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Global power and energy scenario during COVID-19 pandemic: Lessons from lockdown

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Abstract
Technology is advancing progressively at a very sharp rate in every phase of the commercial and economic issues, where energy plays a vital role in hi-tech enrichment. After continuous and multi directive research, human is efficient enough to put their steps on the peak of all imaginable pitches. But a human cannot fight against the environment in all instances. COVID-19, or Corona Virus, is such a type of environmental pandemic. Due to a large spread rate of COVID-19, the human society of the entire Globe is getting affected within a very small period. During its first and second wave, it collapses maximum countries health, economic structures along with the electrical sector. Many countries have enforced the ‘lockdown’ to their citizen for minimizing the community spread rate, which directly affects the energy sector. Standing in this scenario, this study focuses on the significant effect of COVID-19 on the energy sector of the Globe, especially in India. This paper also demonstrates that how several countries are trying to secure their power sector in this pandemic situation.

1. Introduction
The world is advancing rapidly in every sector. Making progress in agriculture, electricity, education, etc. The main aim of development is to lift the capability of human beings to increase their potential to lead the way long and healthy living. But the world has to accept the uncertain challenges, which are also an obstacle for human beings for their development and leading their life by taking their progress down.

A new challenge that the human being is facing in this era is COVID-19. This is a big threat to human life and society. COVID-19 disease was first observed in 2019, discovered in the Wuhan province of China, which is the reason for the global pandemic.

The broad literature and consequence of COVID-19 on human communities have already been explored by several researchers. Chakraborty et al. [1] show the effect of COVID-19 on humanity and the global atmosphere. The authors have discussed the managing process of COVID-19 on humans. Saadat et al. [2] describe the environmental perception of COVID-19. The socio-economic and unpredictable environmental aspects of COVID-19 have been studied in the paper. The guidelines and protocols, which are required for fighting against Corona Virus, have also been deliberated.

The governments of several countries have endorsed the instruction about the work from home for the workers to avoid the community spread of COVID-19. The budding effect of the COVID-19 pandemic on work from home, occupational status, and occupational mobility are discussed in reference [3]. Elavarasan et al. [4] edify about the several executed machinery that supports the government, public, and healthcare systems to fight against the coronavirus. The technological instantaneous, which occurred during the pandemic and their impact on society and the environment, have also been discussed in this paper. Qarnain et al. [5] analyses the electricity consumption activities, which are engaged by G20 member countries in the corona epidemic outbreak. Nicola et al. [6] describe the overall implications of COVID-19 on millions of people socially and economically. Djalante et al. [7] analyze the

Abbreviations: PHEIC, Public Health Emergency of International Concern; SARS, Severe Acute Respiratory Syndrome; NR, Northern Region of Indian Power Sector; WR, Western Region of Indian Power Sector; SR, Southern Region of Indian Power Sector; ER, Eastern Region of Indian Power Sector; NER, North Eastern Region of Indian Power Sector; POSOCO, Power System Operation Corporation Limited; IEA, International Energy Agency; WHO, World Health Organization.

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response of the governments, non-government organizations, and the community during COVID-19 between January and March 2020 in Indonesia. The authors recommend some directions toward more rapid, effective, and comprehensive responses. A large number of industries have been shut down during the lockdown period which is imposed to minimize the adverse effect due to pandemics. This situation creates the hilling of the environment, especially the quality of air. The effect on air quality due to COVID-19 in Indian perspectives is discussed in reference [8], and for Milan in reference [9].

The lockdown due to the COVID pandemic puts a big impact on the power and energy sector throughout the world. The electricity demand has decreased at a high rate at the time of lockdown, which was the reason for the electrical sector instability. The big effort of the power sector professionals saved the electricity grid from that risky situation. Zhang et al. [10] present the impression of COVID-19 on energy consumption in the transport sector of China. Bahmanyar et al. [11] study the impact of the containment methods engaged by European countries on their electrical network to fight against the situation, which is created due to the Covid pandemic. Some countries from Asia, as well as Middle East countries, have also faced energy risk situations like other regions in Globe. The impact of COVID-19 lockdown on the electricity grid for India, Malaysia, and Turkey are deployed in references [12,13], and [14]. Delgado et al. [15] studied the trend analysis of energy demand changes due to the COVID pandemic in Brazil, whereas Pınar Cihan [16] has discussed the electricity consumption details in several industries in Turkey during the Lockdown period. Costa et al. [17] present a socio-economic regulatory model-based approach to evaluate the pandemic effect on the Brazilian Electricity distribution system.

