homes. This impacted human life and all sectors in a significant way. The power sector was not immune. The lockdowns led to an unprecedented crash in electricity demand and a wide gap opening up between the electricity available and demand. The reduction in electricity demand in the BBIN region was as high as 25% (a drop in peak demand of around 40 gigawatts (GW) in the overall BBIN grid size of 180 GW). In terms of daily energy demand, the crash represented a drop of 950- GWh/day, out of the overall grid size of around 3800 GWh/day.

In this report we have limited ourselves to grid-level analysis that covers transmission and the overall grid across the BBIN countries. Since the electricity in these grids could not be stored and had to be balanced in real time, the personnel manning the electricity grids faced challenges in maintaining a minute-to-minute balance between demand and supply, and in managing the load curve, which changed substantially due to the abnormal conditions. Further, maintaining a balance between the different types of generation sources, on the basis of their operating costs, must-run status for renewables, and averting any spillage of zero-cost energy sources, was another important factor for grid operators to consider. Since the grids were to be kept operational on a round-the-clock basis, keeping the workforce healthy and safe and free of COVID-19, as well as keeping the control centres operational and free of any contagion/virus, were also major challenges during this period.

In this paper we describe: a) the perceived vulnerabilities/risks under these conditions, b) the impacts of the COVID-19 pandemic on the operation of electricity grids in BBIN countries, c) the real challenges in operating grids under these conditions, and how they were met, and d) the lessons learnt from this major outbreak, and what policies and frameworks could be developed to better address such situations should they reoccur in the future.

2. Background

The BBIN sub-regional initiative aims to improve economic cooperation and connectivity among the four South Asian countries, Bangladesh, Bhutan, India, and Nepal (Figure 1). Together, they have a population of around 1.55 billion, around one-fifth of the total global population. Taking into consideration the diversity of resources and the demand profile, electricity trade among the member countries in this sub-region is considered one of the important building blocks for larger regional cooperation in South Asia – and ultimately for regional economic integration.

Figure 1: BBIN sub-region

2.1 Country-wise power system snapshot of BBIN

Table 1 below shows a power system snapshot of the BBIN region and includes, for each country, the installed generation capacity and the peak demand and annual energy demand met during 2019–20. As can be seen from the table, the total quantum of energy exchanged among the different countries is around 15.6 thousand GWh per annum. Nepal meets 42%[1] of its peak demand and Bangladesh 9%[2] of its through cross border exchanges, while Bhutan exports the equivalent of 95%[3] of its installed capacity to meet demand in India. Looked at another way, cross border exchanges account for 72%[4] of the total energy in Bhutan's system , 31% in the case of Nepal 10% in the case of Bangladesh and just 1% in the case of India.

Table 1: Power system snapshot of the countries in the BBIN region[i]

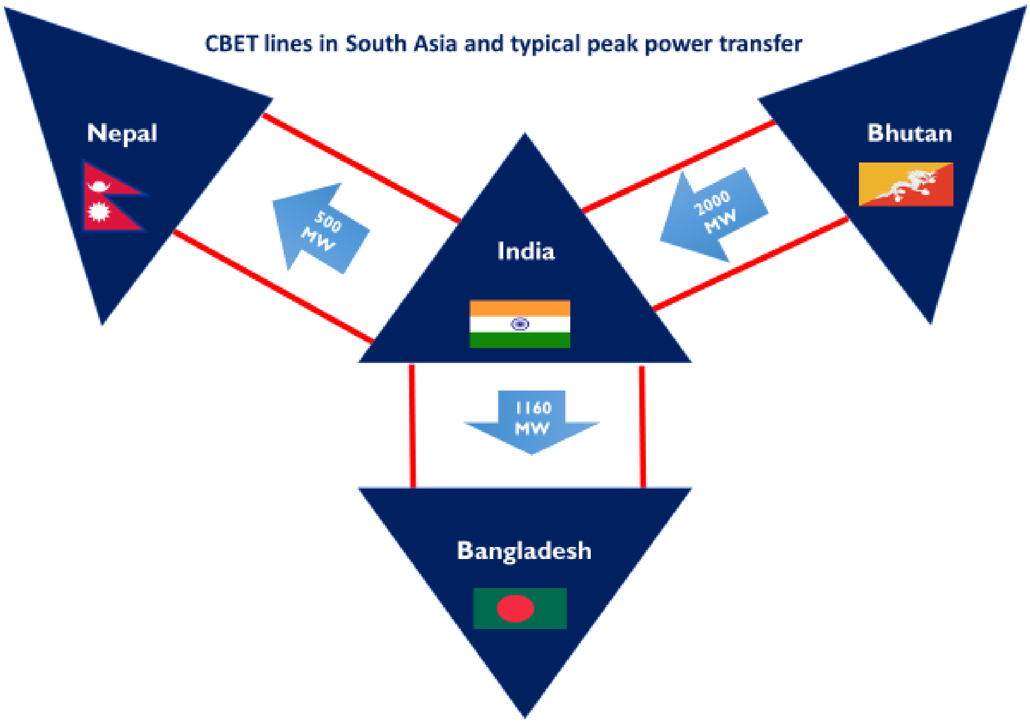
Country	Installed capacity (MW)	Peak demand met (MW)	Annual energy demand met (GWh)	Cross-border exchanges (peak MW)	Annual cross-border exchanges (GWh)	Annual per capita consumption (KWh)
India	370048	182533	1283690	3930	15680 (Import + Export)	1181
Bangladesh	23430	13040	70533	1180	6988 (Import)	375
Bhutan	2326	400	2414	2200	6311 (Export)	2976
Nepal	1100	1300	7551	550	2373 (Import)	245

2.2 Physical interconnections of the countries in the BBIN grid

[1] Calculated as cross border exchanges divided by peak demand met
[2] As above
[3] Calculated as cross border exchanges divided by installed capacity
[4] Calculated as annual cross border exchanges divided by annual energy demand for all examples

The South Asian countries that form the BBIN sub-region are connected through cross-border links. The prevailing interconnections are shown in Figure 2. The major interconnections are at 400 KV and 220 KV level, with a few links at lower voltages also.

Figure 2: Cross-border interconnections among BBIN countries



2.3 Lockdown in BBIN countries due to COVID-19 and its linkage with the electricity grid

On 11 March 2020, the World Health Organization declared COVID-19 a pandemic, after it had spread to more than 100 countries, with a large number of cases of infection, as well as deaths. In the BBIN region, although the spread of COVID-19 was initially confined to a few areas, by the middle of March it had become a serious concern, causing these countries to introduce lockdown measures that limited all economic activities in an effort to ensure social distancing and counter the spread of the virus. The lockdown timelines in the BBIN countries were as follows:

- Bhutan sealed all international borders on 23 March and a district-wise lockdown was imposed from 1 May[ii] following suspected community transmission.
- In Bangladesh, a 10-day nationwide holiday was declared with effect from 26 March, with all public and private offices closed apart from emergency services. The lockdown measures were extended, initially up to 25 April and then in phases until 31 May[iii] .
- In India, with effect from 22 March[iv] all international flights were stopped and from 25 March a lockdown was imposed across the whole country, initially for a period of 21 days up to 14 April but then continued in phases until 31 May.
- In Nepal, a country-wide lockdown came into effect on 24 March, initially until 7 May and then further extended to 2 June[v].

March is considered a relatively low electricity demand period in the BBIN countries, due to moderate temperatures and pleasant weather conditions, meaning the prevailing demand across the BBIN region at the time of lockdown was already on the lower side. The lockdowns caused a further steep reduction in demand and posed major challenges to grid operators in regard to maintaining the load generation balance and keeping the grid security intact.

3. Assessment of the vulnerabilities and risks in the BBIN grid due to COVID-19

3.1 Brief details of the vulnerabilities and risks

The vulnerabilities and risks in the BBIN grid related to COVID-19 can be broadly segregated into four categories, as shown in Figure 3.

Figure 3: Vulnerabilities in electrical grid in BBIN

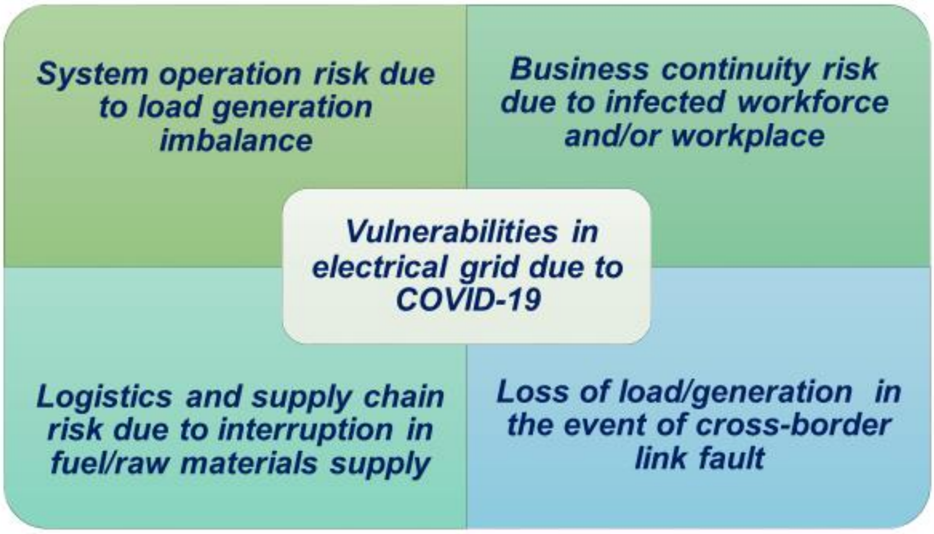


Table 2 below describes the different elements under each category.

