EXPLORING THE IMPACTS OF COVID-19 PANDEMIC ON OMAN'S ELECTRICITY SECTOR

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ABSTRACT: This article reviews the recent trends of Oman's electricity sector before the COVID-19 pandemic outbreak. The impacts of the pandemic on the Main Interconnected System (MIS) of Oman were analyzed using hourly load data. The analysis shows that the MIS demand declined as a result of the decrease in economic activities during the lockdown. In addition, the MIS demand experienced temporal and geographical variations: the former is demonstrated by a shift in peak demand hours, while the latter is represented by a reduction in Muscat's urban areas' load compared with those of other areas.

Keywords: Oman; COVID-19 pandemic; electricity sector; Main Interconnected System; lockdown, load change.

آثار جائحة كوفيد -19 على قطاع الكهرباء في سلطنة عمان

م البادي، ع مالك، ع البادي، ص الرواحي، م الحوسني، م الشبيبي

الملخص: يستعرض هذا المقال الاتجاهات الحديثة لقطاع الكهرباء في سلطنة عمان قبل تفشي جائحة COVID-19. تم تحليل تأثيرات الوباء على الشبكة الكهربائية الرئيسية المترابطة (MIS) في سلطنة عمان باستخدام بيانات الأحمال الكهربائية المسجلة. يظهر التحليل أن الطلب على الكهرباء قد انخفض نتيجة لانخفاض الأنشطة الاقتصادية أثناء الإغلاق. بالإضافة إلى ذلك، شهد الطلب على الكهرباء تغيرات زمانية ومكانية. تجلت التغيرات الزمانية من خلال تحول ساعات ذروة الطلب، بينما تجلت التغيرات المكانية في انخفاض الطلب على الكهرباء في المناطق الحضرية في محافظة مسقط مقارنة بتلك الموجودة في المحافظات الأخرى.

الكلمات المفتاحية: سلطنة عمان؛ جائحة COVID-19؛ قطاع الكهرباء؛ الشبكة الكهربائية الرئيسية المترابطة؛ الإغلاق؛ تغير الاحمال.

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DOI:10.53540/tjer.vol19iss2pp95-105
Submitted on 2021-08-26
Accepted on 2022-05-26

NOMENCLATURE

AER:	Authority for Electricity Regulation
APSR:	Authority for Public Services Regulation
BST:	Bulk Supply Tariff
COVID-19:	Coronavirus Disease 2019
CRT:	Cost Reflective Tariff
IPPs:	Independent Power Producers
IEA:	International Energy Agency
IWPs:	Independent Power and Water Producers
MEDC:	Muscat Electricity Distribution Company
MIS:	Main Interconnected System
MJEC:	Majan Electricity Company
MSM:	Muscat Securities Market
MZEC:	Mazoon Electricity Company
OETC:	Oman Electricity Transmission Company
OPWP:	Oman Power and Water Procurement Company
RAEC:	Rural Areas Electricity Company
TOU:	time-of-use tariff.

1. INTRODUCTION

The outbreak of COVID-19 was reported in Wuhan, China, in December 2019 and continues worldwide. As of October 8, 2020, the COVID-19 pandemic has had over 36.3 million registered cases and claimed over 1 million lives (Worldometers.info 2020). Apart from human suffering and death, the epidemic caused a significant global economic downturn. The largest economies in the world have been among the most affected by the pandemic (Elgin, Basbug et al., 2020).

The COVID-19 pandemic has had direct adverse economic effects in various ways. To mention a few, isolated or hospitalized employees cannot join the workforce with numerous demand- and supply-side consequences. To lower COVID-19 transmission rates and reduce the burden on healthcare systems, governments have adopted a wide range of restrictive public health measures, including school and factory closures, travel restrictions, and community lockdowns (Atkeson 2020). As seen in China, Singapore, and Hong Kong, these steps have helped limit the increase in new infections (Anderson, Heesterbeek et al., 2020). However, such measures have slowed down economic activity by restricting human mobility and industry. The COVID-19 pandemic and associated public health regulations specifically disrupted supply chains and decreased activity in the manufacturing and service sectors, leading to increased layoffs. Stock markets have plummeted around the world, and unemployment claims have risen to unprecedented levels. Millions of employees have lost their jobs and cannot pay their credit card bills. Restaurants and shops are only slowly reopening; many cannot pay their rent. Industrial companies cannot make payments on their equipment leases. Landlords have less income and cannot keep up with their mortgages. Suddenly, the world is awash in credit risk (NERC 2018).

Lockdown initiatives have significantly lowered the need for power in both the consumer and manufacturing sectors over the last few months. The International Energy Agency (IEA) (IEA 2020, IEA 2020) reported that global electricity demand declined by 2.5% in the first quarter of 2020. As a result of the shutdown steps, electricity demand drastically decreased, with knock-on effects on the power mix. During periods of complete lockdown in many countries, electricity demand has been reduced by 20% or more as decreases in commercial and industrial operations greatly outweigh residential demand increases. These demand reductions have raised the share of renewables in electricity supply as such demand generally does not affect their production. Demand for all other electricity sources—including coal, gas, and nuclear power—dropped.

