Factors Affecting Load Pattern in a Tropical Electric Power Distribution Area

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***Abstract*—Electric load forecasting is affected by numerous factors and these vary from one geographical location to another. The ability to identify the factors contributing to the consumption pattern in an area will help in designing an effective and exact forecasting model that will contribute to an effective energy dispatch. In this study, topical weather and various time factors contributing to the power consumption pattern of Ayobo Power Distribution Area of Lagos state, Nigeria were considered. These time factors are categorized as Working Time, Leisure Time and Sleeping Time while the weather season is categorized into dry and raining season. The results show that the load begins to rise from the baseline load and goes to its peak during the working periods and fall considerably for the other two periods. Also, the general power consumption is affected significantly by the two main weather seasons of the year in Nigeria namely wet and dry season. The cooling degree days do also affect the power consumption. It is therefore necessary for these metrics to be considered when designing load forecasting model for this area and thus Nigeria in general.**

***Index Terms*-- Cooling degree days, electric load forecast, tropical weather, time period, season.**

I. INTRODUCTION

The growing consumption of electric energy nowadays has made load forecasting to receive big attention from researchers and utility operators [1]. Load forecasting is an important component of electric power system which is used in predicting future load ahead of the actual load occurrence to establish economical and reliable operations for power stations and their generating units and optimal energy interchange between utilities [2]. Additionally, the recent attention turned towards load forecasting is well deserved because of its importance to power generation and supply which includes but not limited to ensuring continuous supply of electricity to consumers, helping the electric utility in reducing the generation cost, improving the reliability of power systems, reducing the reserve capacity and to schedule device maintenance plan properly.

Electric load consumption patterns are affected by numerous factors in the modern setting. These factors vary from one geographical location to another and can be so diverse. The ability of power system engineers and researchers to identify the factors contributing to the consumption pattern in an area will help to determine accurate forecasting and contribute to an effective energy dispatch at any given time. Some of these factors have deep impacts while others slightly affect the energy consumption [3], [4]. Thus, for any given geographical area, identifying factors that have deep impacts on the energy distribution is a worthwhile effort. A gamut of factors does affect power consumption patterns. These factors include cyclic-time effects, weather effects, random effects like human activities, load management and thunderstorms, and still other random effects.

Over the years, researchers have been seeking the most suitable variables for each particular problem that will enable adequate prediction of the electric load consumption. Most of these efforts led into the development of different techniques and models. Reference [5] considered the impact of relative humidity and in [6] the air temperature, relative humidity, insolation and wind speed were considered. Other authors [7]–[11] assessed how temperature, humidity and precipitation can affect power generation and consumption. Other dynamic factors which include certain temporal, seasonal and annual variations were considered by [12]. Reference [13] maintained that a country's economic situation plays a major role in the electric load. The authors [14] pointed out other factors like season, day type and electricity price as other factors that can impact on the power generation and load consumption pattern. Based on literature, it is evident that weather condition and time can greatly affect the power consumption pattern of an area. Nigeria has a tropical climate with variable rainy and dry seasons, depending on location. Thus in this study, various time factors and weather conditions contributing to the power consumption pattern of Ayobo Power Distribution Area in Lagos State, South-Western part of Nigeria were considered.

II. PERIODIC LOAD TRENDS

Periodic load patterns are usually determined by the property of time of the day, day of the week, week of the month and month of a season. Certain days in a season tend to exhibit similar load patterns over several weeks. For instance, consider the load curves depicted in Figure 1 and Figure 2. The Figure 1 represents the load curve for a 24-hour day on Monday, November 13, 2017 in Ayobo 2 Electric Power Distribution Area. The curves in Figure 2 represent the power consumption pattern for the same location on Monday, November 20, 2017. The load patterns exhibited similar trend for the days though the average values not exactly the same. From the graphs, the load peaked in Figure 1 at 3 pm and has the lowest value at 1 am. Similarly, in Figure 2, the load's peak and lowest were around the same period of the day. Thus it is seen that the periods of the day dictated the load pattern for a particular day in the week.

