Correlation Between Climate Data and Maximum Electricity Demand in Qatar

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***Abstract*—This paper presents the analysis of the impact of weather conditions on the maximum electricity demand in Qatar during the whole year 2012. It points out the maximum daily air temperature as the most influential climate (meteorological) parameter. Correlation between maximum daily temperature and maximum daily electricity demand are also indicated and analyzed. It is noticed that there is a linear correlation between these two variables for maximum temperature values above 22°C because of the air-conditioning type of the major load. During extremely hot summer periods, there is a tendency of increased electricity consumption because of air conditioning. A timely and accurate weather forecast can certainly help prevent the electrical power system overload and reduce the risk of possible power system damage.**

Keywords—Correlation, Electricity Demand, Temperature, Humidity, Qatar, Weather, Air Conditioning

I. Introduction

IN recent decades, the world has witnessed climate changes for which most scientists believe to be of an anthropogenic origin [1]. Some believe that an exaggerated consumption of fossil fuels has led to a significant increase in the concentration of greenhouse gases (GHG) which are considered the main cause of the increase in the global average temperature. Some other people believe that climate change is not affected by the exaggerated fuel consumption and believe that it is a cyclic natural phenomenon. However, a majority of scientists is aligned behind the first hypothesis and are guiding national and international organizations (i.e. Intergovernmental Panel on Climate Change, IPCC) to consider appropriate measures and take urgent and adequate actions to mitigate the effect of the GHG emissions and climate change. Electricity consumption is known to be a major contributor to the GHG emissions. In order to understand very well the impact of electricity consumption on climate change and vice-versa, it is important to study carefully the relationship between electricity consumption and climatic parameters such as temperature and humidity.

Air temperature is considered as an important factor that influences electricity demand especially cooling and heating demand. It is known that electricity load demand increases on hot days leading to an increase in power generation and transmission losses. However, even though the important impact of the temperature on electricity demand has been largely acknowledged, we are still not well informed about the extent of variation of the electricity demand as a function of temperature. For instance, it is known that cooling demand is positively associated with temperature but its rate of variation is not well defined and documented. There is very little information on how much linear or nonlinear is the relationship between electricity consumption and temperature or humidity.

Besides, the relationship between electricity demand and climatic conditions is country dependent because it depends on the geographical location, style of living of people, type of industries and commerce, type of Urbanism, and type of implemented building codes. That is why most of published researches are country specific models and not generalized or universal models. For instance, Holtedahl and Joutz [2] developed and estimated an error correction model of electricity consumption for Taiwan. Yan [3] and Funga [4] studied the influences of climatic variables on variation in residential and urban electricity consumption in Hong Kong. Ang et al. [5] found that residential electricity consumption in Singapore was sensitive to small changes in climatic variables, particularly the temperature, which was closely linked to the growing diffusion of electric appliances for environmental controls, but a large part of the future growth in electricity demand will arise from the growing need for air-conditioning, which will lead to increasingly large seasonal variations in electricity consumption. Parkpoom et al. [6][7] used a multiple linear regression model to study the impact of climate changes on electricity demand in Thailand. Wangpattarapong et al. studied the impacts of climatic and economic factors on residential electricity consumption of only Bangkok Metropolis. Atakhanova and Howie [9] estimated Kazakhstan's aggregate demand for electricity as well as electricity demand in the industrial, service, and residential sectors using regional data. Hondroyiannis [10] found that a long-run residential demand function for electricity in Greece is sensitive to the actual income, price level, and weather conditions. Valor et al. [11] found a strong correlation between daily air temperature and electricity load in Spain. Blázquez et al. published a study on new empirical evidence using aggregated data on residential electricity demand in Spain.

Other studies were conducted for Japan, European countries and the US [12]-[22] and developed country or regional models correlating electricity demand to weather parameters; mainly air temperature. Consequently, there are a variety of studies on the electricity demands published in many countries. However, electricity demand models for each country perspective may require a different framework based on the specificity of each country and even regions within the same country.

In this paper, Qatar is considered as the case study for investigating the climate change impact on electricity demand considering one year (2012) data. Qatar is located in a very hot and arid climate region and its electricity demand is very much dictated by the air-conditioning (cooling) consumptions which are very much tied to temperature. Thus, it is important to estimate the true relationship between electricity demand and temperature in Qatar. A timely and accurate weather forecast can certainly help prevent the electrical power system overload and reduce the risk of shortage in power generation and hence the possible power system collapse.