Table 2: Description of the elements associated with different vulnerabilities and risks

Assessment of vulnerability and risk associated with electricity grid system	
Risk elements	**Description**
System operational risk due to load generation imbalance	• Industrial, commercial, business, and traction demand declines • Domestic demand increases • Load generation imbalance may cause grid instability and pose security threats and make system vulnerable
Logistics and supply chain risk and vulnerability	• Interruptions in fuel supply can impact the plant availability and can constrain the electricity supply • Raw materials availability may be impacted in short term due to supply chain disruption • Disruption in ancillary services and/or other logistics relating to plant operational needs
Risk of prolonged outage and loss of load / generating capacity disruption/fault in the cross-border link	• Potential delays to repairs if cross-border links develop faults • Forced shutdown of the link in order to avert contingent conditions in a country • Operations at the controlling substations at either end halt due to unforeseen circumstances
Business continuity risk	• Workforce may be affected due to virus or need to be quarantined • Control centre may be contaminated or need to be subject to sanitisation/ quarantine • Essential services/logistics like communication/transportation may be affected • Risk/threats due to cyber security issues

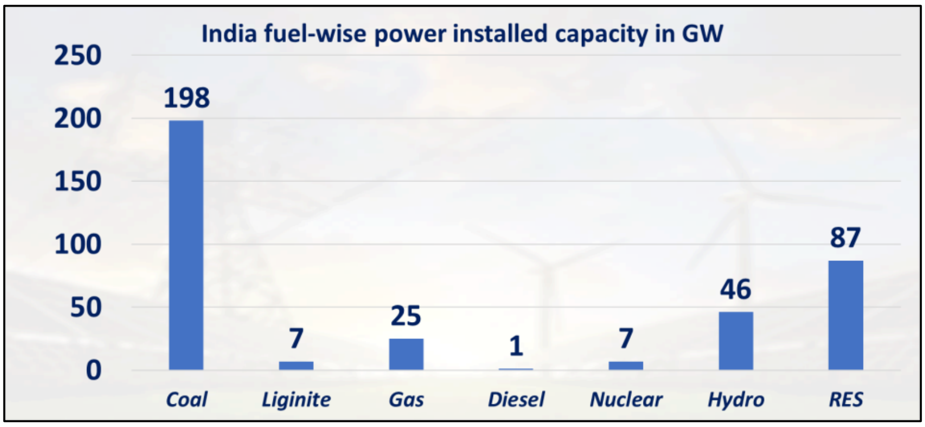
4. Impact of COVID-19 on the electricity grid systems of different BBIN countries

In order to identify the exact effects of lockdown on the electricity sector, the following paragraphs present the trends of electricity consumption in the different BBIN countries during the periods just before lockdown, immediately after lockdown, and in the subsequent weeks/months when restrictions were gradually eased.

4.1 Impact on the power supply position of the Indian electricity grid system

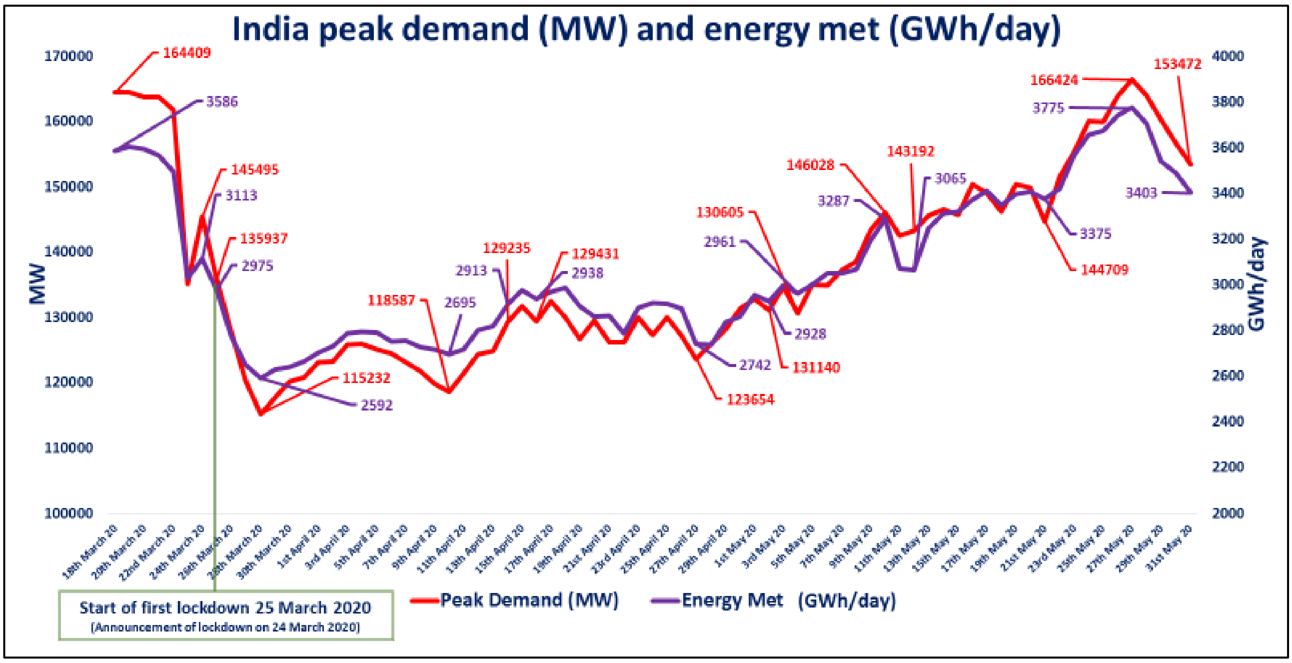
Figure 4 shows a breakdown of the installed capacity in India. As can be seen, while coal-based thermal generation capacity leads, renewable generation capacity comes second, providing 87 GW. The share of renewable capacity in the Indian grid is growing and there are plans to increase it to 450 GW by the end of 2030.

Figure 4: Breakdown of fuel-wise installed capacity in India[vi]



The trend in Figure 5 below shows the power supply position in India just one week before the lockdown period, immediately after lockdown, and during the subsequent period. As can be seen, at the time of lockdown the total peak demand in the All India Grid was around 164,409 MW[vii]. Due to the effects of lockdown this declined to 115,232 MW. Daily energy demand declined from its earlier level of 3,586 GWh/day to 2,592 GWh/day, which translates into a drop of more than 25%. During the 21 day period under the first lockdown, demand declined. It then gradually increased as restrictions were slowly lifted and peak summer load also started to build up. By the end of May 2020, demand in the grid had recovered to the levels immediately prior to lockdown but, with a number of restrictions continuing the load was still lower than at the equivalent point of time the previous year.

