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Impacts of COVID-19 lockdown period on the Algerian power grid demand

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ABSTRACT

The coronavirus disease-2019 (COVID-19) spread out at the end of 2019 has sadly caused millions of human losses and hundreds of millions of cases and stressful health situations. As a result, governments forced the worldwide population to stay confined and change their social activities and working behaviors. Under such conditions all economic sectors have been impacted, therefore global electricity consumption pattern has changed consequently. The object of this study is to calculate energy drop for such circumstances to make strategies to face such events in the future. The study we conducted during the period of confinement aims to identify the effects of the Corona epidemic on electricity consumption in Algeria by emphasizing four months (March, April, May, and June) for four years (2018, 2019, 2020, and 2021) by comparing monthly load curves and calculating load deviation for each month.

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1. INTRODUCTION

With the growth of industry in most countries and overpopulation in all parts of the world, the demand for electric power is incessantly increasing. The lockdown period for the coronavirus disease-2019 (COVID-19) pandemic showed the opposite, indicating a decrease in the consumption of electrical energy in many countries around the world [1]. This has forced researchers to conduct many studies to find out the impact of the period of confinement caused by the spread of COVID-19 on electricity consumption and electrical systems in general.

Worldwide power demand decreased by 2.5% in the first quarter of 2020 compared to the same period in 2019, including 6.5% in China [2], [3]. The first week of lockdown in India has the highest average reduction in peak demand by 20% [4]. In the United States of America, the energy drops down by 7.5% in 2020 [5]. In Europe, many countries presented a reduction of generation by 9% during the month of April 2020 [6], [7]. Latin America and the Caribbean countries have a maximum monthly drop between 11% and 17% [8]. For sub-Saharan African countries which represent 46 of 54 Africa's countries, the drop of power demand has been between 4% to 15% during the pandemic [9]. The drastic drop in energy demand affects positively the share of renewable energy in total production; therefore, it has led to a reinforcement of energy security by decreasing the share of imported energy in some countries [10]–[12].

2. LITERATURE REVIEW

2.1. Demand factor

The demand factor is considered as a ratio of the real power consumed by a system to the maximum possible real power [13]–[15]. It cannot be derived from the load profile but requires the addition of the full system load. The demand factor is always less than or equal to one and can range from 0.8 to 1.

$$\text{Demand factor} = \frac{\text{Load[kW]}}{\max\text{imum\_kW\_rating}} \tag{1}$$

2.2. Availability factor

The fraction of a given operating period in which a generating unit is available without any outages. The availability of a power plant varies greatly depending on the type of fuel, the design of the plant, and the way the plant is operated. All other things being equal, plants that operate less frequently have higher availability factors because they require less maintenance and because more inspections and maintenance can be scheduled during periods of inactivity.

$$\text{Availability factor} = \frac{\text{available\_hours}}{\text{periode\_hours}} \tag{2}$$

Available hours represent the number of hours a unit was in the available state, and period hours or active hours represent the number of hours a unit was in the active state [15].

2.3. Load factor

The load factor is the ratio of the average load over a designated period to the peak load occurring during the period. In practice, over a year, the load factor is reduced by reductions in electricity production caused by the intermittent nature of the energy source, maintenance operations, equipment failures, and variations in electricity demand. It can be derived from load profile and its value is always less than one [13], [15]–[17].

$$\text{Load factor} = \frac{average\_load}{peak\_load} \tag{3}$$

2.4. Diversity factor

Diversity factor is the ratio of the sum of the individual non-coincident maximum actual effective power, that is, real power demands of the various parts of a power distribution system to the maximum operational demand of the whole system. The diversity ratio is always greater than unity. It equals to one only when demand from all subdivisions of the system occurs at the same time [14], [15].

$$Diversity\ factor = \frac{\sum_{i=1}^{n} Pmax_i}{system\ P_{max}} \tag{4}$$

$Pmax_i$ is the individual maximum actual effective power and system and $Pmax$ is the maximum operational demand of the whole system.

2.5. Load deviation

The percentage of load deviation [18], [19] represents a good indicator of the consumption behavior of the electrical network. In our study, the deviation represents the ratio of the difference in electrical consumption on the same day for two consecutive years (n-1 and n) by the consumption of the (n-1) year. Load deviation can be greater, equal or lesser than unity depending on power consumed between two consecutive years.

$$Load\ deviation\% = \frac{Load\ h,j_n - Load\ h,j_{n-1}}{Load\ h,j_{n-1}} \times 100 \tag{5}$$

Here, h represents the day of the year, j_n is the appropriate year, and j_{n-1} is the previous year.

2.6. Load profile

A load profile or load curve is a graph illustrating the variation in electrical demand/load over a specific time. Generation companies use this information to plan how much electricity they will need at any given time. Load profiling gives also a good indication of electrical consumption behavior from a single residence to an entire grid [20]–[23]. Figure 1 illustrates an Algerian national power grid electricity demand load curve on June 26, 2021.