Electricity demand showed the first signs of growth as containment eased in Italy and Germany in April. This pattern was confirmed in May as lockdown steps were weakened by more countries (e.g., India, France, Spain, and the UK). In June, in most countries except India, where the recovery was more pronounced, the electricity demands, weather corrected, remained at 10% below the same month's 2019 level. The demand for electricity in China fell below that during the lockdown in January and more dramatically in February (13% less than in February 2019, the leap year being corrected). Part of the discrepancy was also attributed to a relatively colder winter in China in 2019 than in 2020. Electricity demand in China fully recovered in June 2020 and was even higher than that last year (IEA 2020).

The IEA report (IEA 2020) predicted that all types of fuel demand would be affected. According to the report, oil demand could drop by 9% (around 9 million barrels/day) annually. In large part, coal demand could decline by 8% because electricity demand will be nearly 5% lower throughout the year. Gas and nuclear demand will also fall in response to lower demand for power and industrial applications. However, renewables demand is expected to increase because of dispatch priority and recent growth in capacity caused by new projects. The coronavirus situation has proven that renewable energy is more appropriate for the situation because of its decentralized existence and can be a stable supply during the worst unpredictable scenarios (Norouzi, de Rubens et al. 2020). Global CO_2 emissions are predicted to fall by 8% to levels seen ten years ago, according to the IEA (IEA 2020). The report also warns that the rebound in emissions may be larger than the decline unless the wave of investment to restart the economy is dedicated to cleaner and more resilient energy infrastructure.

The International Finance Corporation reported (Bakovic, Kroese et al.) a 15% decrease in demand in several countries where it does business on average in March and April 2020. Slower growth in demand as a consequence of declining COVID-19–led economic activity could hold oil prices down, yet uncertainty is to be anticipated. Low oil prices would benefit oil-importing nations, especially those where oil prices are linked to natural gas. Given the economic downturn in China and the rising shale gas output in the United States, natural gas prices were still at historic lows before COVID-19. Spot rates in countries with a significant share of renewables hit values near zero marginal costs (e.g., at some hours in Brazil, Mexico, Peru, and Turkey).

According to an international study published in the journal Nature Climate Change (Le Quéré, Jackson et al. 2020) examining daily CO_2 emissions from 69 countries, all 50 U.S. states, and 30 Chinese provinces, reflecting a total of 85% of the world population as well as 97% of global CO_2 emissions, carbon emissions dropped colossally by 17% in April 2020 compared with those last year. Emissions from some nations decreased by as much as 26% on average during the peak of April confinement measures. According to the study, global emissions could decline by 4.4% to 8% by the end of this year. Decreasing factory production, fewer cars on the road, and less power generation contributed to this decline. Moreover, global renewable energy production increased by 3%, mainly powered by new online solar and wind projects over the past year.

In one study (Buechler, Powell et al., 2020), the authors developed a unified modelling framework to quantify and compare electricity usage changes across countries and regions. This study was applied to demand data for electricity from 58 countries and regions around the world, representing about 60% of the world's population and 75% of global electricity demand. Utilizing the 53 countries' daily data, the authors found that the total electricity demand declined by as much as 10% in April 2020 compared with the modelled demand, adjusting for weather, seasonal, and temporal effects. This decrease in demand is characterized by four groups, ranging from a mild 2% shift to a severe 26% decline. The authors explored how government restrictions and mobility patterns were related to electricity demand changes and found that these linkages were most pronounced in the extreme and severe impact groups and less so in the moderate and mild ones. This, in turn, can provide essential information in the future, helping utilities, companies that purchase power directly, and public officials respond more effectively to the impacts of future viral outbreaks and ongoing efforts to build more resilient, sustainable infrastructure systems. A global reduction in electrical energy demand and price was also observed in some countries. The reported drops in consumption reached 25% in Italy, 20% in France, and 12% in the UK (Mylenka and Novyk 2020). One study (Haxhimusa and Liebensteiner 2020) reported that in 16 European countries, when the COVID-19 outbreak was at its peak, electricity demand was reduced by 19%, which resulted in a significant drop in carbon emissions by 34%. The delay or nonpayment of utility bills by end consumers will have a detrimental effect on distribution, transmission, and generation companies. Thus, the lockdowns have caused delays in power projects because of supply chain disruptions, workforce unavailability, and project financing issues. These developments confirm the dependence of the global economy on the energy system.

All countries should consider energy as a basic human right, and governments should seek their supplies from more than one country to avoid delays in energy projects during future global crises. The renewable energy sector was negatively impacted by COVID-19, mainly related to delays in the power plants' equipment delivery or construction. The spread of the virus has caused several industries' shutdowns and issues along the supply chain across multiple industry sectors. Contractors relying on an international workforce are also impacted as travel restrictions, or quarantine measures are imposed, leading to labour shortages. Project developers may be facing penalties or, in some cases, losing tax incentives, tariffs, or other revenue sources. For example, BYD, a producer of rechargeable batteries, was unable to complete the required testing for some batteries, which led to delays in delivering the needed quantities of these batteries to the European market (Mylenka and Novyk 2020). Furthermore, while governments in developing countries are big buyers of renewable energy products, the available funds are diverted for medical purposes because of the virus, which further hurts renewable energy projects. The renewable energy sector's primary global concern is supply chain issues, with solar and wind projects already witnessing logistical delays.