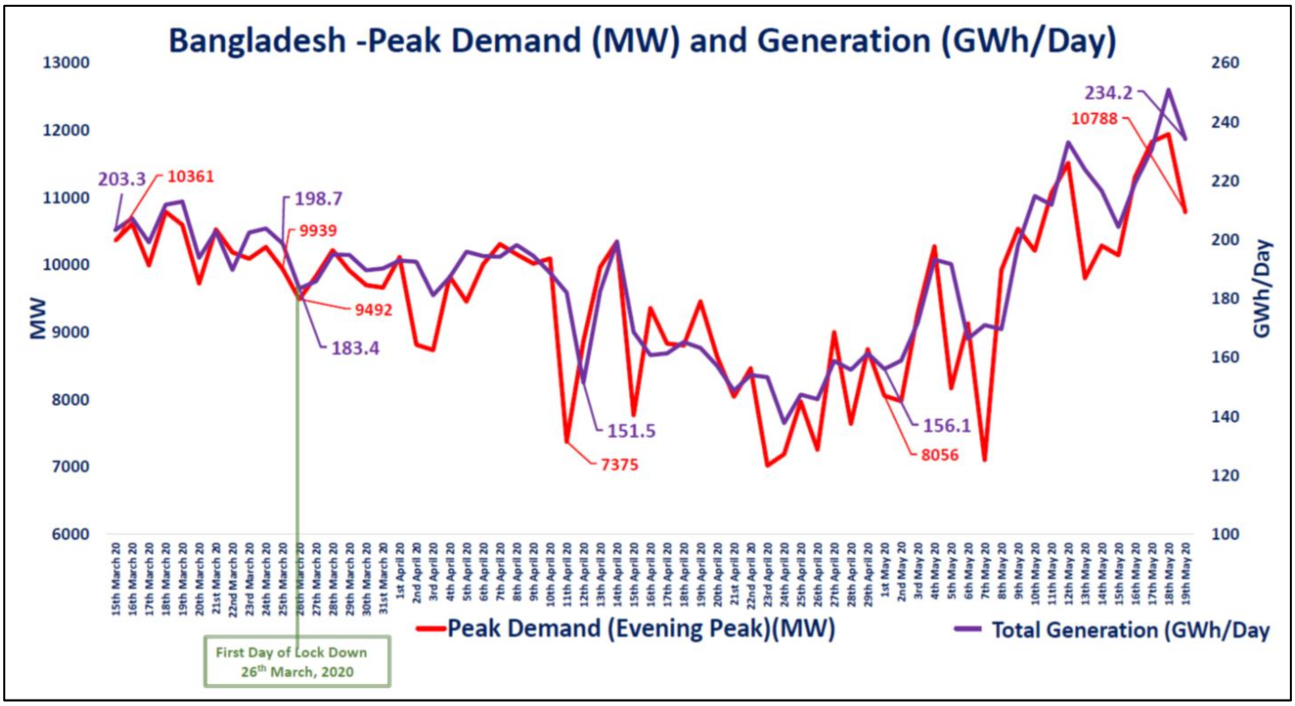
Figure 5: Power supply position in India during COVID-19 lockdown period Error! Reference source not found.vii



4.2 Impact on the power supply position of the Bangladesh electricity grid system

Figure 6 below shows the trend of peak demand met in MW and the daily generation availability in GWh/day in Bangladesh in the week before the lockdown and during subsequent periods.

Figure 6: Power supply position in Bangladesh during COVID-19 lockdown period [viii]



As can be seen, just before lockdown the peak demand and generation were 10,361 MW and 203.3 GWh/day, respectively. Even after lockdown, the decline in demand was very moderate for a considerable period. This can be attributed to the fact that in Bangladesh, a lot of industrial load is associated with export-oriented industries, and the work at such units was allowed to continue (with necessary precautions and safeguards) as it fell into a designated 'essential' category. At the same time, a certain amount of the normal electricity load would have been shifted from industrial / commercial to domestic sectors as working from home increased.

It is observed that from 26 March up to around the middle of April, the decline in load was very gradual and that a substantial decline only occurred around 23 April, with the onset of rains and the reduction in agricultural demand. It is also observed that from the first week of May, the demand started to increase, notably due to the start of summer period as well as due to the easing of restrictions imposed under the lockdown. Towards the second half of May, the load started to increase quickly and surpassed the load present just before lockdown.

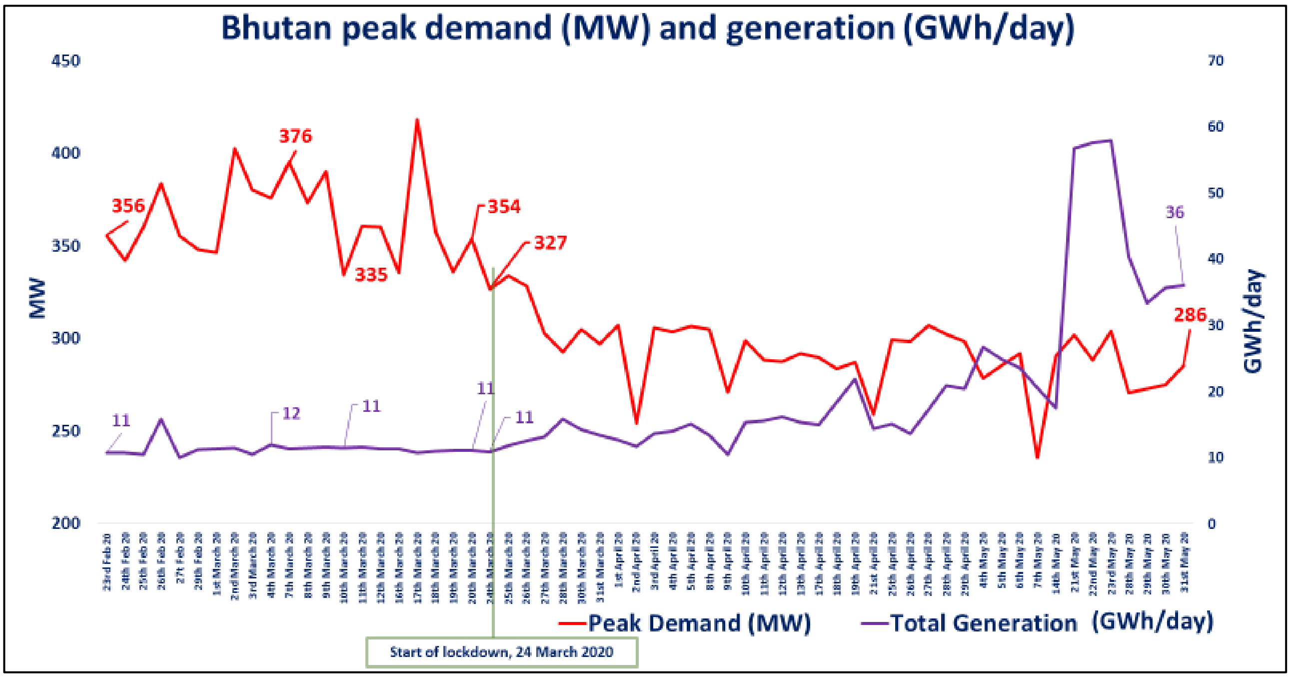
4.3 Impact on the power supply position of the Bhutan electricity grid system

Most of Bhutan's generation capacity is hydro in nature, amounting to around 2,300 MW. Most of this is exported to India under a government-to-government bilateral contract. After lockdown, no reduction was seen in the hydro generation level in Bhutan, as, in line with the existing agreement between governments, all excess over and above local demand was exported to India. Further, after 20 May, the generation level increased substantially, after a sudden increase in the hydro inflows. Again, this was exported to India without any constraints.

Bhutan's own internal demand is only around 300 MW, mostly derived from residential and commercial demand. Under the lockdown, only a small reduction in the overall demand occurred, as seen in Figure 7 below[5].

[5] The sudden rise in generation on 21st and 22nd May is due to a sudden increase in the water inflows at the hydro plants .

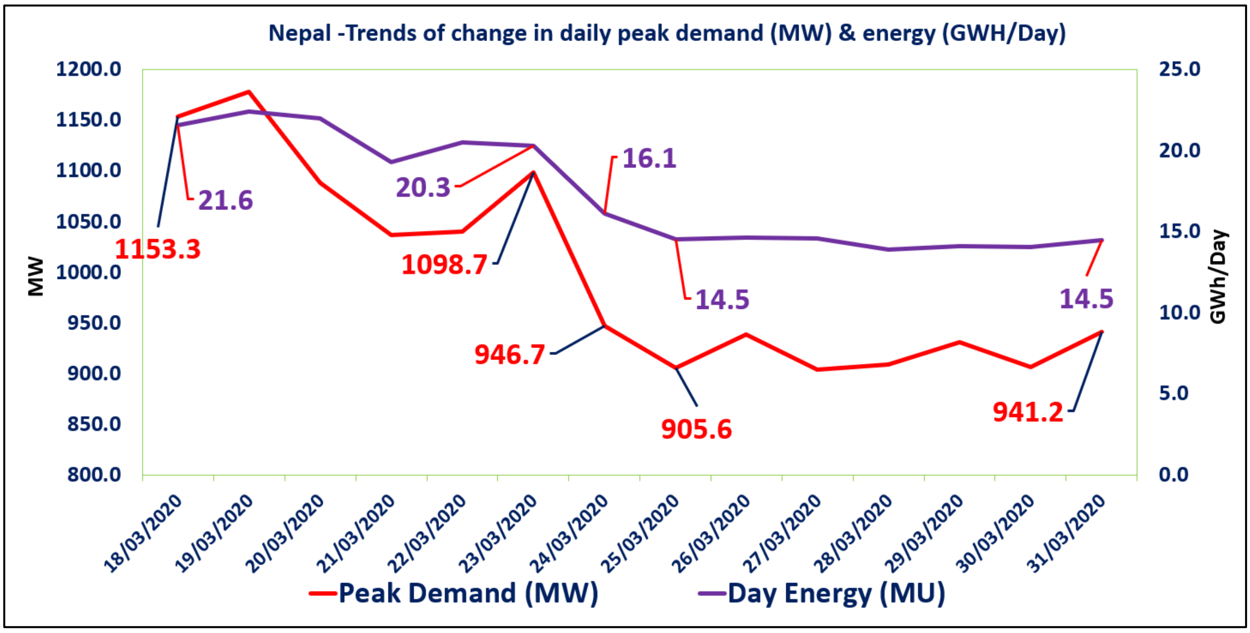
Figure 7: Power supply position in Bhutan during COVID-19 lockdown period [ix]



4.4 Impact on the power supply position of the Nepal electricity grid system

In Nepal, a substantial reduction in peak load, as well as in the daily energy consumption, was observed during the lockdown period. Figure 8 below compares the peak demand and daily energy met (GWh/day) values in Nepal during the whole week prior to lockdown with the corresponding values immediately after lockdown. There was a drop of around 15–20% in the case of peak demand and around 25–30% in the case of daily energy. The Nepal grid was equipped for meeting these changes – by varying generation at its hydro plants as well as by moderating the quantum of imports from India.