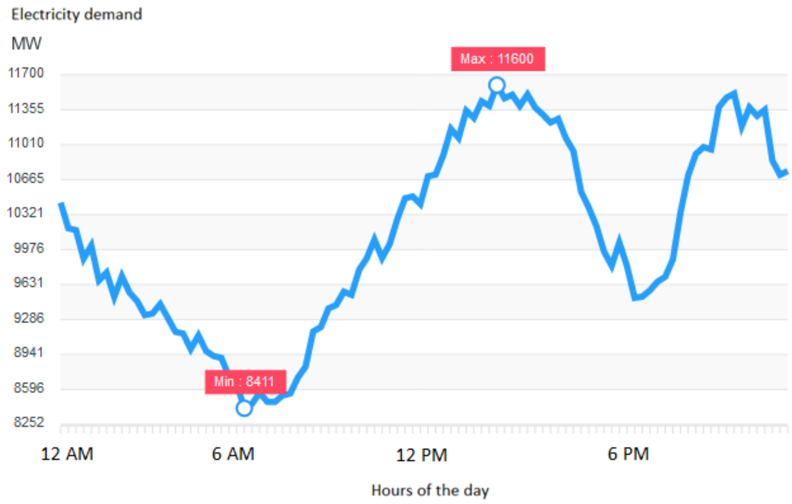


Figure 1. Algerian national grid electricity load curve on 26/6/21 [24]

Figure 2 displays a weekly load curve of the Algerian national grid from 1 to 7 March 2019. Weekly load curves give an overview of electrical consumption over a week and emphasize the difference between weekdays and weekends which gives an indication of the socio-economic strategy of the country. It also shows the influence of public holidays on the national grid power demand.

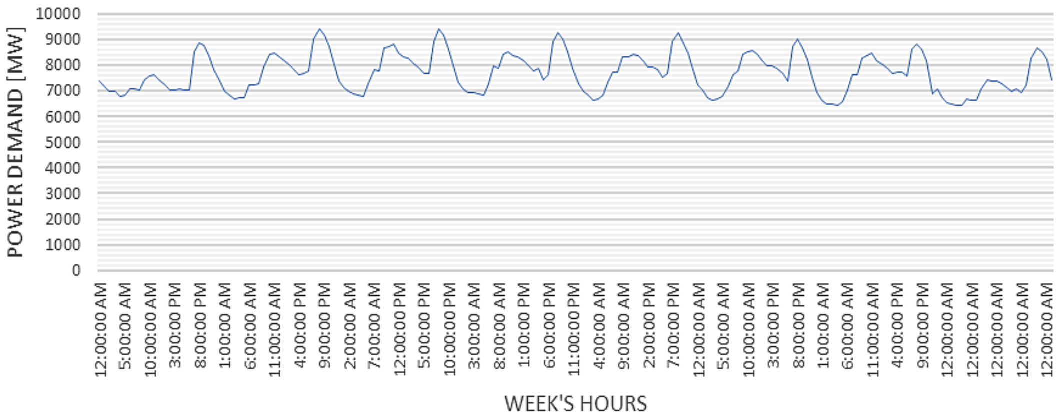


Figure 2. Algerian national grid weekly load curve

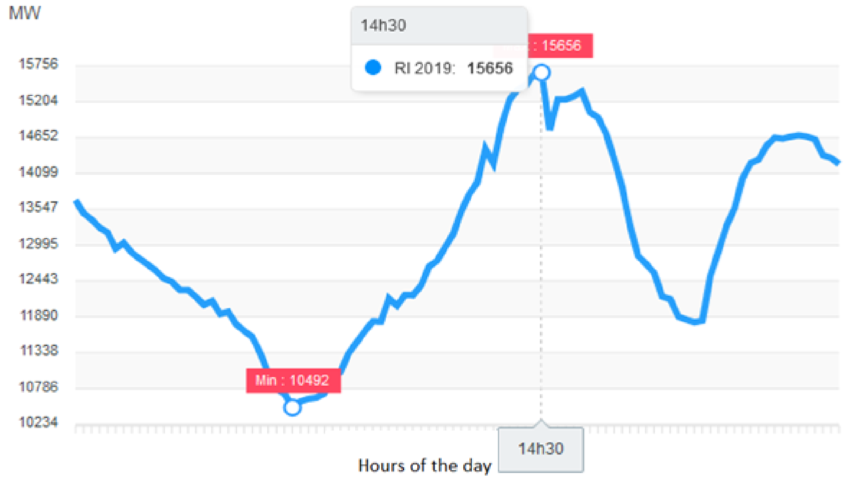
2.7. Peak demand

The peak demand for an electrical network is simply the highest demand for electrical energy which occurred over a specified period of time. The peak demand is generally characterized as annual, daily, or seasonal and has the power unit. Peak demands happen when the highest levels of energy are synchronously consumed; therefore, these peaks could affect power system stability, utility pricing, and future grid growth [25], [26]. Figure 3 shows the difference in terms of shape and peak between winter as shown in Figure 3(a), and summer as shown in Figure 3(b) load curves of the Algerian national grid.