The effects of COVID-19 on energy systems have been studied in terms of system operation (Elavarasan, Shafiullah et al. 2020, Noorazar, Srivastava et al. 2020, Safari, Price et al. 2020), demand and load forecasting (Agdas and Barooah 2020, Chen, Yang et al. 2020), energy policy (Graff and Carley 2020), and energy markets (Graf, Quaglia et al. 2020, Wang, Yang et al. 2020, Ruan, Wu et al. 2021). The pandemic has raised many unanswered questions about the long-term operation and planning of power systems (Navon, Machlev et al., 2021), such as the incorporation of renewable energy sources (Hosseini, 2020) and their impact on frequency stability (Milano, Dörfler et al. 2018), power system expansion planning in the light of the COVID-19 pandemic (Gorenstin, Campodonico et al. 1993), and the need for the availability of new tools to system operators in times of global health crisis (Wang, Yang et al. 2020).

Most papers in the literature that estimate changes in demand during the COVID-19 pandemic account for temperature and temporal variables (e.g., seasonality, day of the week). Some papers do this by using a predictive model to estimate what demand would have been during 2020 without a pandemic, incorporating temperature and temporal influencing factors into regression models (Prol and Sungmin 2020, Ruan, Wu et al. 2020). Others take an econometric approach, estimating changes via fixed effects in the model controlling for key electricity demand factors such as time of day, day of the week, week of the year, and temperature, essentially comparing electricity demand for an hour during COVID-19 to that for a similar hour in a similar week of the year after controlling for temperature (Leach, Rivers et al. 2020). Another approach uses a direct comparison to historical data, adjusting the results using the temperature sensitivity of the load (McWilliams and Zachmann 2020).

As the economic activities of modern societies are heavily dependent on the use of electricity, monitoring electricity consumption patterns can provide some insight into the impact of lockdowns that are imposed due to pandemics such as COVID-19 (Janzen and Radulescu 2020). This paper analyzes the demand profile of the MIS system after the pandemic compared to the previous year for the same date and time. The comparison is also made at the three distribution company levels.

Although the COVID-19 pandemic affected the global economy adversely, at the same time, it had some positive impacts. These include; increasing global renewable energy production, low oil prices that benefit oil-importing nations, reduction in global CO_2 emissions, reduction of electrical energy demand, reducing the flight services and providing many services online.

Following this introduction, the article will review recent trends in Oman's electricity sector before the COVID-19 pandemic in Section 2. Afterwards, the article presents the direct implications of COVID-19 on the main interconnected system in terms of spatial and temporal changes. In addition, Section 3 presents some indirect implications of COVID-19 on the electricity sector in Oman. Section 4 discusses the recommendations related to the operation and planning of the Omani power sector. Section 5 presents the main conclusions of the article.

2. RECENT TRENDS IN OMAN'S ELECTRICITY SECTOR

The demand in MIS represents about 88% of the consumption in Oman's electricity sector (APSR 2020). This study focuses on the demand change patterns of the Main Interconnected System (MIS) of Oman. The recent trends of Oman's electricity sector are summarized in the below sections.

2.1 Overview of Oman's Electricity Sector

Before May 2005, Oman's electricity sector was a vertically integrated system owned and operated by the Ministry of Housing, Electricity, and Water (Albadi 2017, Albadi, Al-Badi et al. 2020). The Electricity Sector Law, which was issued on July 7, 2004, through Royal Decree 78/2004, established a new market structure. Generation, transmission and distribution activities were unbundled through the establishment of different government-owned companies. In addition, the Authority of Electricity Regulation (AER) was established to regulate the new market structure (APSR 2020). In August 2020, the AER was renamed the Authority for Public Services Regulation (APSR), as its mandate was extended to include electricity, water, and gas public services.

Currently, there are three distinct power systems in Oman: the Main Interconnected System (MIS) in the northern part of the country (Fig. 1), the Dhofar Power System (DPS) in the south, and small isolated systems in the Rural Areas Electricity Company (RAEC). In 2019, the number of registered customer accounts reached 1,114,502, 121,190, and 41,586 in the MIS, DPS, and RAEC, respectively. The supplied electricity reached 29.618769 TWh, 3.075685 TWh, and 1.101589 TWh in the MIS, DPS, and RAEC, respectively (AER 2019).

2.2 MIS Demand Trends since Restructuring

The recent MIS trends are summarized in the figures below. The supplied energy of the MIS increased consciously from 8.4 TWh in 2005 to 29.62 in 2019 (Fig. 2) but did not increase afterwards. This might be attributed to the application of the cost-reflective tariff (CRT) and the use of energy efficiency measures. A similar trend can be found in the MIS's peak demand.

Apart from the drastic increase in supplied energy, another significant achievement of electricity sector restructuring in Oman is the continuous improvement of the MIS's efficiency. Its transmission and distribution losses decreased from almost 25% to about 8% (Fig. 3). However, the subsidies increased from OMR 66.3 million in 2005 to OMR 441 million in 2019 because of the increase in power-subsidized demand and capacity investments (Fig. 4). This increase is attributed to the increase in supplied energy and the fact that permitted tariffs are lower than the economic cost (Albadi 2017).