Figure 8: Power supply position in Nepal during COVID-19 lockdown period [x]



5. Response by different BBIN countries to the impacts on their electricity grid system due to COVID-19

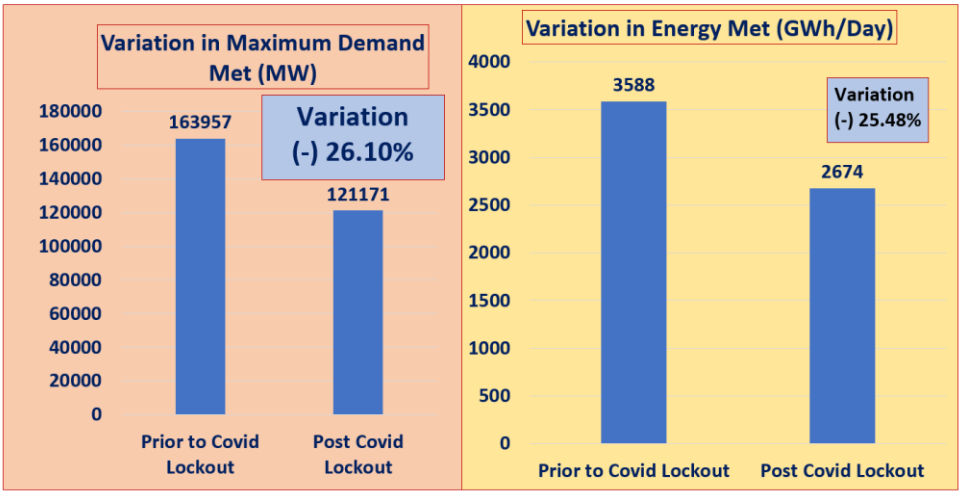
Due to the lockdowns imposed in the different BBIN countries, there was a large reduction in the electricity demand throughout the sub-region. The utilities manning the electricity grids were required to take all necessary measures to manage their grids by ensuring load / generation balance in real time. Further, as the ill effects of the outbreak continued for a long time, there were other challenges, including maintaining a balance between the different types of generation sources, keeping the workforce healthy and safe, and keeping the control centres free of any contamination and operational on a round-the-clock basis. The response by the utilities in the different countries, individually as well as collectively as a sub-region, are detailed below.

5.1 Actions initiated at the country level by the Indian electricity grid system

i) Maintaining grid safety and security

As can be observed from the figures in Section 4.1, there was a steep decline in the load in the Indian grid under lockdown. As shown in Figure 9, which compares the load for the week just prior to the date of imposition of the first lockdown (i.e. 25 March 2020) with the week immediately after imposition of the lockdown, the decline was 26.10% in terms of peak demand and 25.48% in terms of daily energy demand.

Figure 9: Reduction in demand in Indian Grid due to lockdown[xi]

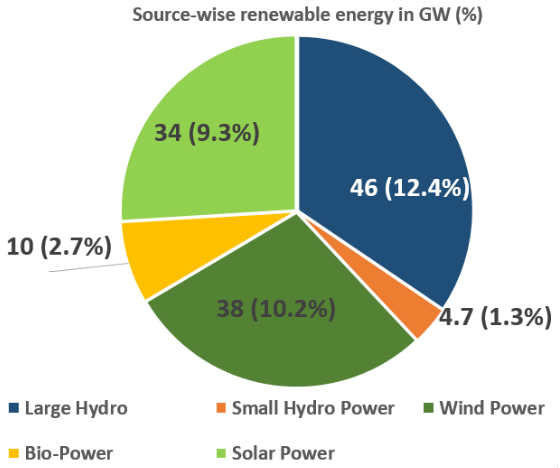


Since the seasonal demand at this point in time was already low, further reducing generation presented a real challenge for the system operators. Maintaining the system voltages, which are critically high under such low load conditions, was another challenge. All of these challenges were met by the operators by carrying out load restrictions on several generating units, mostly coal-based thermal units, as well as by controlling the voltages and other parameters by taking necessary proactive and corrective steps.

ii) Preserving the must-run status of renewables

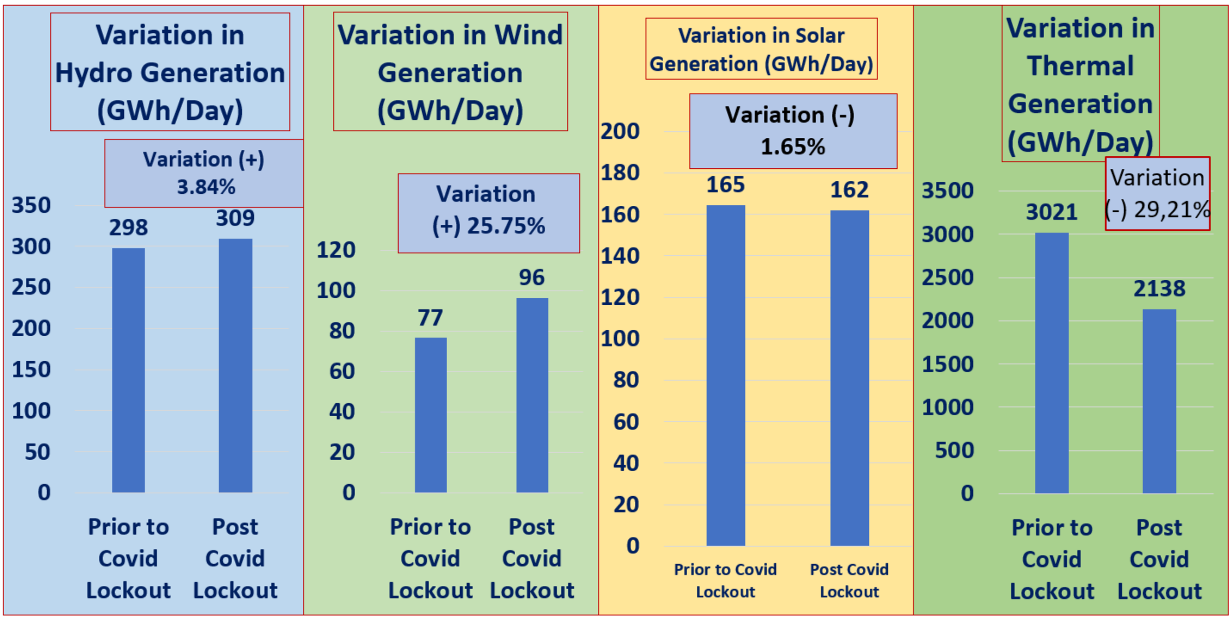
As of February 2020, out of the total installed capacity of 370 GW in India, hydro generation stood at 45 GW (12.4%) while the other renewable capacity totalled 86.3 GW or 23.5% (out of which wind and solar capacity were 37.6 GW (10.2%) and 34 GW (9.3%), respectively – see Figure 10).

Figure 10: India – Source-wise renewable energy in GW (%)[xii]



During the lockdown period, there was a reduction in peak demand in the Indian grid of around 40 GW (from 160 GW to 120 GW) and a reduction of around 900 GWh (from 3,500 GWh/day to 2,600 GWh/day) in terms of daily energy demand. After imposition of the lockdown, the details of the load adjustments made to address this crash in demand for the different primary sources of generation are given in Figure 11 below.

Figure 11: India – source-wise adjustment in generation during lockdown[xiii]



It can be seen that after imposition of the lockdown, there was no reduction in hydro generation – rather, there was a slight increase in the generation level, based on hydro inflows. In the case of wind generation, there was a substantial increase of 25.75% due to an increase in wind potential, which generally starts in March. As regard solar generation, almost the same level of generation was maintained. The only generation source where load reduction was carried out is thermal generation, where daily reduction was in the range of 900 GWh, almost equivalent to the total crash in demand in India.

The above data therefore substantiates that immediately after the imposition of lockdown, most of the reduction in generation was achieved by reducing load on the coal-based thermal generating stations, while in the case of renewable energy sources, there was almost no reduction and their must-run status was maintained.

iii) Deriving strength through an institutional mechanism – FOLD

To maintain the security and integrity of the All India Grid, immediately after imposition of lockdown, meetings were held with all stakeholders in the country, including load dispatchers from national, regional, and state control centres, and issues of common interest were discussed. These meetings were held through video conferencing under the aegis of the Forum of Load Dispatchers of India (FOLD). During the meetings, the protocols and strategies for operating the system at reduced load were discussed and an action plan was formulated to meet any contingencies in the grid.