2.8. Electricity market in Algeria

Access to electricity and gas is a major issue for social and economic development in Algeria. The Historical National Society of Electricity and Gas (SONELGAZ) has held the electricity production, transport, and distribution sector since July 28, 1969. The electrical operator system (OS) conducts and coordinates the production and transport of electricity then it ensures interconnected network protection. Table 1 presents the assessment of renewable installations in the Algerian national grid [27].

(a)



(b)

Figure 3. Algerian national power demand curve (a) winter peak and (b) summer peak

Table 1. Overall assessment of renewable installations connected to the Algerian national grid [28]

Facilities	Capacity (MW)	Year of commissioning
Hybrid pilot plant (gas-solar thermal concentration or CSP) of Hassi-R'mel	25 (CSP)	2011
Solar photovoltaic pilot plant in Ghardaïa	1.1	2014
Kabertène wind power plant (Adrar)	10.2	2014
Photovoltaic solar power plants of the program launched in early 2014 by SKTM	343	2018
10 MW photovoltaic solar power plant of Sonatrach (Bir Rebaa Nord or BRN) near Ouargla	10	2018
Total	389.3 MW	

2.8.1. The evolution of electric demand in Algeria

Algerian electricity demand reached a record 16,822 megawatts (MW) on August 14, 2022, which represents an increase of about 600 megawatts compared to the peak of 2021, which is the equivalent of a high-powered power plant. This strong increase in the demand for electricity is a direct consequence of changing consumption habits, in particular the widespread use of air conditioning systems, demographic growth, and social welfare. This is also demonstrated by the shift in peak demand from winter to summer. Figure 4 shows the Algerian electricity network peak of the year 2022. The latter coincides with a strong heat wave that hit the country in mid-August 2022.

The peak demand evolves gradually over the years and occurs especially in August as shown in Table 2. In 2020, we recorded a lower peak demand than in 2019 due to the COVID-19 pandemic. From 2021, demand peaks resume their ascent.

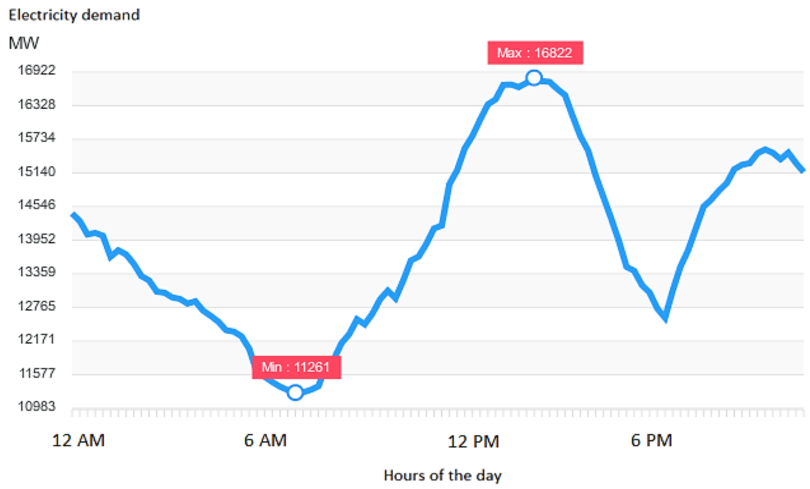


Figure 4. Peak demand on August 14, 2022

Table 2. The evolution of the peak demand for electricity in the Algerian power system

Year	Peak demand (MW)
08/2022	16,822
08/2021	16,224
07/2020	14,714
08/2019	15,656

3. EFFECTS OF THE LOCKDOWN PERIOD ON ELECTRICAL POWER SYSTEMS

3.1. Direct impacts

The COVID-19 pandemic impacts directly power systems, such effects include fluctuations in electricity demand in all regions affected by COVID and also the resulting effect on the cost of energy. Electrical system load can be categorized mainly into residential, commercial, and industrial types. These types of loads have a typical load pattern and system operators manage generation accordingly. During the lockdown of COVID-19, the percentage of electricity demand for these sectors has changed hence a new character of load curves in different countries was observed [29]–[31].

3.2. Indirect impacts

Indirect impacts mark the threats created on certain parameters which support the power sector in many ways such as new projects, investments, and consumer relations. The impact on these parameters, however, does not affect the actual operation of the electrical system, but it would have prolonged effects on the development of electrical systems [32], [33]. Due to COVID-19, energy demand has decreased in the industrial and commercial regions; however, it has increased in residential areas. Almost all regions affected by the event experienced a reduction in overall electricity demand. Centralized generation of electricity from fossil fuels has declined due to dropping demand. Nevertheless, due to national policies, the level of penetration of renewables into the grid has increased and this has posed both positive and negative issues [34]–[36].

4. RESULTS AND DISCUSSION

In this section, we will analyze a set of electricity consumption data from the Algerian national power grid. The dataset consists of the hourly consumption of 4 months (March, April, May, and June) in 4 years (2018, 2019, 2020, and 2021). We will perform load curve comparisons and calculate load deviations over these periods.