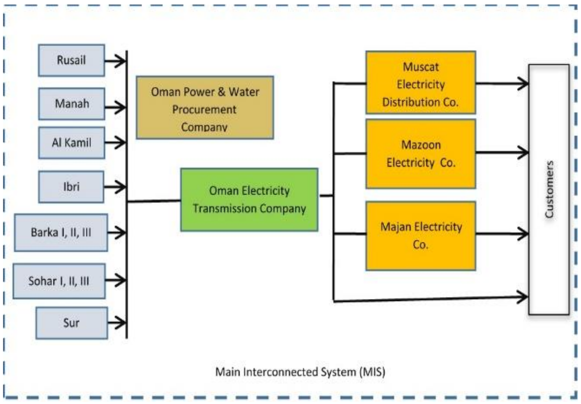

Figure. 1. The structure of Oman's Main Interconnected System (MIS).

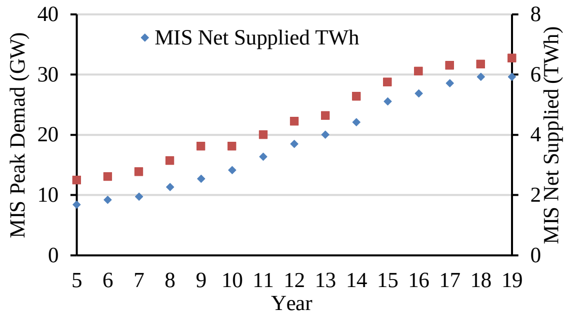

Figure. 2. Evolvement of MIS-supplied energy (TWh) and peak demand (GW).

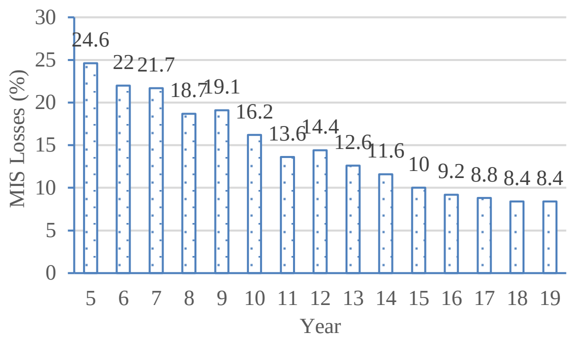

Figure. 3. Evolvement of MIS losses since electricity sector restructuring.

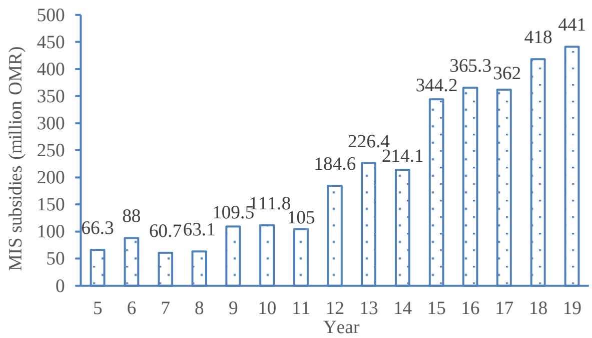

Figure. 4. Evolvement of MIS subsidies since electricity sector restructuring.

2.3 Impacts of Cost-Reflective Tariff

To encourage economic efficiency, the Oman Power and Water Procurement Company (OPWP) purchases energy from the producer based on a bulk supply tariff (BST) that reflects the marginal cost. The BST energy charge has a time-of-use (TOU) tariff structure, and it is applied to distribution companies (MEDC, MZEC, MJEC) but not end-use consumers. To reduce subsidies, large industrial, commercial, and government customers who consume more than 150 MWh per year started paying the CRTs from January 2017 onward. The CRT has several components, including the BST energy charge (OMR/MWh), a transmission charge (OMR/MW), a distribution charge (OMR/MWh), and a fixed service charge (Albadi 2017). These charges are subject to the approval of the APSR. The transmission charge is linked to the system's peak demand. Therefore, the CRT's application on large customers helped reduce both the MIS's peak demand and supplied energy. CRT customers started energy efficiency programs as well as rooftop PV projects.

2.4 Recent Investments and Projects

According to the OPWP, the first solar power plant in Ibri (500 MW) will be commissioned in 2021 (OPWP 2020). Three more solar independent power producers (IPPs) of a similar size will be commissioned in 2022, 2023, and 2024 as well as a wind IPP of 100 MW in the Sharqiyah region for completion in 2023 (OPWP 2020). This will enable the OPWP to reach its target of 16% electricity production from new solar, wind, and waste-to-energy projects by 2025. Apart from renewable energy projects, other major developments in the MIS include activating the Electricity Spot Market in 2020, connecting the MIS to Duqm via a 400 kV transmission line in 2023, and creating demand response programs (OPWP 2020).

On December 15, 2019, authorities announced that 49% of the Oman Electricity Transmission Company (OETC) shares would be sold to China State Grid International Development (OETC 2020). This $1 billion deal is the start of partial privatization projects that will include other Nama Holding Group government-owned companies, such as MEDC (NAMA 2020).

3. IMPLICATIONS OF COVID-19 ON MIS

3.1 COVID-19 in Oman

On February 24, 2020, the first two cases of COVID-19 were confirmed, and the first death was recorded on April 1 of the same year. Since then, the country has restricted movement among the governorates by installing checkpoints on entry and exit points on the roads. On April 10, the Muscat governorate was put under lockdown, which was lifted on May 29. The purpose of the lockdown was to reduce confirmed cases and family gatherings during the month of Ramadhan and the Eid al-Fitr seasons. A second lockdown was established among all governorates, including the main roads and inter-governorate roads, from July 25 to August 8, 2020 (MoH 2020). The second lockdown was to restrict social activities and family gatherings during the Eid al-Adha season. These restrictions had a direct impact on Oman's economic activities and reduced the demand for electricity.