Figure 12: Meeting of FOLD members through video conferencing during lockdown [xiv]

During the meeting, it was made clear that all Load Dispatch Centres (LDCs) – at the state level, as well as the Power System Operation Corporation Limited (POSOCO) – were committed and fully geared up to handle this new challenge. All LDCs followed the various guidelines issued by the Government of India. At POSOCO, more than 50% of the staff tasked with off-line functions were off-site and working from home. A link to a brief report issued by POSOCO, dated 24 March, is given in endnote xiv.

iv) Operation of the control centres on round-the-clock basis

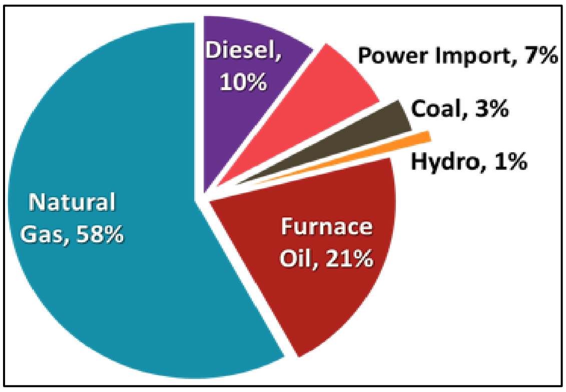
Continuity of LDC operations, particularly round-the-clock operation of the control centres, was successfully maintained by strictly following social distancing protocols among the operating personnel and through sanitisation and closely guarded and supervised upkeep of the work area. Other logistics and support, including communication services, emergency supply services, and daily area upkeeps etc., also ensured smooth operation of the control centres. Those working in functions which are not real time and which are off-grid in nature worked from home, in order to minimise interaction among personnel.

5.2 Actions initiated by the Bangladesh electricity grid system

i) Maintaining load generation balance and grid security in the country

Installed capacity in Bangladesh is in the order of 23.43 GW. As shown in Figure 13, a major component is generation based on natural gas, followed by furnace oil and diesel. A substantial quantum of power is imported from India through cross-border links. The share of generation from coal and hydro is low. During lockdown, load generation balance was achieved in Bangladesh by reducing the generation at oil/diesel plants, followed by natural gas plants.

Figure 13: Source-wise generation in Bangladesh[xv]



ii) Modulating imports by Bangladesh from India through cross-border links

The cross-border interconnections between Bangladesh and India include a 1,000 MW (2X500 MW) HVDC back-to-back link at Bheramara (Bangladesh) connected to Baharampur (India), and a 400 KV D/C (currently operating at 132 KV level) radial link between Comilla (Bangladesh) and Surajmaninagar (India). The daily peak demand by Bangladesh on these links before, during and after lockdown remained largely above 1000 MW. Figure 14 shows the imports by Bangladesh from India during the period 19 March to 31 May in terms of weekly average peak – MW and weekly average daily energy import. Imports of electricity from India largely mirrored overall consumption patterns in Bangladesh, falling by around 25% between mid-March and mid-April, before recovering again. The fact that imports were not cut more aggressively to cope with falls in demand in Bangladesh is probably due to the competitive price of imports compared to generation costs in Bangladesh (see Figure 15).

Figure 14: Details of imports by Bangladesh from India through cross-border links – weekly average peak MW and Energy GWh/day[xvi]

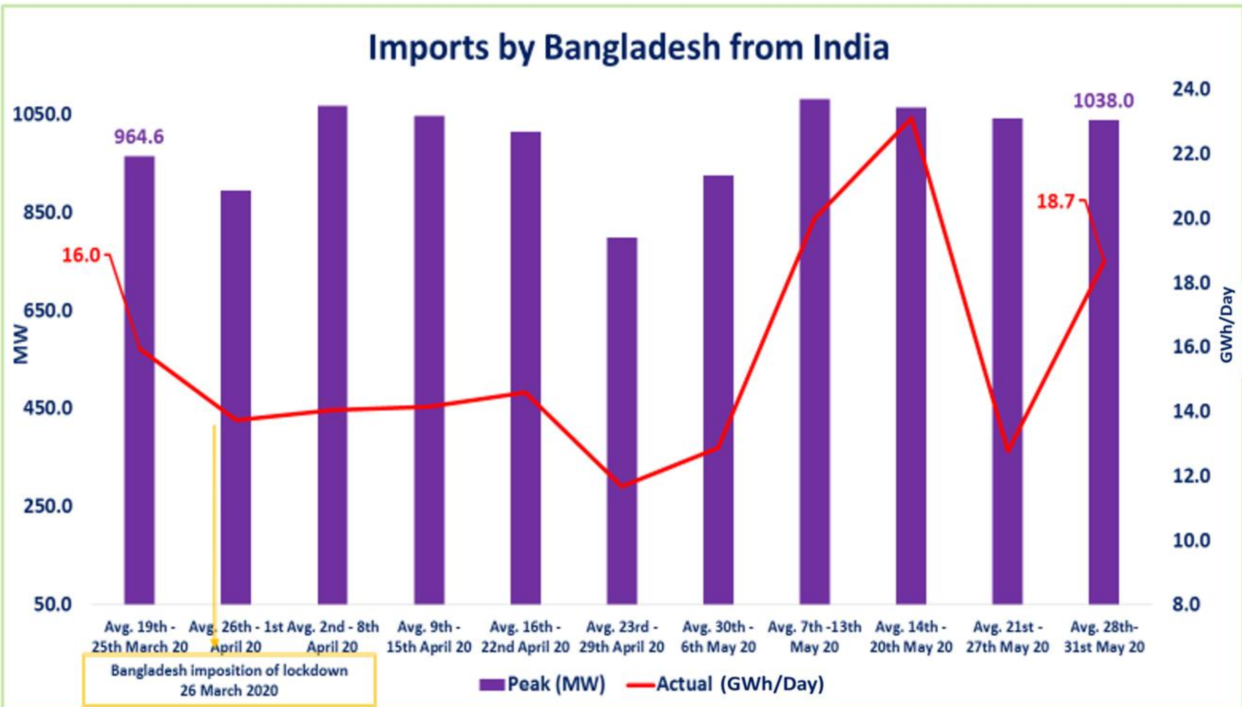
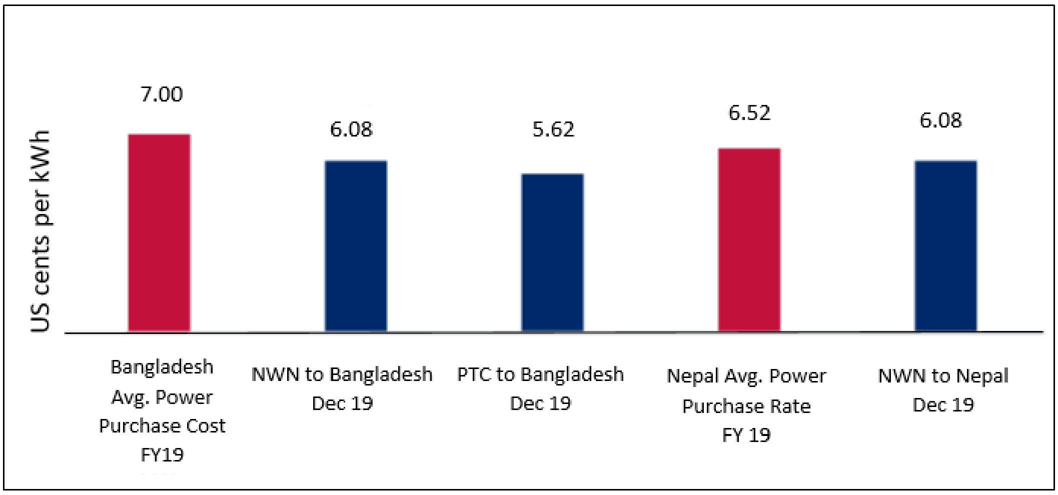


Figure 15: Bangladesh power purchase cost comparison[xvii]