4.1. Comparison of load curves for the month of March 2018/2019/2020 and 2021

Figure 5 presents a comparison between 4 load curves for the last ten days of March 2018, March 2019, March 2020, and March 2021. These curves are plotted from historical data which represent the hourly electricity consumption of the Algerian national electricity network. Curves are fitted into a single figure to make comparison easier and clearer.

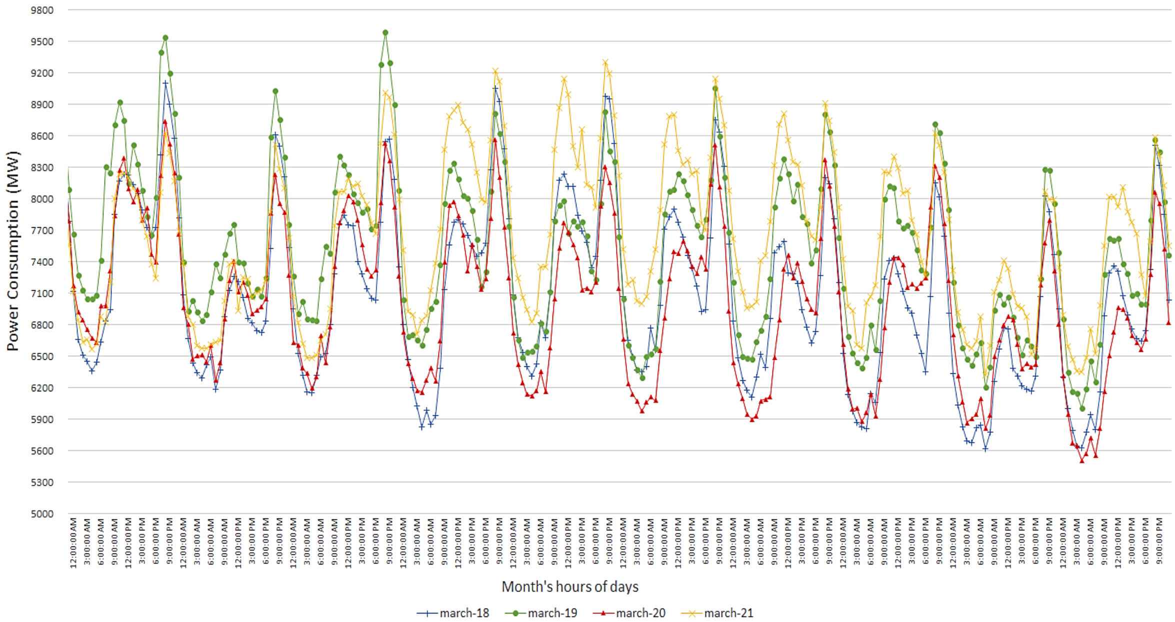


Figure 5. Comparison of load curves for the last ten days of March 2018/2019/2020/2021

Note that for 2019 (green), there was a normal increase in consumption from 2018, however, values of the 2020 curve (red), are the lowest throughout the days. It was unusual and coincided with the first appearance of coronavirus cases in Algeria. In 2021 (orange), consumption resumed its increase; however, this rise was not as significant as it was from 2018 to 2019. Table 3 presents the average hourly consumption data for the month of March.

Table 3. Average energy consumption for the month of March

March	2018	2019	2020	2021
Average energy consumption MW/h	7104.827	7616.651	7415.538	7541.753

Figure 6 shows the load deviation percentage for the month of March. It consists of 3 curves (histograms) which represent three deviations. Each deviation is calculated from 2 consecutive years such as 2018 to 2019, 2019 to 2020, and 2020 to 2021. Deviations are calculated based on (5).

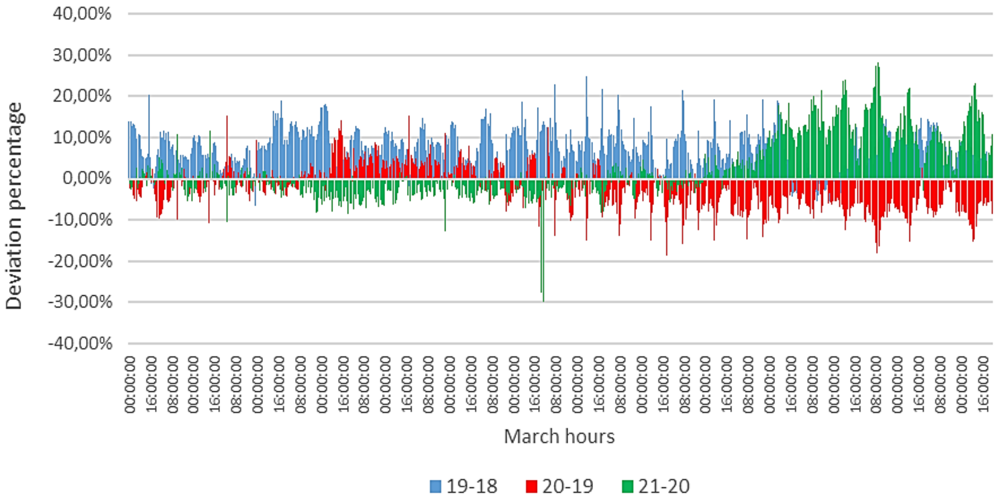


Figure 6. Load deviation percentage for the month of March

Deviation 19-18 (blue) the percentage increases between 2019 and 2018. Here the difference is always positive with an average of 7.48% as shown in Table 4. Deviation 20-19 (red) the percentage increases and decreases between 2020 and 2019. Here we see a curve with a negative trend with an average of -2.58%, this coincides with the beginning of partial confinement in the country. Deviation 21-20 (green) the percentage decreases and increases between 2021 and 2020. Here a positive deviation is observed with an average of 2.11%.