3.2 Capacity Investment Charge

Since the beginning of 2020, oil prices have been falling, primarily caused by the decline in oil demand because of global lockdown measures to contain COVID-19. The decline in prices is compounded by the failure of OPEC+ to compromise on supply cuts (Haxhimusa and Liebensteiner 2020). Oil revenues are now set to plummet further in 2020, following a massive wave of declining global demand set off by the pandemic. Oman's economy is expected to shrink by 2.8% in 2020. Despite significant diversification efforts in recent years, the country's fiscal position is still highly exposed to oil price fluctuation as oil contributes nearly 35% of the GDP, 74% of revenue (with gas), and 66% of export. Oman's budget breaks even at almost $87 per barrel, so sub-$30 oil, coupled with a lower production quota under the April OPEC+ deal, will imply a nearly 17% gaping budget deficit in 2020 (Cornell 2020).

The MIS's electricity demand declined as a result of the lockdown and the decrease in commercial and industrial activities. Because of the financial implications of COVID-19 on oil prices, on May 17, 2020, the OPWP informed eight IPPs and independent water producers (IWPs) listed on the Muscat Securities Market (MSM) about its intention to temporarily suspend investment fees from energy and water capacity fees. However, on May 27, 2020, the OPWP retracted this letter following a statement confirming the Ministry of Finance's commitment to continue providing the necessary financing for the electricity sector, which was announced on May 21, 2020 (OPWP 2020).

3.3 Load Changes caused by COVID-19

Omani authorities have been taking precautionary measures against the spread of COVID-19 since the first COVID-19 case was detected in Oman on February 24, 2020. By mid-March, schools, colleges, and universities were closed. The Supreme Committee of Oman, under the chairmanship of the minister of interior, was tasked with handling the developments resulting from the spread of COVID-19. The committee made more tough decisions to prevent the spread of the virus from March 18, 2020, onward. These included the closures of restaurants, shopping malls, religious places, shops and marketplaces, sports and cultural clubs, sports halls, courts, health clubs, barbershops and beauty salons, etc. The committee ordered the suspension of all gatherings, activities, and conferences, closed all tourist sites, restricted entry to the sultanate from all land, sea, and air entry points with the exception of Omani citizens, and stopped Omanis from leaving the sultanate. On Wednesday, April 8, 2020, Omani authorities ordered a 12-day lockdown of the Muscat province to prevent the further spread of COVID-19. According to their directive, all movement into and out of the province was prohibited between Friday, April 10, and Wednesday, April 22. This lockdown was further extended until May 29, 2020.

For comparison purposes, we have selected two periods from March 18 to April 9 and then from April 10 to May 29 in the years 2019 and 2020 to observe the pattern of the MIS's load data and the three distribution companies' load data during the mentioned periods. The second lockdown was much stricter than the first, which included banning people from entering or leaving the Muscat Governorate, which was implemented on April 10. The hourly data used in this analysis were obtained from the Load Dispatch Centre of OETC.

A. March 18 to April 9

Figure 5 and Table 1 compare the MIS's load and weather temperature from March 1 to March 17 of 2019 and 2020, a period before the lockdown occurred in 2020. Before the lockdown, the overall peak during this period was 3,280 MW in 2019 and 3,359 MW in 2020, with a positive difference of 80 MW. The average load during the same period was 2,635 MW in 2019 and 2,822 MW in 2020, with a positive difference of 187 MW. Energy consumption during this period was 1,075,212 MWh in 2019 and 1,151,388 MWh in 2020, with a positive difference of 76,175 MWh. The weather temperature during this period was also, on average, lower in 2019 compared with that 2020. In 2019, the average temperature for the period was 23.2°C, and in 2020, it was 24.2°C.

Figure 6 and Table 1 compare the MIS's load and temperature from March 18 to April 9 in 2019 and 2020, during a lockdown period in 2020. The overall peak during this period was 4,757 MW in 2019 and 4,006 MW in 2020, with a negative difference of 752 MW. The average load during the same period was 3,246 MW in 2019 and 2,833 MW in 2020, with a negative difference of 413 MW. Energy consumption during this period was 1,792,046 MWh in 2019 and 1,563,914 MWh in 2020, with a negative difference of 228,132 MWh. The weather temperature during this period was also, on average, higher in 2019 compared with that 2020. In 2019, the average temperature was 28.0°C, and in 2020, it was 26.8°C. Some of the higher loads in 2019 can be attributed to the weather during this period, but overall, a significant load reduction can be observed in 2020 after the lockdown. It is also possible that weather temperature is also affected by the lockdown as the previous trend of 2019 from March 1-17 is a bit on the higher side. Per the load growth forecast, a growth of 2%–3% was expected in 2020. However, the load growth appears to be limited and balanced by the decrease in demand caused by the lockdown. Thus, the overall load trend seems to match last year's trend if the weather is corrected. The closures of shopping malls, mosques, schools, industrial areas, and commercial activities have resulted in a significant drop in system load. An increase in residential load may have been caused by the lockdown, partly balancing the reduction in commercial and industrial loads.

Table 1. Comparison of System Load, Energy, and Weather Temperature for the period 1-17 March and March 18–April 10 in 2019 and 2020 for MIS.