5.3 Actions initiated at the country level by the Bhutan electricity grid system

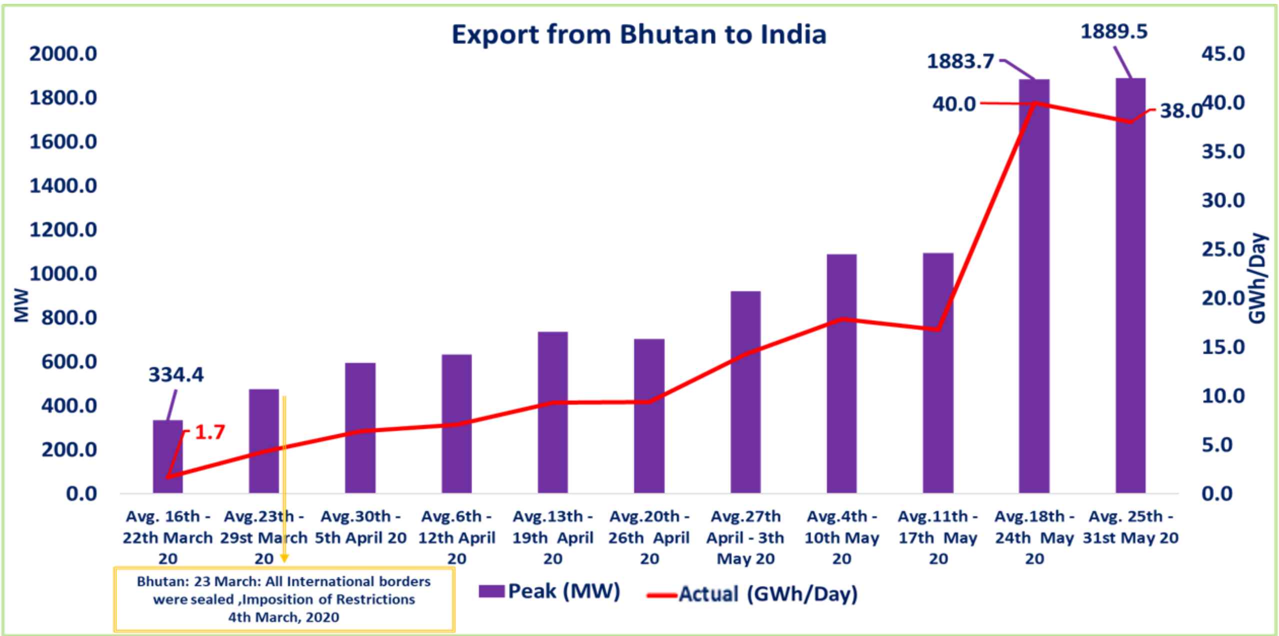
i) Dispatch of the hydro generation from Bhutan grid during COVID-19

Bhutan's power system is generally hydro-based and operates on 'run of the river' basis. Further, all the country's hydro plants, except Dagachhu, have a bilateral back-to-back agreement with the Government of India, under which whatever generation is carried out at these plants is transferred to India, after meeting the consumption of customers in Bhutan. These generating plants are connected to the Indian grid through 400 KV, 220 KV, and 132 KV cross-border transmission links between Bhutan and India. The maximum value of such exports by Bhutan reaches 2,000 MW. Under lockdown, when the load in Bhutan was reduced, the entire excess generation over and above local demand continued to be transferred to the Indian grid through the existing transmission links. Maintenance of the load / generation balance in the electricity grid of Bhutan was therefore relatively straightforward and the country did not face any difficulties.

ii) Enhancement in the level of exports from Bhutan to India with an increase in hydro generation

Figure 16 below shows the details of exports from Bhutan to India in terms of Daily Energy as well as Peak-MW. As stated above, whatever generation is carried out at the generating stations of Bhutan, the same is exported to India, after meeting its own demand. Since all the generating stations at Bhutan are hydro based, run of the river types, the increasing pattern of exports from Bhutan to India from mid-March 2020 to end-May 2020 is basically a reflection of the increase in generation at the hydro plants of Bhutan due increase in river inflows during this period. The increase in generation level is modest from end- April to mid-May and then increases steeply mid-May onwards. During the last week of May, hydro generation reached full load, including some extra generation within the overload capacity. Since by this time the lockdown restrictions in India had also been relaxed in most places and the peak summer load had also picked up, no problems were encountered in absorbing additional generation from the Bhutan grid.

Figure 16: Details of exports by Bhutan to India through cross-border links – weekly average peak MW and energy GWh/day[xvi]

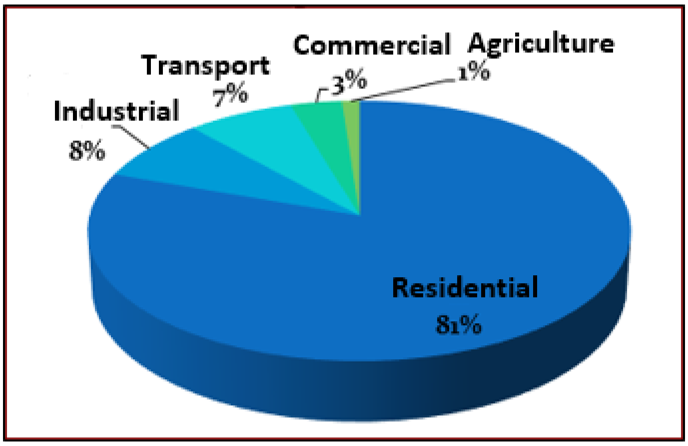


5.4 Actions initiated at the country level by the Nepal electricity grid system

i) Nature of load in Nepal and effects due to COVID-19

As can be seen from Figure 17, in Nepal, more than 80% of the load is from the residential sector. The balance (20%) is made up by all other sectors, including industrial, commercial, agricultural, and transport. As a result, during lockdown, the reduction in demand was only modest, with the residential load continuing largely as before. At the same time, Nepal was able to address the decline in demand in other sectors by reducing imports from India through existing cross-border links, as well as by reducing generation at its hydro plants.

Figure 17: Electricity consumption pattern in Nepal[xviii]

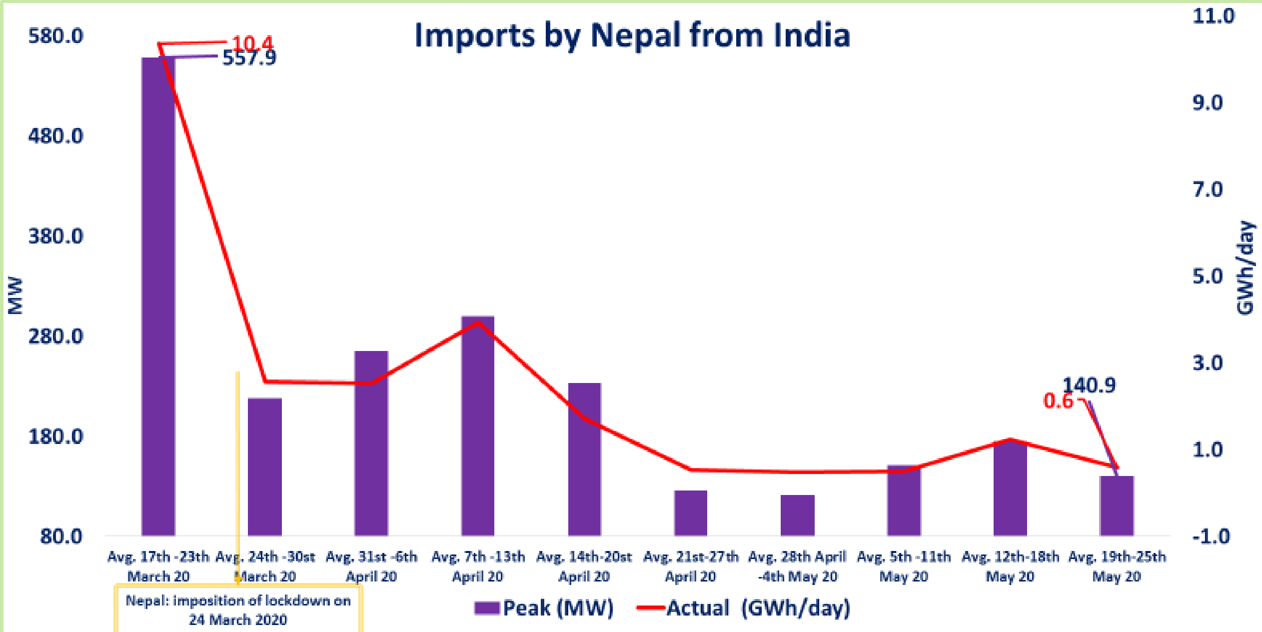


ii) Modulating imports by Nepal from India through cross-border links

The central part of Nepal, including the area around Kathmandu, is connected to the Indian grid through a 400 KV D/C line (currently operating at 220 KV level), and in addition there are a few other links operating in radial mode at 220 KV and 132 KV/66 KV. Currently, the direction of flow of power is from India to Nepal and the maximum quantum of this flow towards Nepal reaches around 500 MW, depending on the demand and the available generation at its own hydro stations.

Figure 18 below shows the imports by Nepal from India during the period 17 March to 25 May in terms of weekly average peak (MW) and weekly average daily energy imports (GWh/day). It can be clearly seen that the quantum of imports by Nepal from India was substantially reduced as a result of lockdown.

Figure 18: Details of imports by Nepal from India through cross-border links – weekly average peak MW and energy GWh/day[xvi]



Since Nepal's own generating stations are hydro based, and are considered to be zero-cost energy plants, it is natural that the generation from its own stations would be consumed first, to be followed by imports. The action by the operator to reduce the imports due to reduction in demand was thus justified and based on merit order.