In section 2 of this paper, the geography and weather data for Qatar are presented and discussed. In section 3, the electricity demand profile in Qatar is presented and discussed. Section 4 presents the relationship estimation method and the estimation results. Section 5 summarizes the findings and gives some concluding remarks.

II. Geography & Weather Data

A. Geography

Qatar is a peninsula entering 161 km north into the Arabian Gulf from Saudi Arabia. It lies between latitudes 24°N and 27°N, and longitudes 50°E and 52°E. Much of the country consists of a low, barren plain, covered with sand constituting a completely flat land with elevations ranging between 0 and 119 meters only.

The 2010 census recorded the total population at 1,699,435 [30]. The population has climbed to 1.83 million by the end of 2012, showing 7.5 percent growth over the previous year. In January 2013, the Qatar Statistics Authority estimated the country's population at 1.9 million.

B. Weather Data

The weather in Qatar is characterized by its high temperature and low humidity during the hot season (summer) and low temperature and high humidity during the cold season (winter). The average high temperature is about 32.6°C and the average low temperature is around 21.4°C while the yearly rain precipitations are 71 mm only.

Fig. 1 and Fig. 2 illustrate the profiles of daily maximum air temperature and humidity in 2012, respectively. The maximum recorded temperature and humidity were 48°C and 99%, respectively. The minimum recorded temperature and humidity were 16°C and 11%, respectively.

Fig. 3 and Fig. 4 illustrate the per month daily variation of air temperature and humidity in 2012, respectively. Notice that during the same month, the temperature and humidity witness very large fluctuations.

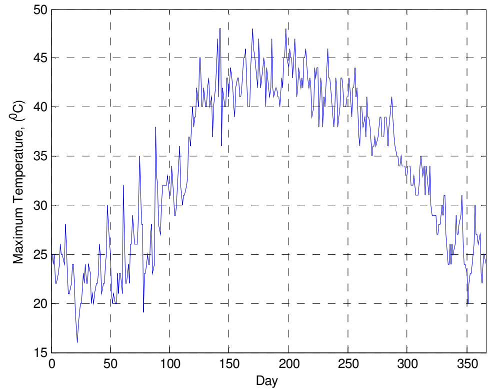

Fig. 1. Profile of daily maximum air temperature in 2012.

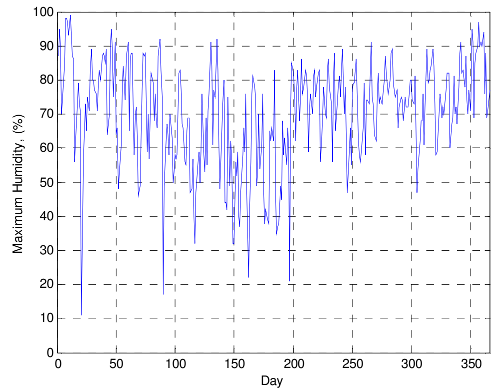

Fig. 2. Profile of daily maximum air humidity in 2012.

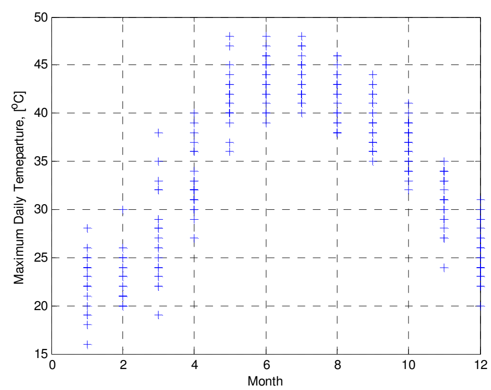

Fig. 3. Variation of daily maximum air temperature per months in 2012.

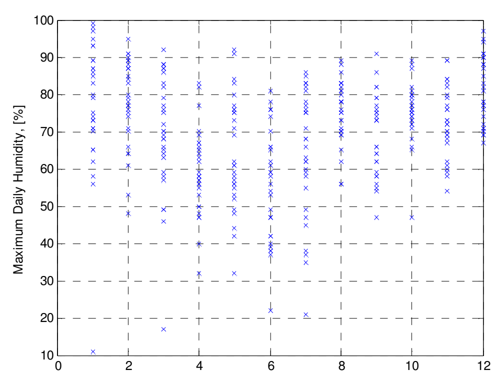

Fig. 4. Variation of daily maximum air humidity per month in 2012.