	March 1 to March 17				March 18 to April 10		
	2019	2020	Diff.		2019	2020	Diff.
Max load (MW)	3280	3359	80	Max load (MW)	4757	4006	-752
Avg. load (MW)	2635	2822	187	Avg. Load (MW)	3246	2833	-413
Energy (MWh)	1075213	1151388	76175	Energy (MWh)	1792046	1563915	-228132
Max Temp (ºC)	31.9	31.4	-0.5	Max Temp (ºC)	40.9	40.0	
Avg. Temp (ºC)	23.2	24.2	1	Avg. Temp (ºC)	28.0	26.8	

Table 2. Comparison of Peak Load and Energy for the period April 10–May 29 in 2019 and 2020 for Distribution Companies and MIS

Companies	Load/Energy	2019	2020	Difference
MEDC	Max. Load (MW)	2243	2012	-231
	Energy (MWh)	1882871	1794286	-88584
	Load Factor (%)	70%	74.3%	4.4%
MZEC	Max Load (MW)	1936	2007	71
	Energy (MWh)	1522088	1643013	120925
	Load Factor (%)	65.5%	68.2%	2.7%
MJEC	Max. Load (MW)	1528	1470	-58
	Energy (MWh)	1348166	1359617	11450
	Load Factor (%)	73.5%	77.1%	3.5%
MIS (Total)	Max. Load (MW)	5536	5415	-121
	Energy (MWh)	4753125	4796916	43791
	Load Factor (%)	71.6%	73.8%	2.3%

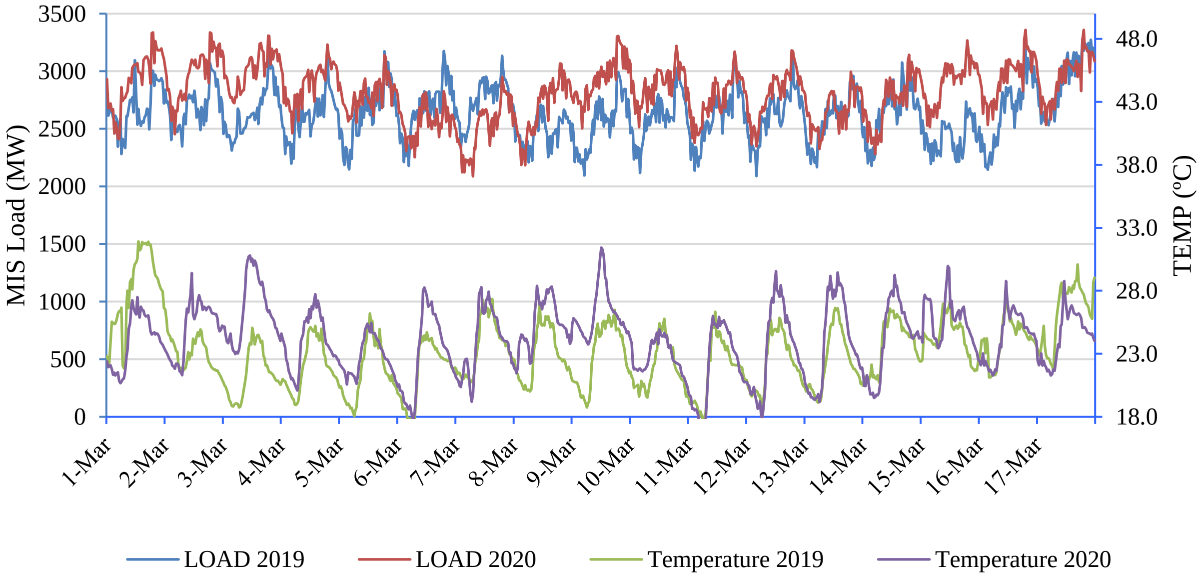

Figure. 5. Comparison of MIS load and temperature for the period March 1–17 in 2019 and 2020.