5.5 Actions initiated in the BBIN at the sub-regional level

The following important actions were initiated at the sub-regional level to address the issues faced because of COVID-19.

i) Support to regional players through uninterrupted operation of cross-border links

As already deliberated in detail in Sections 5.2–5.4, all cross-border links among the BBIN countries continued to operate without any interruption. This rendered a very useful service to particularly Bangladesh, Bhutan, and Nepal. Due to the availability of these links, all of these countries were able to achieve a load / generation balance in their areas with ease, by modulating the flows through these links without any restriction. In the absence of these links, either these countries would have had to reduce/spill the generation at their plants or they may have had to impose load restrictions in the absence of adequate generation in real time.

As far as India's role in this is concerned, it fulfilled its contractual obligations with Bhutan, Bangladesh, and Nepal, and was able to absorb the additional power through links from these countries due to the very large size of its grid and its capacity to absorb these variations by flexing generation at its thermal plants.

ii) BBIN countries' secretary-level meeting to evaluate the state of energy amidst the COVID-19 pandemic

In order to enhance mutual cooperation and support among the BBIN countries, energy secretaries of Bangladesh, Bhutan, India, and Nepal held a virtual meeting on 17 April to evaluate the state of energy amidst the COVID-19 pandemic[xix]. Issues related to energy generation, demand, and distribution were discussed and special attention was given to the demand and supply gap in the regional grid due to the crash in demand in all countries. In the meeting, the Energy Secretary of the Government of Nepal also thanked India for agreeing to reduce the volume of energy export to Nepal due to the reduction in demand.

6. Framework, strategies, and protocols to ensure a resilient BBIN electricity grid system

The COVID-19 lockdowns reduced electricity demand in most of the electricity grids in the BBIN sub-region, causing load generation imbalance. However, operating grids with reduced load was comparatively less problematic compared to others difficulties and challenges presented by the virus, including challenges in the health sector, the movement of people and essential goods and services, and the loss of jobs and opportunities. While the problems faced in respect of health have been given prominent attention, the electricity sector has not been greatly discussed. The people working in the sector have been silent warriors. At the same time, it should not be forgotten that the uninterrupted availability of electricity is necessary to run all essential services under a pandemic situation – be it hospitals and ventilators, cold storage to keep essential food and supplies intact, or transportation and communication systems. Keeping electricity grids safe and secure is not only desirable, it is essential. Experience of the COVID-19 pandemic suggests the importance of putting in place a policy framework for ensuring a resilient electricity grid to deal with such situations if they occur in the future, and to ensure grids are operated in the utmost safety and security.

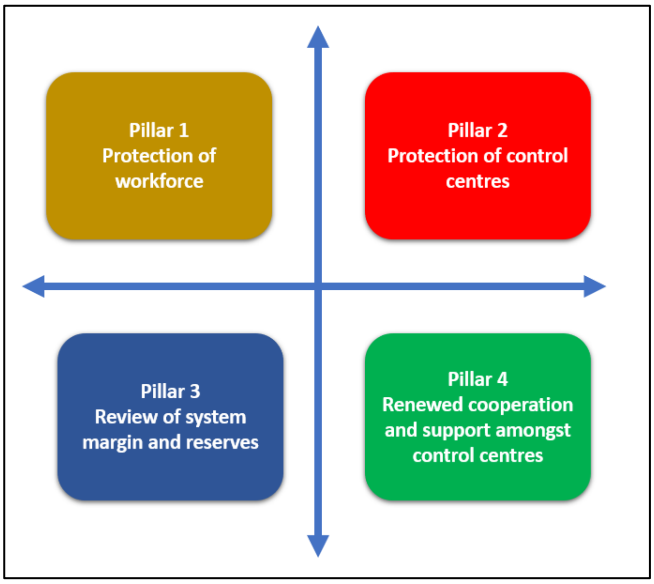
6.1 Main pillars of a framework for a resilient electricity grid system

Important factors in the operation of the electricity grid during COVID-19-like situations include: the workforce (which operates the grid and consistently maintains its safety and security); the control centres (where grid-related operations are carried out on a round-the-clock basis); and the system margins and reserves available in the grid (which come in handy in the event of a crisis and contingency). There is also a need for renewed cooperation and support amongst different control centres, so the different players of the grid are able to take decisions in a cohesive, coordinated, and harmonious manner.

It is extremely important that an action plan is in place to address all four of these factors (presented in Figure 19 as pillars), that all parameters directly or indirectly related to these factors are continuously monitored, and that the necessary mechanisms for resolving any issues related to these parameters are available.

The four pillars are all related in one form or another, and therefore while developing a policy framework a holistic view needs to be taken.

Figure 19: Main pillars of a framework for a resilient electricity grid system



6.2 Identifying and classifying the scale of the problem

During a pandemic, assessing the severity of the situation is important in order to decide on the specific timing of a particular action plan. The severity of a disease can be classified based on the following three stages:

- Stage 1 is the first appearance of the disease through people with a travel history, with everyone contained, their sources traced, and no local spread from those affected. The number of those infected is quite low at this stage.
- Stage 2 is local transmission, when those who are infected and have a travel history spread the virus to their close friends and family. At this stage, every person who comes into contact with the infected person can be traced and isolated.
- Stage 3 is community transmission, when infections happen in public and a source of the infection cannot be traced. At this stage, large geographical lockdowns become important as random members of the community start to develop the disease.

The proposed framework suggests the time for initiating a particular action plan under the different pillars, based on these three stages. See Table 3 below.

6.3 Matching action to the severity of the situation – a decision making framework

Table 3: Details of action plans under the different pillars

Pillar 1 – Protection of workforce			
Item	**Stage 1**	**Stage 2**	**Stage 3**
Do's and don'ts related to personal hygiene are issued to all work staff and such instructions are reviewed at regular intervals	✓	✓	✓
Access to office/control centre to be limited to persons related to on-line functions only	✓	✓	✓
PPE kit must be used by personnel with greater likelihood of coming into contact with others, such as operators sharing the same control room, support staff etc.			✓

Possible reduction in frequency of travel of control room operating personnel from home to office and back, by decreasing the number of operating days in each month and increasing the number of duty hours in each day/shift		✓	✓
Put in place a system of grouping workers and having groups work in shifts, so that in the event of a person being infected, quarantine/thorough checking is limited to just the persons in that particular group		✓	✓
In order to meet any contingencies, identification of reserve manpower roster to be put in place	✓	✓	✓
Pillar 2 – Protection of control centre			
Item	**Stage 1**	**Stage 2**	**Stage 3**
Entry by guests/outsiders to be completely stopped. Only authorised people who are responsible for grid operation and control are permitted to enter	✓	✓	✓
Thermal vision scanning facility at entry point: all persons entering the premises duly checked for any health-related issues		✓	✓
Within a control room, glass partitions installed between adjacent seats/different operating personnel, in order to ensure social distancing among co-operators		✓	✓
Use of paperwork avoided and all records, logbooks, reference documents and instruction sheets etc. made available in electronic form	✓	✓	✓
A separate control room with bare minimum of essential facilities created and kept operational in standby mode, to be used in the event of any need to quarantine the main control room		✓	✓
Provision of communications links maintained, with adequate redundancy and reserves	✓	✓	✓
Pillar 3 – Review of system margins and reserves			
Item	**Stage 1**	**Stage 2**	**Stage 3**
In the event of load crash due to lockdown or other restrictions, there may be load generation imbalance in the grid and therefore grid security must be continuously reviewed		✓	✓
Due to change in the load due to abnormal conditions, load forecasting based on historical data may not be accurate; forecasting must instead be based on the current situation		✓	✓
To take account of possibility of an interruption in fuel supply, affecting the generation in a particular area, security studies need to be carried out, keeping in mind the actual position of generation availability, rather than the installed capacity		✓	✓
Total transfer capability (TTC)/available transfer capability (ATC) across the different control areas needs to be worked out afresh, looking at new load generation conditions; to be used strategically		✓	✓

Share information about any abnormal conditions in the grid with stakeholders, to enable them to apply grid supporting measures		✓	✓
Pillar 4 – Renewed cooperation and support among control centres			
Item	**Stage 1**	**Stage 2**	**Stage 3**
Prepare daily reports covering any special effects/developments in the grid due to the abnormal situation and share with the other control centres	✓	✓	✓
Check the healthiness of any system protection schemes/strategic schemes areas different control areas in order to keep them in state of readiness	✓	✓	✓
Hold virtual meeting among the operating personnel of the different control centres at regular intervals in order to synergise grid operations	✓	✓	✓
Discuss and review planned shutdown of 'cross-border'/'inter-control area' transmission elements/generation units in light of the abnormal situation		✓	✓

7. Summary

The months of March and April are generally considered low demand months in each of the BBIN countries, due to favourable weather conditions. In 2020, demand dramatically declined further due to COVID-19-related lockdowns, resulting in a reduction in cross-border power trade in the region.