III. Electricity Demand Data

Qatar has witnessed a remarkable growth in electricity demand which has ranked it among the highest per capita electricity consuming country in the world. This has also put it on the top list of per-capita greenhouse gas emitting countries in the world. However, Qatar has officially declared during the previous UN Climate Change Conference COP18 in Doha, that its Government is committed to considerably reduce its CO_2 footprint within the next decade through different initiative such the implementation of renewable energy and energy efficiency technologies.

Fig. 5 shows the classification of Qatar electricity consumption by sector in 2012. Notice that the highest electricity consuming sector is the residential one followed by the commercial and then the government. These three sectors are known to be high consumers of electricity for the ventilation and air conditioning which are very much dependent on the weather condition.

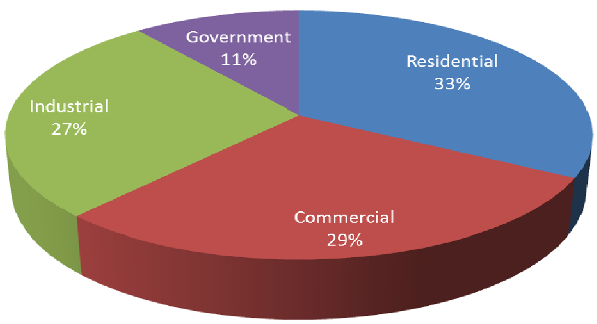

Fig. 5. Classification of electricity consumption by sector in Qatar in 2012.

Fig. 6 shows the variation of the maximum daily electricity demand as a function of the week days. Notice that the lowest electricity demand occurs during Fridays (day 6) which is a non-working day during which most of the industries are closed.

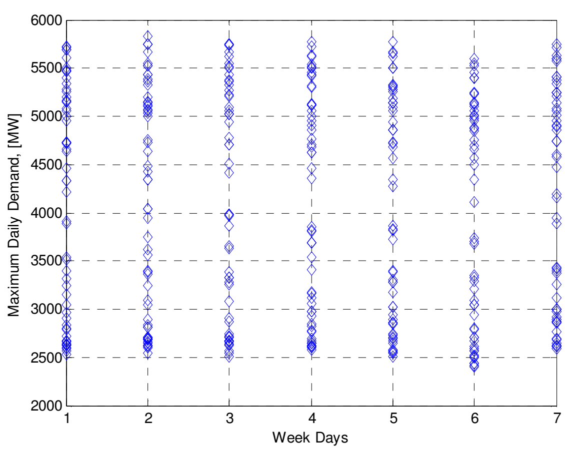

Fig. 6. Variation of load demand as a function of week days during 2012 (1=Sunday and 7=Saturday).

Fig. 7 shows the profile of the daily maximum electricity demand in 2012. Comparing Fig. 7 to Fig. 1, one can clearly notice the good clear correlation between maximum daily air temperature and maximum daily electricity demand.

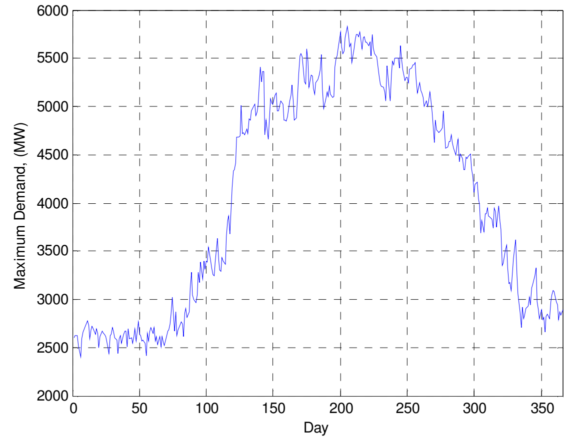

Fig. 7. Profile of daily maximum electricity demand in 2012.

Fig. 8 shows the profile of monthly maximum power demand. This figure shows also the correlation between hot months and high maximum electricity demand.

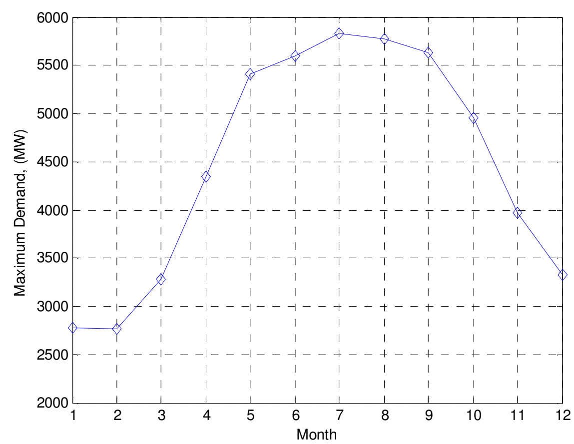

Fig. 8. Profile of monthly maximum electricity demand in 2012.