After the detailed literature, it should be concluded that various authors had studied COVID-19, but, according to the literature, no one has addressed the negative impact of COVID-19 on the power and energy sector in detail along with the power sector professional’s fight towards the uninterrupted and stable power sector operation which is deliberated in this study.

The main highlights of this paper are as follows:

- WHO declared the COVID-19 outburst as a Public Health Emergency of International Concern (PHEIC) and conveying the maximum level of fear to the world.
- Energy demand has reduced significantly in this pandemic.
Commendable performance of planning, coordination, execution, and resilience of power sector officials made the Grid more secure in the pandemic, which is analyzed in this paper.

- The status of COVID-19, statistics of global electricity demand, and several policies implemented by leading countries have been discussed in this work.

The rest of the paper is presented as follows: Section 2 describes the global status of COVID-19. The impact of COVID-19 in the Indian power sector is analyzed in Section 3. Section 4 studies the impact of COVID-19 in the global power sector, with more details in United States, Spain, Italy, Ireland, Ukrainian, and Brazil.

2. Global status of COVID-19

Coronavirus is a common virus that infects humans or animals, typically causes respiratory infections that vary from the common cold to more severe diseases such as Severe Acute Respiratory Syndrome (SARS). The main concern forms this virus is that it can spread very easily, it can spread from the person who is infected by COVID-19 to the other person by small droplet from the nose or mouth, and even if they breathe in these small droplets from an infected person, which is excluded when a COVID-19 person speaks, sneezes or coughs [18, 39].

The main origin of COVID-19 is in Wuhan, China. But as it is a communicable disease, it had transferred from one infected person to another person, which is held to spread all over the world. As of 11th October 2021, approximately 222 countries are affected due to this pandemic [19]. This takes a storm through the affected countries. Disturbingly a large number of human beings lost their life. As per precaution, countries have implemented necessary quarantine; social distancing and lockdown have been put all over the world. This pandemic is a terrible experience faced in the last few decades. This is creating a huge impact on human lives and livelihoods. This contagion has created a worldwide crisis in the sector of health, power, financial, and a collapse in commodity prices, which is in a complex state [20].

The worldwide effect of COVID-19 till 11th October 2021 can be observed in Fig. 1 and Fig. 2. According to the data, almost all countries are affected due to the COVID-19, and simultaneously the infected cases and deaths are also increasing day by day. The five most affected countries due to COVID-19 are the USA, India, Brazil, Russia, and France. As the rate of cases due to COVID-19 is increasing drastically, therefore, the death rate has also increased. Fig. 3 and Fig. 4 show the
3. Impact of COVID-19 in Indian power sector

Nowadays, the electricity demand is increasing at a huge rate due to the habitual change of human beings throughout the world. Human society is trying to build them more modernize by the use of updated electrical and electronic instruments, which increases the electricity demand. The Government of maximum countries had built new generating stations to fulfill the desired power requirement. All the power sectors are run after study the forecasted load flow.

There is a possibility of power sector blackout, or grid collapse if an enormous mismatch is occurring between power generation and demand. Like all other countries, the power sector of India has also faced enormous problems due to the spread of COVID-19. To stop the community spread of COVID-19, the Government of India has imposed the ‘lockdown’ all over India like other countries. All industries, academic institutions, shopping malls, etc. are fully shut down at the time of ‘lockdown’, which causes a significant reduction of power demand.

Fig. 5 shows the realistic appearance of the evening peak hour demand, which was met by the Indian Power Sector in different months of 2020 and 2021. Fig. 5(a), 5(b), 5(c), 5(d),5(e) and 5(f) showing the peak demand met in the evening for the month of January 2020 [23]
In this month, the peak evening power demand is decreasing in March 2020. But in the actual case, the peak evening power demand is 159438 MW and 141577 MW, whereas the maximum and minimum demand in March 2019, February 2020, and March 2021 [23, 24, 25, 26, 27, 28], respectively.

The electricity demand is high at the summer session as compared with winter due to the increase in the use of air conditioners, cooler, etc. From the Indian perspective, the summer is generally starting from the end of February. Therefore, this is very obvious that energy demand is increasing day-by-day from that time, which can see in Fig. 5(a) and 5(b).