As the major player in the BBIN region, India's grid played an important role in maintaining the load / generation balance. It faced the following main challenges: i) managing the load / generation balance continuously in real time; ii) protecting the must-run status of renewable generation by dispatching it in full; iii) absorbing the additional availability in the grid through flows through cross-border links; and iv) ensuring the continuity of the operation of the LDCs and other control centres. All of these challenges were successfully overcome.

Learning from this event a framework for a resilient electricity grid system operation is proposed based around 4 key pillars of action to (1) protect the workforce, (2) protect the control centres, (3) review system margins and reserves, and (4) ensure cooperation and support amongst control centres. Key actions under each of these pillars have been set out and scaled according to three escalating levels of severity of a pandemic.

About the authors

Professor Jyoti K Parikh is the Executive Director of Integrated Research and Action for Development (IRADe), New Delhi. She was a **Member of the Prime Minister's Council on Climate Change –India and is a co-recipient of the Nobel Peace Prize awarded to IPCC authors in 2007.** Dr. Parikh has made valuable contributions towards environment & climate change issues in developing countries. Dr. Parikh served as a Senior Professor at Indira Gandhi Institute of Development Research (IGIDR), Mumbai, and was the Acting Director of IGIDR during 1997-98. Recently, she has been appointed as the advisor for Global Commission on Adaptation set up by UN Secretary General and Gates foundation managed by World Resources Institute.

Mr. Vinod Kumar Agrawal is the Technical Director at Integrated Research and action for Development, and is responsible for steering the technical functions under the SARI/EI program intended towards enhancement of the Cross-Border Energy Trade in South Asia region. Mr. Agrawal has more than 4 decades of experience in the power sector and before joining IRADe he was Executive Director in POSOCO (Power System Operation Corporation) and has worked extensively towards operation and control of regional and national grid in India and its synchronisation with the neighbouring countries in SA region. He has rich experience in the area of power system operation and its safety and security, integration of renewables with the grid and entire gamut of power market operations and governance.

Mr. Rajiv Ratna Panda is currently working as Head-Technical with Integrated Research and Action for Development. Mr. Panda is an engineer, management, research and development professional with 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.

Mr. Vinay Kumar Saini is currently working with Integrated Research and Action for Development as Senior Research Analyst. He is having experience of around 8 years wherein he got exposure to various domains of Energy such as Power, Coal, Smart Grids, Energy System Modelling, etc. His international experience includes Energy system modelling of Nepal, Bangladesh, Bhutan, and India on TIMES; Research report on Coal industry of Indonesia and Australia including areas such as institutional setup, regulatory setup, licensing and coal pricing. Mr. Saini holds an engineering degree and a post graduate in management with specialization in Power Management from National Power Training Institute.

Dr. Jasleen Bhatti is currently working as a Consultant with Integrated Research and Action for Development. She has more than 10 years of rich experience in the areas of energy, climate change and sustainability & has several publications in journals of international repute. She obtained her doctorate in Energy from IIT Delhi in 2016 and thereafter has worked as an Assistant Professor with IP University and EMPI Business School. She is the co-author of a global report on Smart Grids titled "Synergy" that was prepared by DST. Dr. Bhatti has also worked with FITT at IIT Delhi and was involved in facilitating technology transfer from the academia to the industry.

Front cover image credit: https://www.electronicdesign.com/power-management/article/21807827/wireless-makes-the-electric-grid-smarter-and-more-reliable

The views expressed in this Energy Insight do not necessarily reflect the UK government's official policies.

References

[i] Compiled by the authors from various sources:

a. Executive Summary on Power Sector – March 2020' by Central Electricity Authority; http://cea.nic.in/reports/monthly/executivesummary/2020/exe_summary-03.pdf

b. Monthly Operation Report prepared by POSOCO and NLDC; https://posoco.in/reports/monthly-reports/

c. Annual Report 2018-19 prepared by Bangladesh Power Development Board, pages. 12 and 13; www.bpdb.gov.bd/bpdb_new/resourcefile/annualreports/annualreport_1574325376_Annual_Report_2018-19.pdf

d. National Transmission Grid Master Plan (NTGMP) of Bhutan (2018) prepared by Department of Hydropower and Power Systems, Ministry of Economic Affairs, Royal Government of Bhutan; www.moea.gov.bt/wp-content/uploads/2018/11/National-Transmission-Grid-Master-Plan-2018.pdf

e. A Year in Review - Fiscal Year 2018/2019 prepared by Nepal Electricity Authority; www.nea.org.np/admin/assets/uploads/supportive_docs/annual_report_2076.pdf

f. Presentation on Energy Situation in Nepal prepared by International Centre for Hydropower (2019); https://tekut.no/wp-content/uploads/2019/09/Country-Presentation-Nepal-2019.pdf

g. Presentation on 'Present Status and Future: Power Sector of Bangladesh and Prospects of Renewable Energy in Bangladesh', by Bangladesh Power Development Board Renewable Integration through Balancing Technologies Regional Conference that was organised by IRADe and The Asia Foundation on 12 June 2019 at Shangri-La's – Eros Hotel, Ashoka Road, New Delhi

h. Presentation on 'Perspective and plan of Hydro Energy Development in Nepal, 2019' by Department of Electricity Development, Nepal at Renewable Integration through Balancing Technologies Regional Conference that was organised by IRADe and The Asia Foundation on 12 June 2019 at Shangri-La's – Eros Hotel, Ashoka Road, New Delhi

i. Second Quarterly Report (2020) prepared Bhutan Power System Operator; http://bpso.bpc.bt/category/quarterly/

[ii] https://en.wikipedia.org/wiki/COVID-19_pandemic_in_Bhutan

[iii] https://en.wikipedia.org/wiki/COVID-19_pandemic_in_Bangladesh

[iv] https://en.wikipedia.org/wiki/COVID-19_pandemic_in_India

[v] https://en.wikipedia.org/wiki/COVID-19_pandemic_in_Nepal

[vi] Monthly Report (February 2020): Fuel-wise Power Installed Capacity in GW, prepared by Central Electricity Authority; www.cea.nic.in/reports/monthly/installedcapacity/2020/installed_capacity-02.pdf

[vii] Monthly Operation Report prepared by POSOCO and NLDC; https://posoco.in/reports/monthly-reports/

[viii] Daily Operational Report by Power Grid Company of Bangladesh Ltd.; http://pgcb.gov.bd/site/page/0dd38e19-7c70-4582-95ba-078fccb609a8/-

[ix] Daily Reports prepared by Bhutan Power Corporation Ltd., Bhutan Power System Operator; http://bpso.bpc.bt/category/load-generation/

[x] Based on data sourced from national system operator of Nepal

[xi] Variation in Demand met in Indian Grid : https://posoco.in/reports/daily-reports/daily-reports-2019-20/

[xii] Monthly Report: India – Source Wise Renewable Energy in GW (%), prepared by Central Electricity Authority; www.cea.nic.in/reports/monthly/installedcapacity/2020/installed_capacity-02.pdf

[xiii] Resilient Indian Power System: Multiple challenges during "COVID-19" pandemic outbreak and their mitigation' prepared by IRADe; https://irade.org/website/wp-content/uploads/2020/04/Resilient-Indian-Power-System_Multiple-challenges-during-%E2%80%98COVID-19%E2%80%99-pandemic-and-their-mitigation.pdf

[xiv] Advisory by Power System Operation Corporation Ltd (POSOCO) dated 24th March, 2020; https://posoco.in/wp-content/uploads/2020/03/Status_note_COVID19_24th-March-2020.pdf

[xv] Presentation on 'Present Status and Future: Power Sector of Bangladesh and Prospects of Renewable Energy in Bangladesh', by Bangladesh Power Development Board Renewable Integration through Balancing Technologies Regional Conference that was organised by IRADe and The Asia Foundation on 12 June 2019 at Shangri-La's – Eros Hotel, Ashoka Road, New Delhi

[xvi] Procedure for Scheduling of Collective Transactions through Real Time Market (RTM) prepared by National Load Despatch Centre, May 2020; https://posoco.in/reports/daily-reports/daily-reports-2020-21/

xvii Impact of COVID-19 pandemic on South Asian Power Sector, May 2020 prepared by IRADe, SARI/EI and USAID; https://sari-energy.org/wp-content/uploads/2020/02/BIMSTEC-Background-Paper_February-2020.pdf

xviii Presentation on 'Perspective and plan of Hydro Energy Development in Nepal, 2019' at Renewable Integration through Balancing Technologies Regional Conference that was organised by IRADe and The Asia Foundation on 12 June 2019 at Shangri-La's – Eros Hotel, Ashoka Road, New Delhi

xix BBIN Energy Secretaries Evaluate State of Energy amidst the Pandemic (17 April, 2020) prepared by South Asia Sub regional Economic Cooperation; www.sasec.asia/index.php?page=news&nid=1141&url=bbin-energy-sec-meet-amidstcovid19&enews=77