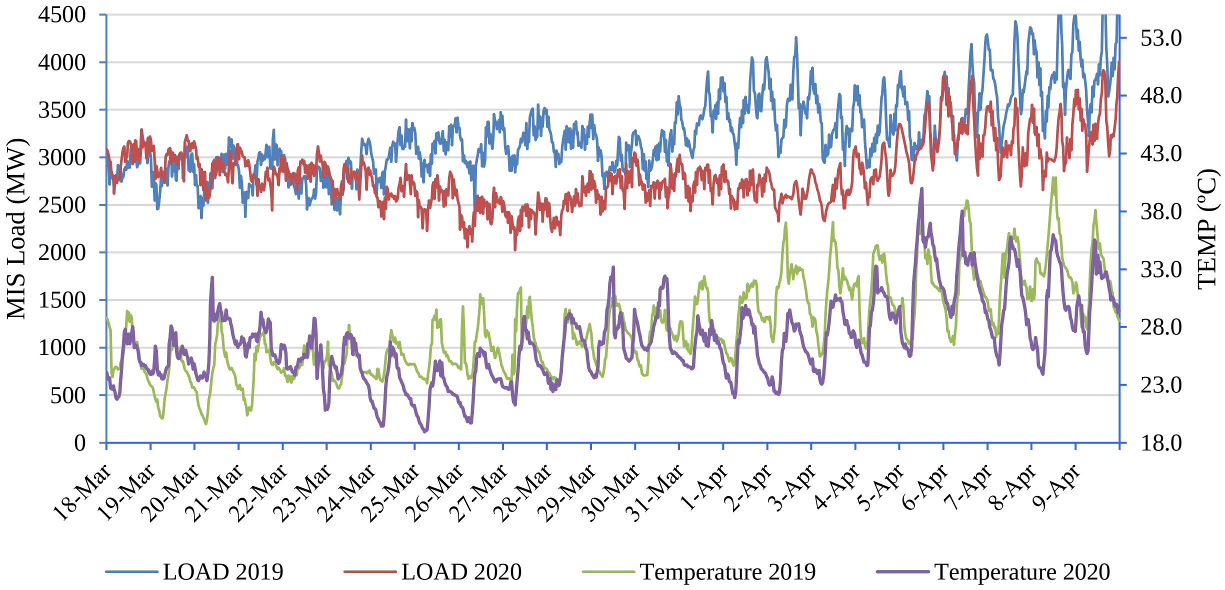

Figure. 6. Comparison of MIS load and temperature for the period March 18–April 9 in 2019 and 2020.

B. April 10 to May 29

Figures 7–10 show the daily peak trend of load for the distribution companies and the MIS for the period 2019–2020. Table 2 compares the maximum load and energy experienced by distribution companies and the MIS from April 10 to May 29 in 2019 and 2020. In the case of MEDC, both peak demand and energy were reduced in 2020, whereas for MZEC, energy consumption and maximum demand in 2020 were higher than those in the previous year. The reason is the composition of industrial and commercial, and residential sectors in MEDC and MZEC. Since most of the commercial activities take place in the Muscat area, the MEDC load was reduced during the lockdown period. Another factor is that most of the people who work in the Muscat area come from different parts of Oman, and when the lockdown was announced, they moved back to their respective places. Overall, the MIS's peak load was reduced by 2.1% (121 MW); however, this year's energy consumption was higher than that of the last year for this period. Lower peak demand and higher energy consumption are suitable for electric utilities as this suggests a better utilization of assets. There is a yardstick used called the load factor for this purpose. The load factor (LF) is defined as follows:

$$LF = \frac{Energy\ Conumption(MWh)}{Peak\ demand\ (MW) \times hours\ (hrs)} \times 100\% \qquad (1)$$

The load factor could be annual, seasonal, etc., depending on the selected period. The higher the load factor, the more efficient use of existing resources and enhanced social welfare. Therefore, we observe that the system load factor improved from 71.6% to 73.8% during the lockdown period. It may be noted that system peak is not simply adding a maximum load of distribution companies. This is because the maximum demand of these distribution companies is not coinciding with the system peak. The load factors of distribution companies have also improved during the lockdown period. It may be noted that although the peak load of MZEC increased in 2020, the load factor of MZEC still improved by 2.7%. One of the highlight and lesson learned from lockdowns are that the system load factor and distribution companies' load factors improved, reflecting greater efficiency and enhancing social welfare as consumption during non-peak hours increased, making better use of utility plants and lowering the average cost of electricity.

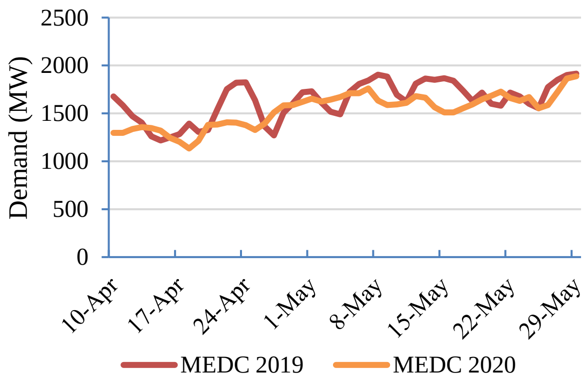

Figure. 7. Comparison of MEDC load for the period April 10–May 29 in 2019 and 2020.

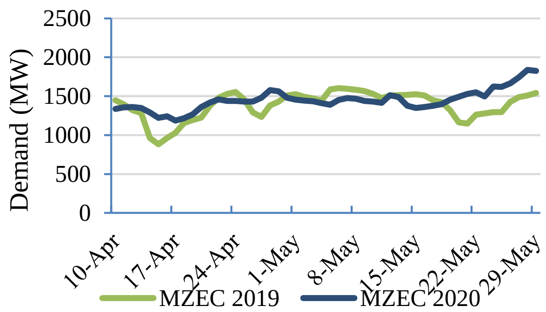

Figure. 8. Comparison of MZEC load for the period April 10–May 29 in 2019 and 2020.

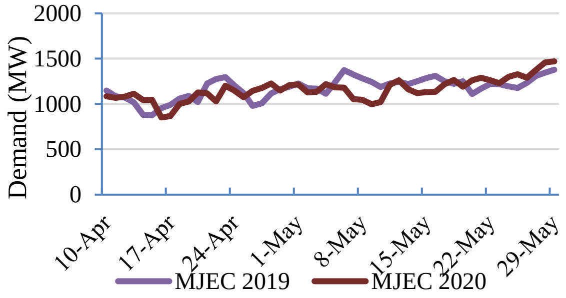

Figure. 9. Comparison of MJEC load for the period April 10–May 29 in 2019 and 2020.