The various periods of the day can be classified into three main categories namely; Working Time, Leisure Time and Sleeping Time [13]. The various load behaviour with respect to time (period of the day) and weather are further discussed for the Ayobo 2 Power Distribution Area, for the month of November and December 2017 (dry season of the year). It is to be noted that the area is predominantly a residential and commercial area with only few industries available.

A. Working Time

The working period in a commercial area of Lagos State starts around 5 am and proceeds to 6 pm. During the working time, the load begins to rise from 9 am and goes to its peak by 11 am. This actually defines the official office hour resumption. This can be seen on the load pattern for the location on Figure 3. There is a steady rise in load from the waking up time in the morning - 4 am to 6 am. This is due to people using their electrical and electronic appliances as they prepare to go out for the day's work or business.

There is always a sharp drop in load between the periods of 7 am to around 9 am (Figure 1 to Figure 3). This can be attributable to the fact that people do leave their house and commute to their various work place or schools at this period. From 9 am, all the commercial and industrial workers would have started settling into their offices, thus the commencement of commercial and industrial activities. Hence, this results into a steady rise in power consumption from around 9 am till 6 pm. Furthermore, the sharp increase experienced from about 3 pm, is due to the returning of residents which comprises of students and certain workers especially those that work at schools. At this point, electricity is used for cooking, cooling, studying and relaxation purposes. Thus the electrical load in the apartments once again peaks up adding to the sustained increased commercial loads up till 6 pm. There is a variation in load consumption between 4 pm and 6 pm in the evening, because most commercial activities begin to decline in the commercial centres and at the residential areas the load increases in that proportion.

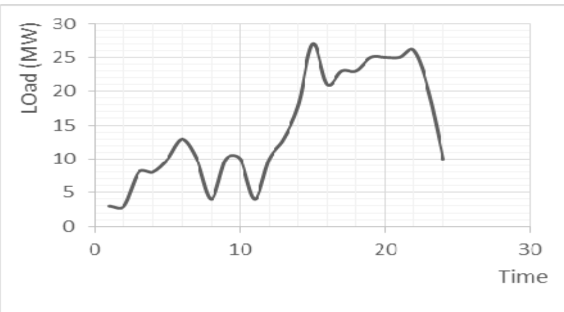

Figure 1. A 24-Hour load curve for Monday November 13, 2017 for the study area.

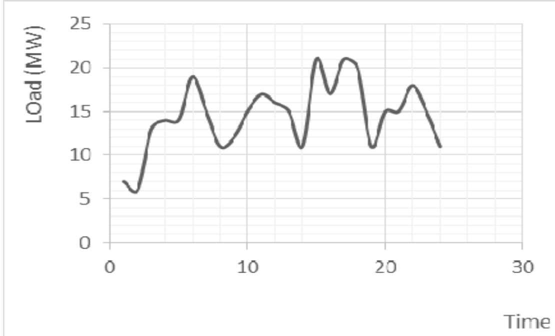

Figure 2. A 24-Hour load curve for Tuesday, November 20, 2017 for the study area.

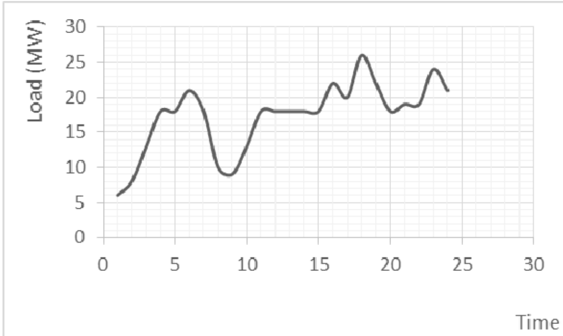

Figure 3. A 24-Hour load curve for Tuesday, December 5, 2017 for the study area.

B. Leisure Time

Most workers and commercial centres close between 4 pm to 6 pm after which people return home. Thus the larger number of workers returns home at 6 pm. The people in the residential homes remain indoors and ready to retire for the night at 10 pm. This period of time is regarded as the leisure time. In residential areas, at this period, electricity is used to watch TV, charge mobile devices, prepare dinner, for cooling and lighting purposes. Other electrical energy users at this period include certain small businesses, some relaxation centres and clubhouses. After this period householders will retire for the night. Hence, the load exhibits higher peaks than in the working time. At this period, there will be higher power consumption by the domestic consumers and less from commercial areas. This is observable from Figures 1 to 3 above. But as from 10 pm which is considered as the start of the sleeping time, the load continues to drop.