Table 4. Average load deviation for the month of March

March	19-18	20-19	21-20
Mean deviation	7.48%	-2.58%	2.11%

Table 4 presents the average hourly load deviations for the month of March. This average represents the sum of hourly deviations divided by the number of setpoints over the month. It constitutes a good indicator of the evolution of monthly electricity consumption.

4.2. Comparison of load curves for the month of April 2018/2019/2020 and 2021

Figure 7 presents a comparison between 4 load curves for the ten last days of April 2018, April 2019, April 2020, and April 2021. These curves are plotted from historical data which represent the hourly electrical consumption of the Algerian national electrical grid. Curves are fitted into a single figure to make comparison easier and clearer.

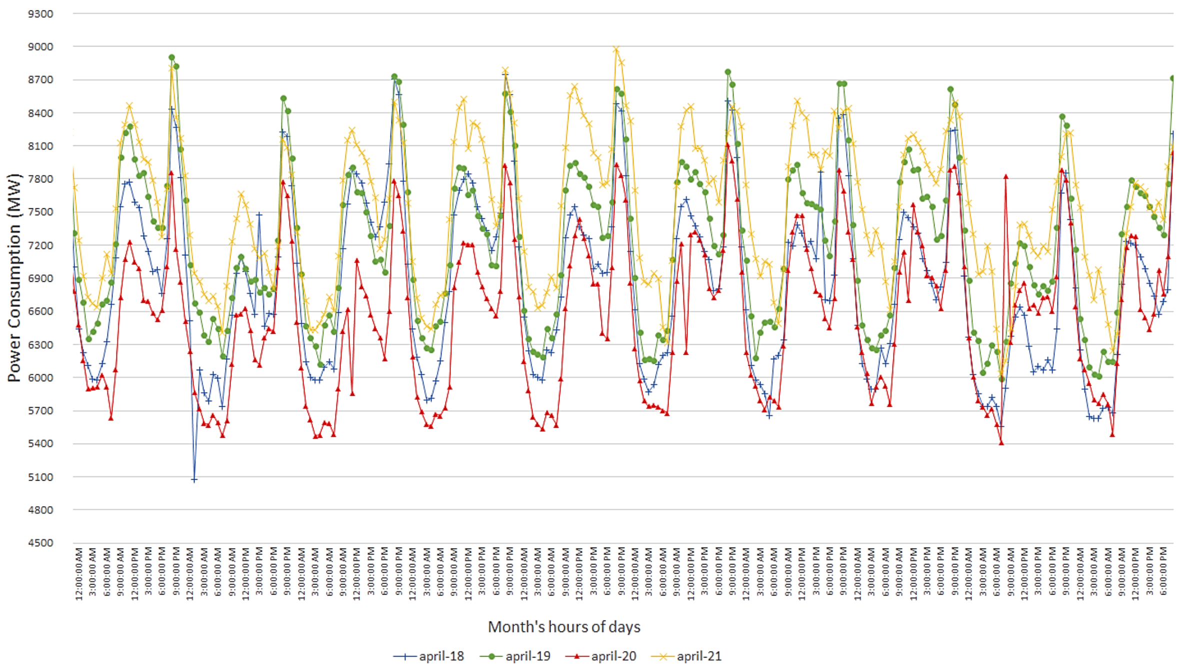


Figure 7. Comparison of load curves for the last ten days of April 2018/2019/2020/2021

We note that the values of the 2020 curve (red) are the lowest throughout the days, which is unusual and matches with the sanitary quarantine in Algeria. For 2019 (green) there was a natural increase in consumption compared to 2018. In 2021 (orange) consumption resumed its normal increase. Table 5 presents the average hourly consumption data for the month of April.

Table 5. Average energy consumption for the month of April

April	2018	2019	2020	2021
Average energy consumption MW/h	6825.56	7162.334	6576.384	7472.077

Figure 8 shows the load deviation percentage for the month of April, it consists of 3 curves (histograms) which represent three deviations. Each deviation is calculated from 2 consecutive years such as 2018 to 2019, 2019 to 2020, and 2020 to 2021. Deviations are calculated based on (5).