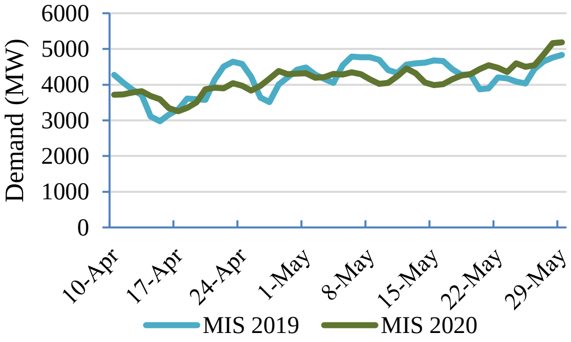

Figure. 10. Comparison of MIS load for the period April 10–May 29 in 2019 and 2020.

4. Recommendations for Power Sector's Operation and Planning

We can learn from the recommendations and lessons learned in different parts of the world regarding power sector operation and planning during the pandemic time in the following references (Elavarasan, Shafiullah et al. 2020, Noorazar, Srivastava et al. 2020, Safari, Price et al. 2020) (Navon, Machlev et al. 2021). Here we will discuss some technical and non-technical recommendations that are more relevant to the Omani power sector.

1. Power companies need to ensure the safety and security of their employees.
2. Because of the immobility, consumers may not pay bills during this time. As a result, utilities should take precautions to avoid disconnecting customers due to late payments or insufficient funds in their accounts.
3. The government may compensate for the financial loss to power companies that may occur because of the nonpayments of electricity bills or due to suppressed demand.
4. With the changing situation of Covid-19 infection cases and fresh waves of variants of the virus, the Supreme Committee's decisions also change, sometimes putting more restrictions on lockdown and travel ban and sometimes relaxing the restrictions, which lead to the unpredictability of electricity demand. Therefore, there is a need to have more accurate short-term load forecasting for economic dispatch and to minimize the risk of electricity interruptions.
5. OPWP should keep its renewable target as planned earlier, and there is no need to delay the procurement of renewable energy plants because of the suppressed demand. Similarly, power distribution companies should keep investing in renewable energy plants to support the government policy on renewables. However, MIS should account for the technical difficulties faced by system operator when the share of renewable become large. The high share of renewables may negatively impact the grid stability resulting in frequency fluctuations and high ramp rates. For that ramp rate, control algorithms with an energy storage system should be developed. In this regard, the interconnection with GCC countries will also help to stabilize the grid.
6. In order to fulfil peak load demand, demand-side load management strategies decrease investment costs in the power generation and transmission sectors. Oman should not only look into demand-side management programs as a policy but also promote energy efficiency measures in industrial and commercial sectors, such as energy-efficient green buildings.
7. Since there will be more restrictions in coming years on countries regarding greenhouse gas emissions, it is, therefore, recommended that OPWP consider a generation mix with nuclear as an option in their long-term plans.
8. The modern trend is moving from the conventional grid to the smart grid (Al Abri, Malik et al. 2020). Oman should consider modernizing its grid toward a smart grid. The smart grid will give a lot of flexibility in meeting and matching the demand with supply under uncertain conditions like a pandemic. An EPRI (Electric Power Research Institute) report outlines an initial approach to quantifying and monetizing about 22 smart grid benefits, which include: optimized generation operation; deferred generation, transmission, and distribution capacity; reduced ancillary service costs; reduced congestion costs; reduced equipment failure; reduced maintenance costs; reduced meter reading costs; reduced electricity theft; reduced emissions; reduced wide-scale blackouts, and so on (Wakefield 2010, Malik and Bouzguenda 2013). As a case study in Oman, a research paper has evaluated the demand-side management (DSM), energy efficiency measures and distributed generation benefits of the smart grid in the MIS system of Oman. Grid enhancement, customer contribution to the grid, and both options at the same time are among the scenarios developed. The scenarios are evaluated for peak reduction, and their benefits are calculated in terms of avoided generation, transmission, and distribution costs, as well as environmental costs.

5. CONCLUSIONS

The COVID-19 pandemic has had adverse effects on different sectors that are essential for people's livelihoods, such as health systems, different industrial and commercial sectors, the oil market, the international markets, the labour market, and the electricity market. Oman's energy sector, like those of the rest of the world, has been gravely affected by COVID-19. Energy demand decreased after the reduction of commercial and industrial activities and the closure of schools. The reduction of the industrial load has also had a significant impact on the country. The government and society have taken steps to support those who cannot pay their energy bills after losing their jobs. Although Oman has not faced severe human casualties, its economic activities have been affected. In Oman, oil and gas contributed nearly 74% of the revenue in 2018, and global demand has declined this year (Group 2020). Thus, the overall economy shrunk by 2.8% in 2020. Oman's government has announced relief measures to mitigate this economic impact and help individuals and businesses navigate these unprecedented times. Some examples of these measures are the decreasing interest rate and tax on some activities and the postponement of loan instalments for small and medium establishments for several months. The positive impact of COVID-19 is that the world has witnessed changes consistent with forecasted developments, such as digital solutions, low emissions, and clean energy. Thus, this new investment should be geared toward building a healthier, more resilient, and net-zero-emissions economy. Innovation in both technologies and business models is the primary driver of economic growth.

Acknowledgment

The authors acknowledge the support received from OETC and SQU.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding this article.

FUNDING

The authors did not receive any funding for this research.

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