In January 2020, the maximum and minimum demand was 159438 MW and 141577 MW, whereas the maximum and minimum demand in February 2020 was 166160 MW and 148153 MW. Therefore, there is a clear indication of the increase in power demand month by month. By following this trend, the electricity demand must be an increase in March. But in the actual case, the peak evening power demand is decreasing in March 2020. In this month, the maximum and minimum peak power demand was found at 157480 MW and 108906 MW, which is very less as compared to the adjacent months as well as the same month in the next year. This condition is occurring due to the lockdown in India, which is imposing by the Government of India to fight against COVID-19. The full shutdown of the industry and academic institutions creates these situations, which are very dangerous for the power sector. The swift fall in demand can create an imbalance in the grid, which may cause grid failure.

Fig. 6 shows the comparative studies of peak demand met by the Indian Power Sector for the several months of 2020 and 2021, whereas Fig. 7 shows the relative arrangement of peak energy met by the Indian Power Sector. From these figures, it is clear that the peak demand met, and energy met both are decreasing in March 2020 compared with the previous and next year same month energy data as well as nearer month energy data [23, 24, 25, 26, 27, 28].

Indian Power Sector is the World’s third-largest power sector as per the quantity of power production and the number of customers. Based on the geographical location, the Indian Power Sector has been divided into five regions named Northern Region (NR), Western Region (WR), Southern Region (SR), Eastern Region (ER), and North Eastern Region (NER). Fig. 8 demonstrates the region-wise hourly energy met data for January 2020, February 2020, March 2020, April 2020, May 2020, and March 2021 [23, 24, 25, 26, 27, 28]. The first two sub-figures of Fig. 8 show the same trends in the energy met by every region. But, after the execution of full lockdown, the energy demand is drastically reduced in every region of the Indian Power Sector, which is shown in the last sub-figures of Fig. 8. In this scenario, the Indian Power Sector has taken several policies to balance the power generation and demand for maintaining safety in the grid.

Fig. 9 shows the comparison of the energy requirement and energy met in the Indian power sector for February 2019 and February 2020. As per the energy necessity of the customer, Western Region is the largest, and the North-Eastern region is the smallest energy province in India.

The statistics of energy requirements and met for March 2019 and March 2020 are shown in Fig. 10. Unlike the previous month of 2020, i.e., February 2020, the energy demand and met both are increased in February 2020 with the change rate of 10% from the same month of the previous year, being common in a developing world.

The nine minute event has put the grid operating system into an alarming state. Electrical grid management is very serious and complex work. The national and state load dispatch centers and Power System Operation Corporation Limited (POSOCO) work in the same direction with the power generators and distribution corporations to maintain grid operations and a standard frequency of 49.5–50.2 Hz. A good balance line of demand and supply should be synchronized all the time, otherwise, grid failure can occur which can tense to blackout. In the nine minute event, the grid could have faced this type of failure, but a commendable parade of planning, coordination, execution, and resilience of the power grid handled the situation very well. The Indian power sector managed a huge demand drop of approximately 32GW in 25 min [29]. The grid operators had ensured that in this hard time one of the most important lifelines of the nation would not be interrupted. After the PM’s appeal for solidarity, POSOCO comes to the action and draws the possible variation in demands in the load. Grid operators after accessing demand from the previous Sunday from the state load dispatch centers. It was estimated that a 12–14 GW electricity demand drop could occur due to the household lighting loads across the country during this event. Due to an increase, or decrease, in generation at a high rate, gas-based and hydro-based generations are put into action. All around 118 gas-based and hydro-based power plants, with a capacity to provide approximately 19,392 MW, were recognized. Fig. 11 shows the entire procedure which had followed by the Indian load dispatch centers to operate the grid safely during the nine minute event.

4. Impact of COVID-19 in global power sector

Like other crucial sectors, COVID-19 hits very deeply in the Power Sector.
sector throughout the world. As per the International Energy Agency (IEA) report, approximately 25% of weekly energy demand is reduced globally after full lockdown executed by many countries [30]. As of 27th April 2020, maximum countries in Europe had implemented strict lockdown to fight against COVID-19 due to which power consumption has reduced. The details of the power consumption reduction are as follows [31]: (a) Italy – 25% (very strict lockdown), (b) France – 20% (strict lockdown), (c) Iberia – 18% (very strict lockdown), (d) Belgium and Dutch –18%, (e) UK – 12% and, (f) Poland –8%.