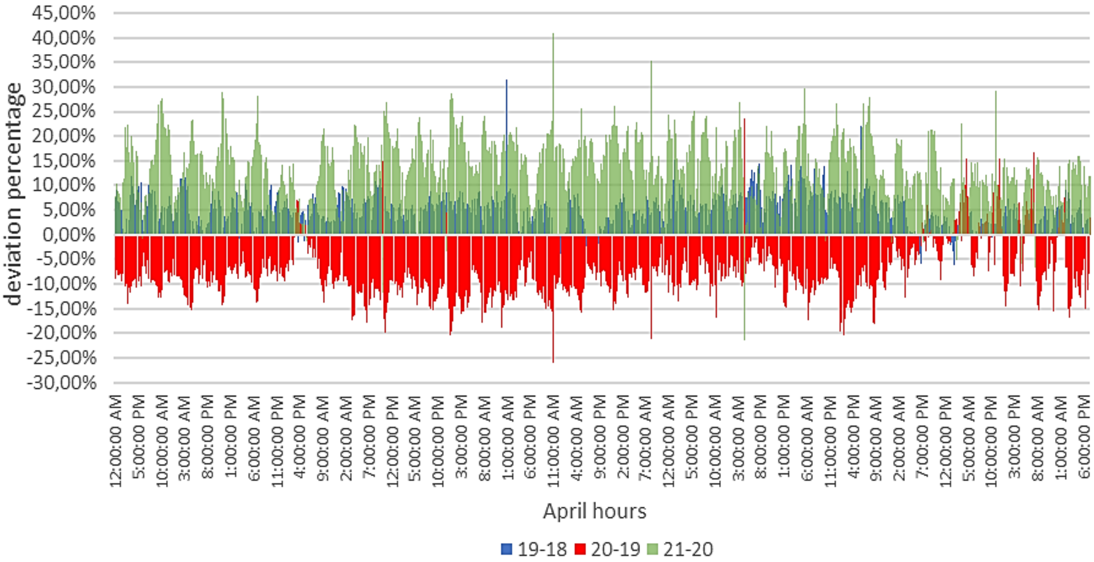


Figure 8. Load deviation percentage of for the month of April

For the deviation 19-18 (blue) the percentage increases between 2019 and 2018, therefore, the difference is always positive with an average of 5.08% as shown in Table 6. For the deviation 20-19 (red) the percentage decreases between 2019 and 2018, so, the difference is still negative with an average of -7.99%. this is due to the expansion of the confinement for all parts of the country. For the deviation 21-20 (green) the percentage increases between 2019 and 2018, thus, the difference is always positive with an average of 13.93%. Table 6 presents the average hourly load deviations for the month of April.

Table 6. Average load deviation for the month of April

April	19-18	20-19	21-20
Mean deviation	5.08%	-7.99%	13.93%

4.3. Comparison of load curves for the month of May 2018/2019/2020 and 2021

Figure 9 presents a comparison between 4 load curves for the last ten days of May 2018, May 2019, May 2020, and May 2021. These curves are plotted from historical data which represent the hourly electrical consumption of the Algerian national electrical grid. Curves are fitted into a single figure to make comparison easier and clearer.

Note that the values of the 2018 curve (blue) are the lowest on some days of the month. For 2019 (green) there is a natural increase in consumption throughout the month, however, the 2020 curve (red) has decreased, which is unusual and matches with continued lockdown in Algeria. In 2021 the consumption (orange) resumed its increase more than it was from 2018 to 2019. Table 7 presents the average hourly consumption data for the month of May.

Figure 10 shows the load deviation percentage for the month of May, it consists of 3 curves (histograms) which represent three deviations. Each deviation is calculated from 2 consecutive years such as 2018 to 2019, 2019 to 2020, and 2020 to 2021. Deviations are calculated based on (5).

For the deviation 19-18 (blue) the percentage increases between 2019 and 2018, therefore, the difference is always positive with an average of 6.56% as shown in Table 8. For the deviation 20-19 (red) the percentage decreases, so we can see a curve with a negative trend with an average of -4.19%. For the deviation 21-20 (green) the percentage increases and decreases, we see a curve with a positive trend with an average of 6.55%. Table 8 presents the average hourly load deviations for the month of May.