It is important to note that this variation of the maximum electricity demand is also affected by the population growth, and the urban, economic and industrial developments in the country over the days and months of the year. However, it is very difficult to disconnect this effect from the weather effect since it requires a precise and continuous monitoring of the population growth along with the urban, economic and industrial developments. Therefore, in the following analysis these parameters will be neglected since we will be analyzing only one single and same year.

IV. Correlation Between Maximum Electricity Demand and Weather Data

Without knowing the true relationship between the different weather parameters, estimates of temperature effect on electricity demand may be sometimes biased. Some previous researches used temperature variables in a linear form, using HDD (heating degree days), CDD (cooling degree days), and other temperature variables to explain the seasonality of cooling and heating demands. Some other studies suspected that the linear addition of temperature variables to the demand equation may provide, in some cases, a biased relationship between electricity demand and temperature. Some other conjectures consider that the relationship between temperature and electricity demand should be nonlinear. Many studies on the relationship between electricity demand and temperature use monthly data to estimate electricity demand. Temperature related variables in the studies are just included in terms of monthly averages or summation. But it was suspected that the aggregates, averages or summations may not be appropriate for seasonality, since responses of energy demand to temperature may be very instantaneous and nonlinear. Then using the aggregates may neglect nonlinear characteristics and produce some bias. Moreover, it was suspected that temperature responses are not all the same over time. Many researches on this topic assume that temperature responses are invariant over time which of course demand from one case study to another. Some studies found out that in some cases using the temperature of a certain time of a day or daily average may cause the bias in the estimation of the temperature effect.

However, since the most important parameter that interests the power system control and dispatch centers is the maximum (peak) daily power demand, it is therefore suggested that the maximum electricity demand and the maximum temperature and humidity per day should be used.

A quick comparison of Fig. 1 and Fig. 7 show that there is a clear correlation between the maximum temperature and maximum electricity demand on daily and monthly bases especially for hot days and months. While comparing Fig. 2 and Fig. 7 shows that there isn't any clear correlation between the maximum air humidity and the maximum electricity demand.

To illustrate and analyze more in details these results it is important to plot the variations of the daily maximum electricity demand as a function of the daily maximum temperature and humidity. Fig. 9 and Fig. 10 show the variation of the daily maximum electricity demand as a function of the daily maximum temperature and humidity, respectively, during the whole year 2012. Notice that the earlier remarks regarding the correlations between temperature, humidity and electricity demand are clearly illustrated by these two figures.

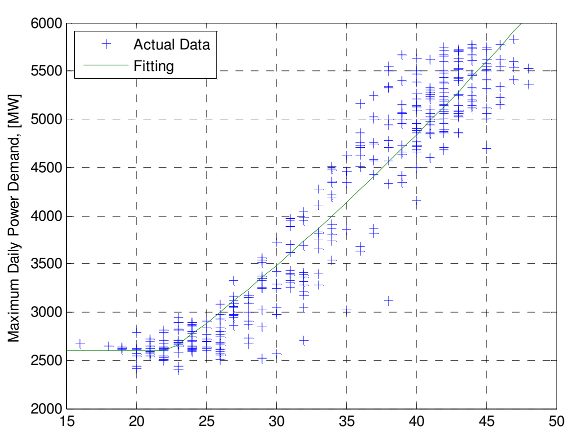

Fig. 9. Variation of daily average power demand as function of mean temperature during the whole year 2012.

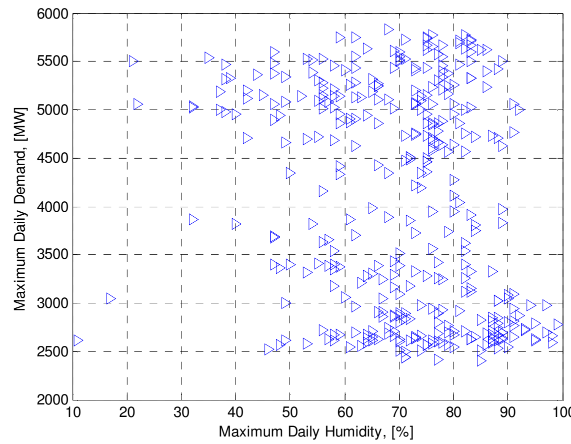

Fig. 10. Variation of daily maximum power demand as a function of maximum humidity during the whole year 2012.