Energy consumption is divided into four categories, i.e., commercial, residential, transport, and industrial. The percentage usage of energy for four different countries in Europe with the said categories is shown in Fig. 12. From this figure, it is clear that energy is consumed on a very large scale in residual and industrial customers.
On 30th January 2020, WHO Chief has declared the COVID-19 outburst as a Public Health Emergency of International Concern (PHEIC) and conveying the maximum level of fear to the world. After the declaration from WHO, maximum countries had taken several steps for fighting against the Coronavirus, where Imposing Lockdown is the most important step. The full shut down of industries, academic institutions, shopping malls, etc. in lockdown period minimizes the energy consumptions, which directly affect the commercial and industrial area.

Fig. 13 shows the year-wise electricity demand changes for leading covid affected countries like India, Italy, Spain, Germany, France, and Great Britain [32]. The energy demand is decreasing in all the places as compared to the previous year at the strict or partial lockdown period. Figs. 14 and 15 show the electricity energy status for the United States and India during and after the lockdown period [32]. In the lockdown period, renewable energy sources have taken a leading role in power generation throughout the world due to their natural availability and...
The effect of COVID-19 in different countries is discussed as follows.

### 4.1. United States

- In California and New York, the peak energy demand is decreased by an average of 3–7% after imposing a strict lockdown. Other regions of the country (like WA, Seattle) have also faced the same problem after starting the lockdown.
- The greater impact has been seen in the morning peak demand all over the country.
- Fig. 16 shows the electricity demand statistics in the US for 16th May 2019 and 16th May 2020. One case is without lockdown, whereas the other is with lockdown [33].
- The electricity demand is 317,718 MWh on 16th May of this year. On the other hand, 367,777 MWh was the electricity demand on the same day of the previous year. Therefore, an
instantaneous fall has been seen in the electricity demand which occurs due to the lockdown.

4.2. Spain

- In the first week of lockdown, almost 15% of peak energy consumption has been reduced.
- As compared to the first week, some lesser effect was obtained in the second week with a reduced rate of 7–10% [34].
- Fig. 18 shows the weekly electricity demand information in Spain for 2019 and 2020. This figure shows that after implementing the full lockdown, the electricity demand is decreasing harshly.
Fig. 15. Electricity Energy Status in India in 2020 [32].

Fig. 16. Electricity Demand Statistics in US [33].
The following situation has occurred during the lockdown (shown in Fig. 17):

**First Work Week**
- 0% to 15% reduction in peak energy demand.
- Demand held initially before dropping substantially as industry closed.

**First Weekend**
- 2% to 4% reduction in peak energy demand.
- Within range of normal weekend load.

**Second Week**
- 9% reduction in peak energy demand.
- Monday showed signs of following first week with ~10% reductions initially.

Fig. 17. Different Situations Occurred during Lockdown in Spain.

![Graph showing electricity demand comparison in Spain.](image)

Fig. 18. Electricity Demand Comparison Statistics in Spain [34].

**Partial Lockdown**
- 3% to 4% reduction in peak energy demand.
- Lockdown limited to North Italy, as people adjusted to the change.

**First Days**
- 10% to 14% reduction in peak energy demand.
- Reduction in weekday peak and energy usage compared week-to-week and year-over-year.

**Weekend**
- 6% to 10% reduction in peak energy demand.
- Minimum demand, energy use reduction.
- Weekend demand still lower than weekdays.

**Day 5-10**
- 18% to 22% reduction in peak energy demand.
- Peak and daily energy usage down compared to same week last year.

Fig. 19. Different Situations Occurred during Lockdown in Italy.

- The following situation has occurred during the lockdown (shown in Fig. 17):

**4.3. Italy**
- 10–21% drop occurred in peak energy demand and use, growing over the first week.
Load profiles have persisted largely unaffected with lessening in magnitude.

**Fig. 20** shows the comparative study of electrical load in Italy for 2019 and 2020 [34]. Like the previous case, i.e., Spain, in this case, also the electricity demand is declining severely after implementing the full lockdown.

The following situation has happened during the lockdown (shown in Fig. 19):

### 4.4 Ireland

- Like other countries, Ireland has also faced the same problem regarding energy demand and power production during the lockdown period.
- **Table 1** shows the monthly electricity production in Ireland for January, February, and March of 2020 [35]. This table shows that the energy supply is decreasing in March 2020 as compared to January and February. There is a reduction of 122 GWh energy demand in March from the previous month. This is due to the lockdown, which is imposed by the Government to fight against Corona Virus.