The leisure time load consumption during the weekdays slightly varies from that of the weekends. Industrial electricity consumption from the few available industries in the area may slightly reduce at this period. Around 8 pm every day, there is a rise in load and it gets to the peak at this period on the weekends as can be observed from Figure 4 and 5. Another reason why the total load rises is because those householders that might go out for certain religious and social ceremonies on the weekends would be back at home at this period. Thus energy will be needed for lighting, cooking and relaxation in this period.

C. Sleeping Time

The remaining period of the day from 10 pm to 5 am constitutes the sleeping period. At this period the load has its minimum values as can be seen from Figure 2. During this period, electricity consumption is expected from mainly cooling appliances (refrigerators, deep freezers, air conditioners and fans) and few lighting for security as most householders would retire for the night. Thus, the power consumption is expected to slightly drop from what it was during the leisure time since industrial loads at this period remain unchanged from the value it had during the leisure time. As the sleeping time ends at 5 am, the load resumes its pattern for working time.

D. Weekend load pattern

At the weekends, the energy demand tends to be slightly different from the weekdays especially during the working and leisure time. This occurs because during the weekends (Saturday and Sunday), the white collar jobs and most commercial centres are mostly closed but the event centres, some industries, many religious centres and other social activities open. Consequently, the consumption tends to be higher compared to weekdays. Figures 4 and 5 are load curves for weekend in the month of December 2017.

The surge in power consumption at this period is due to the lighting, cooling, the public address systems, music gadgets used in the event and worship centres and for relaxation purposes at home as may people stay at home during weekends than weekdays. To this end, the weekend consumption pattern differs significantly from weekdays. This makes it an important parameter to be considered during the design of a load forecasting model.

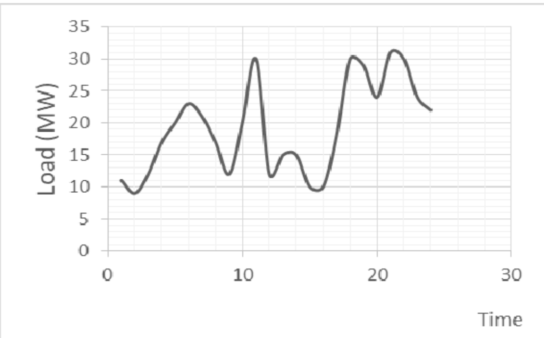

Figure 4. A 24-Hour load curve for Saturday, December 9, 2017 for the study area.

III. WEATHER EFFECTS ON LOAD CONSUMPTION PATTERN

The load consumption is greatly affected by the weather condition of a particular place. Weather effects can often cause a fluctuation in energy demand in an area. For instance, sea breeze, after moon thunderstorms and precipitation can cause a decrease in the temperature in a locality where it occurred and thus cause overestimated load [2].

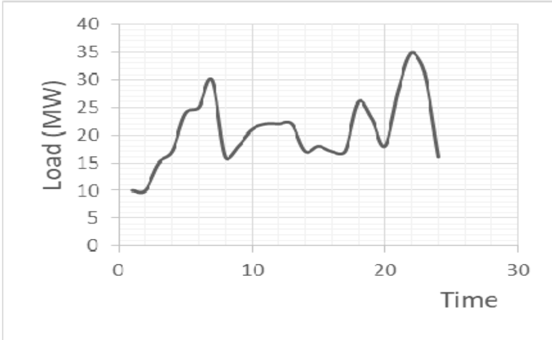

Figure 5. A 24-Hour load curve for Sunday, December 10, 2017 for the study area.