It can be noticed from Fig. 9 that for temperatures below 22^{o}C, the average daily demand is almost constant and equal to about 2600 MW.

This was expected for Qatar because most of air-conditioning systems in residential, public, and commercial buildings will provide very little or no cooling energy if the outside temperature is below or equal 22^{o}C. In other countries where heating is required during cold weather, the electricity consumption curve rises again at very low temperatures [16]. This is not the case for Qatar where heating is rarely used.

For temperatures above 22^{o}C, the daily maximum electricity demand increases almost linearly with the maximum daily temperature. Therefore, the linear fitting function defined by (1) can be used to represent the maximum electricity demand variation for all temperatures above 22^{o}C as illustrated in Fig. 9.

$$f(x) = \begin{cases} K, & x \le 22^o C \\ ax - b, & x > 22^o C \end{cases} \quad (1)$$

It was noticed that there is very little deviations of electricity demand responses to temperature variation among the different days of the week. This can be explained by the effect of the daily lifestyle and habits that are specific to Qatar. Fig. 11 shows the fitted curves for daily and weekday's variation of the average power demand as a function of daily maximum temperature. Here, (1) is used along with the assumption of constant power demand when the temperature is equal or below 22^{o}C. Fridays are having the least power demand because most of local industries do no work during this day. Table 1 lists the obtained values of the coefficients *K*, *a* and *b* of the linear fitting function in (1) determined for daily average and also for every weekday curve. Notice that the minimum values and the slopes of the linear curve fittings are slightly different but these differences can be considered negligible and take the average daily maximum as a reference for all week days.

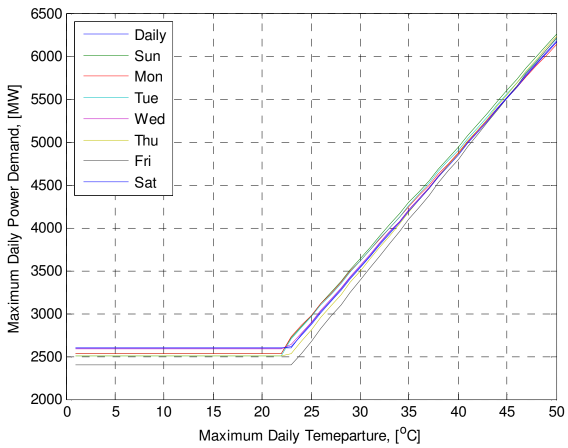

Fig. 11. Curve fitting of the variability of daily maximum power demand as a function of maximum temperature for different weekdays and during the whole year 2012.

TABLE I. FITTING CURVE COEFFICIENTS *K*, *a* AND *b* FOR (1)

Day	*K*	*a*	*b*
Daily	2600	131.3499	393.2162
Sun	2537	131.0248	296.3457
Mon	2539	126.2267	172.9306
Tue	2512	129.5837	276.2931
Wed	2583	130.3686	354.7064
Thu	2513	136.7635	606.0919
Fri	2397	141.4399	856.4986
Sat	2594	131.5046	406.8557

Notice from Fig. 11 that at medium values of the maximum daily temperature, the day of the week has significant impact on the response to the maximum electricity demand for maximum daily temperature variations, while at high values of the daily maximum temperature (i.e. above 35°C) there are no substantial impacts and the weekday curves almost intersect and are all very close to each other.

V. CONCLUSION

The correlation between weather data and maximum electricity demand in Qatar was investigated in this paper for the year 2012. It was noticed that there is no clear or significant correlation between the daily maximum electricity demand and daily maximum humidity while there is a clear linear correlation between the daily maximum temperature and the daily maximum electricity demand. This linear relationship is valid for temperatures above 22°C because the major load is air conditioning which consumptions do not vary much for temperatures below 22°C. Besides, it was found that Fridays are having the least maximum power demand and this is because most of the local industries are not working during this day.

During extremely hot summer periods, there is a tendency of increased electricity consumption because of air conditioning. A timely and accurate weather forecast can certainly help prevent the electrical power system overload and reduce the risk of possible power system damage.

In this paper, we have neglected the effect of the population growth and the development of urban, economic and industrial sectors over the same year period because they are difficult to estimate as they are very much inconstant. However, to improve the accuracy of the estimation of the correlation between weather data and maximum electricity demand, it is important to have a better estimate of these variables.

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