### 4.5 Ukraine

- For proper operation of the electrical system and to steady its financial condition at the lockdown time, the Ukraine Parliament has approved a Law named “On Amendments to Certain Legislative Acts of Ukraine Aimed at Preventing the Occurrence and Spread of Coronavirus (Covid-19)” on 17th March 2020 [36].
- The electricity requirement has decreased by approximately 8% as compared to the same time of the last year. This situation forces the Ukraine Government to stop the power import from Belarus and Russia.
- On 11th April 2020, the price of energy in the day-ahead market touched a historic low of UAH 606.26 (€20.46) per MWh.

### 4.6 Brazil

- The senate of the Brazilian Government announce the state of emergency on 20th March 2020 due to the COVID-19 [37].
- As of 27th April 2020, the electricity demand is decreased by approximately 20% due to the emergency in the country (Source: Brazilian Electric Energy Trade Chamber, CCEE).
Fig. 21. Electricity Demand Comparison Statistics in Brazil [37].

Fig. 22. Electricity Production Comparison Statistics in Turkey [40].

Fig. 23. Electricity Generation Comparison Statistics in France [41].
Fig. 21 shows the energy consumption by the Brazilian citizens on and before the lockdown which is executed to combat Coronavirus.

4.7. Turkey

Like other countries, the effect of COVID-19 has also been shown in the power sector of Turkey. Due to the lockdown during the COVID pandemic, the power requirement is decreasing drastically in Turkey [40]. The electricity production comparison statistics in Turkey are shown in Fig. 22. From the statistics, it can reveal that the electricity production is reduced in March, April, May, June, and July of 2020 if compared with the same month of the previous two years. This is only occurred due to the lockdown effect of COVID-19.

4.8. France

The electricity generation comparison statistics in France are depicted in Fig. 23. The energy production of the first 5 months in 2020 is compared with the previous year same month’s energy production. From March 2020, the electricity generation is reduced at a huge rate due to the effect of lockdown throughout France which is occurred to minimize the spread rate of COVID-19 [41].

4.9. Germany

The share of variable renewable energy (VRE) of Germany is shown in Fig. 24. In maximum EU countries like Germany, new records were seen during the COVID-19 lockdown. The VRE share is increased after the softened of lockdown. This is the direct indication of the reduction of power demand during the lockdown in Germany [32].

Fig. 25 shows the energy demand scenarios throughout the world in different regions for the last 20 years [38]. As the above discussion, it has been renowned that the power consumption in 2020 has declined due to the lockdown during Covid-19 (shown in Fig. 25), which could affect the power sector, but the electricity grid personnel has done a tremendous job by controlling the whole power system by which the customer, as well as the suppliers, have a smooth procedure.
4.10. Summary

This paper shows the overall impact of COVID-19 in the Power Sector throughout the world. After the detailed study, it can reveal that Coronavirus is a burning threat not only for human health it is a major warning to the electricity sector also. For the proper treatment of humans against Covid, uninterrupted electricity is necessary, but it is difficult due to the lockdown. A sudden change in the power demand creates a huge imbalance in the power network, which may reason for the grid failure as well as for the blackout. This situation may be threatened for the continuation of the fight against covid. In this present scenario, this paper provides detailed data about the power demand and generation throughout the world and show how the electrical situations in the power sector professional handled the critical situations during this lockdown period.

5. Conclusions

The COVID-19 pandemic forces to implement lockdown in almost all the countries around the globe. The frontline warriors like doctors, nurses, other medical staff, police officials are doing a tremendous job on their part to fight against the pandemic. Further, more people are doing a marvelous job for other essential needs. The officials and workers of the power sectors are one of them. The operators had ensured that in this hard time one of the most important lifelines of the world would not be interrupted. They are doing a commendable job during this lockdown period. Due to the huge decline in the electricity demand, there is a possibility of excess power in the grid which further causes a rise in the frequency and finally can occur grid failure. The power sector is balancing the power generation and demand by additional operation of hydro, gas, and renewable energy. By the endless effort of the power sector officials, the grid is securely working. In this scenario, the statistics of electricity demand are presented in detail for several countries in this work which can be helpful for the secure operation of the power sector. The status of COVID-19 is incorporated in this work. Several policies which had been implemented by leading European countries, as well as India, have been also deliberated.

CRediT authorship contribution statement

Subhojit Dawn: Data curation, Formal analysis, Investigation, Methodology, Software, Supervision, Validation, Visualization, Writing – original draft. Shreya Shree Das: Data curation, Formal analysis, Investigation, Methodology. Sadhan Gope: Resources, Software, Validation, Writing – original draft. Bishwajit Dey: Software, Supervision, Validation, Visualization, Writing – original draft. Fausto-Pedro García Márquez: Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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