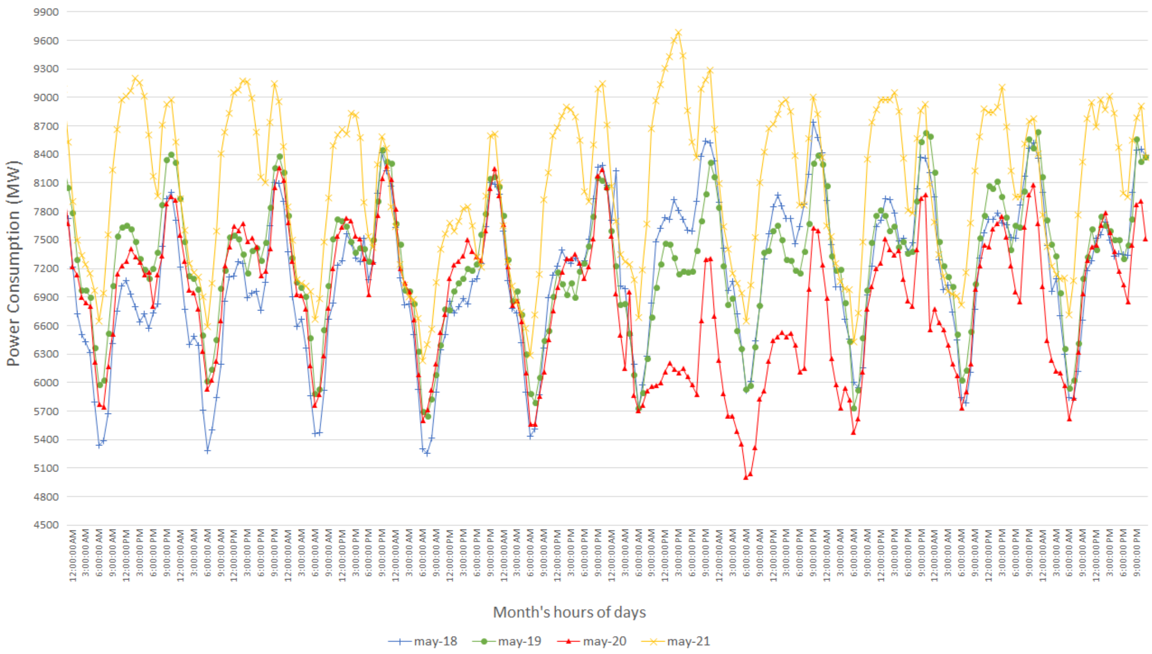


Figure 9. Comparison of load curves for the last ten days of May 2018/2019/2020/2021

Table 7. Average energy consumption for the month of May

May	2018	2019	2020	2021
Average energy consumption MW/h	6871.384	7293.904	6979.344	7402.754

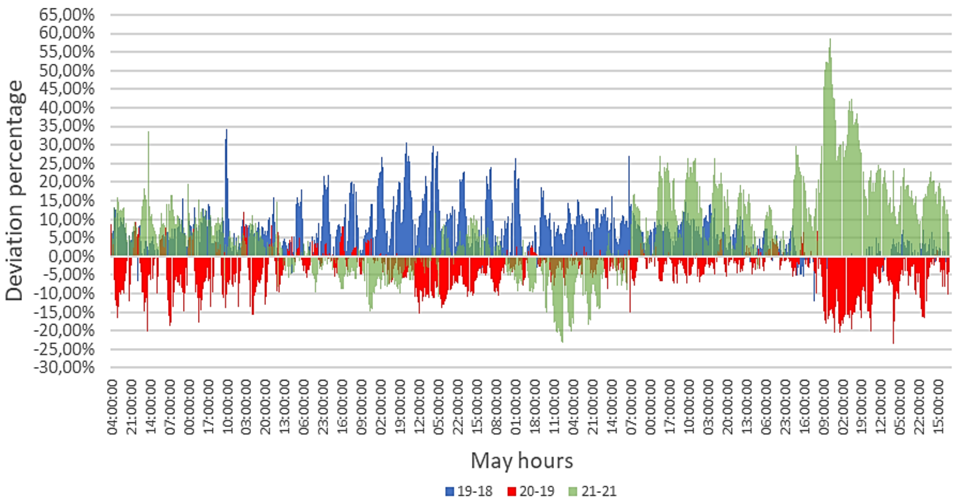


Figure 10. Load deviation percentage for the month of May

Table 8. Average load deviation for the month of May

May	19-18	20-19	21-20
Mean deviation	6.56%	-4.19%	6.55%

4.4. Comparison of load curves for the month of June 2018/2019/2020 and 2021

Figure 11 presents a comparison between 4 load curves for the ten last days of June 2018, June 2019, June 2020, and June 2021. These curves are plotted from historical data which represent the hourly electrical consumption of the Algerian national electrical grid. Curves are fitted into a single figure to make comparison easier and clearer.

We note that the values of the 2020 curve (red) are the lowest throughout the month, which is unusual and matches with the continuing lockdown in Algeria. For 2018 (blue) and 2019 (green) there was a normal increase in consumption. In 2021, the consumption resumed its increase. Table 9 presents the average hourly consumption data for the month of June.

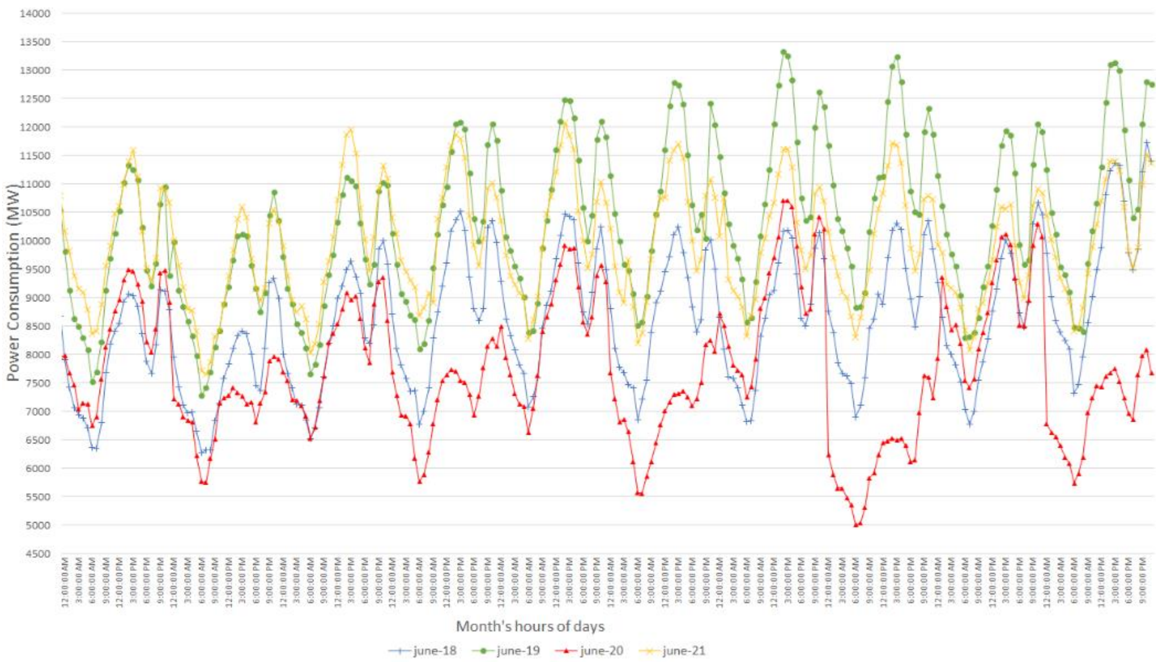


Figure 11. Comparison of load curves for the last ten days of June 2018/2019/2020/2021

Table 9. Average energy consumption for the month of June

June	2018	2019	2020	2021
Average energy consumption MW/h	7784.541	8894.05	7497.729	9064.268

Figure 12 shows the load deviation percentage for the month of May, it consists of 3 curves (histograms) which represent three deviations. Each deviation is calculated from 2 consecutive years such as 2018 to 2019, 2019 to 2020, and 2020 to 2021. Deviations are calculated based on (5).

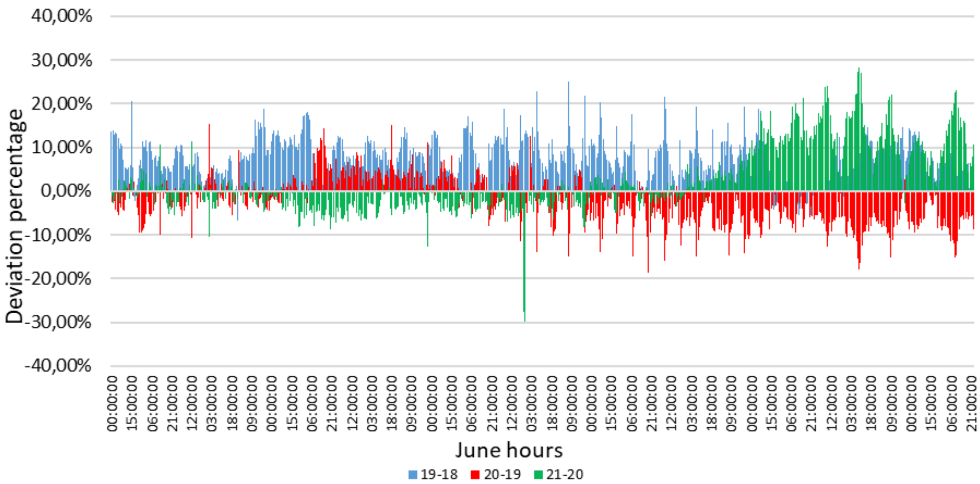


Figure 12. Load deviation percentage for the month of June

For the deviation 19-18 (blue) the percentage increases between 2019 and 2018, we see a curve with a positive trend with an average of 14.28% as shown in Table 10. For the deviation 20-19 (red) the percentage decreases, so, we see a curve with a negative trend with an average of -13.96% which is due to the maintenance of the lockdown and the beginning of the summer holiday period. For the deviation 19-18 (green) the percentage increases, therefore, the difference is always positive with an average of 21.64%. Table 10 presents the average hourly load deviations for the month of June.

Table 10. Average load deviation for the month of June

June	19-18	20-19	21-20
Mean deviation	14.28%	-13.96%	21.64%

5. CONCLUSION

In this work, we have presented a study on the Algerian national grid through the lockdown period to know the difference in electrical energy consumption before, during, and after the epidemic period of COVID-19. We have noticed from the data a decrease (-2% to -13%) in electric energy consumption during quarantine. This decrease is due to the interruption of some commercial and industrial activities in Algeria.

From our study, we conclude that sanitary lockdowns affect power systems through a diminution in consumer demand which varies from country to country and depends on the spread of the pandemic, therefore, the necessity is very important to raise awareness among decision-makers and politicians about future pandemics and disasters that could affect the globe and to prepare scenarios to deal with large drops of energy demand that disturb power grids.

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