Largely, Ayobo area of Lagos State has two main seasons that determine what the temperature would be at any given time namely the wet season (March to October) and dry season (November to February). High temperature in the dry season increases the body temperature and hence the uneasiness of the body. This necessitates additional use of cooling appliances which invariably changes the consumption pattern [1]. Other factors such as humidity, wind speed and wind chill index, and cloud cover can also affect the load in an area [8],[12], [13]. Humidity increases the severity of temperature which will trigger the use of more cooling appliances hence affecting the load curve [14]. On the other hand, high wind speed creates a cooling effect on humans, thus affecting the load consumption to a reasonable degree. Furthermore, when there is high breeze, people tend to use electric cooling systems less which results in low power consumption [3], [7]. Likewise, high cloud cover, especially during the raining season causes cooling effect in the environment because of high wind index that is associated with it [16]. This is the reason why temperature during the raining season is usually lower than the dry season. Thus, less electric cooling in homes, offices and commercial centres are used and this invariably means less electric load or lower consumption.

Temperature is a significant energy driver in the study area. Thus general energy consumption during the dry season has higher peaks. This is due to increase in the cooling degree days (CDD) during the dry season. CDD is a measure of the severity and duration of hot weather used to quantify the cooling requirement [17], [18]. When compared to other tropical climates, the results show that load consumption patterns in Nigeria exhibit similar features as other tropical countries such as Singapore, Indonesia, etc [19], [20]. One day each is presented from the month of August and October 2017 in Figures 6 and 7. Also, two weekdays (December 19 and 21, 2017) in the month of December are presented. It is observed that for the two days in the month of October, the peak energy demand is below 30 MW. For the month of December, the peak load for the two days presented is well above 30 MW. In Figure 8, the peak load for the presented day is up to 36 MW while in Figure 9, it is up to 35 MW. The minimum load in both seasons appears to remain the same around 10 MW. Thus, the weather of the area played a significant role in the energy demand.

IV. CONCLUSIONS

Several factors affecting the electrical load consumption in the study area ranging from time period of the day, weather, nature of business activities in the area and other socio-economic factors have been considered. This study has identified time period of the day, weather, weekdays, weekends, temperature and humidity as major factors that affects the load consumption pattern in the study area and by extension, Nigeria as a whole.

Certain days of the week drive more electric load than others. This may be attributed to the commercial nature of the study area, duration of power availability, temperature and humidity. The dry season is also identified as an important energy driver as temperature is generally higher during the period resulting in more utilization of electric cooling appliances. High humidity also worsens the effect of temperature on human comfort thus more energy is needed in homes and offices for cooling. Conversely, days with high breeze and cloud cover such as the case in the raining season cause people to use less electricity.

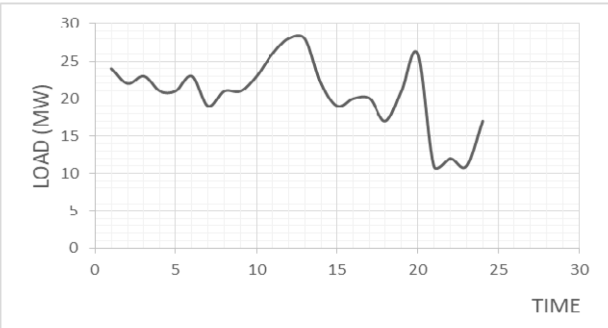

Figure 6. A 24-Hour load curve for Thursday, August 31, 2017 for the study area.

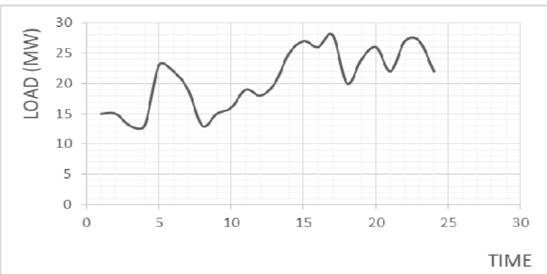

Figure 7. A 24-Hour load curve for Monday, October 9, 2017 for the study area.

Other socio-economic factors that have a bearing on the electrical load distribution in the area include pubic holidays, customer classes and football matches. When these factors are used in designing a load forecasting model, it will no doubt produce a justifiable load demand forecast for the study area. Moreover, the utility power supplier−Ikeja Distribution Company−can utilize the information herein for better planning of power distribution.

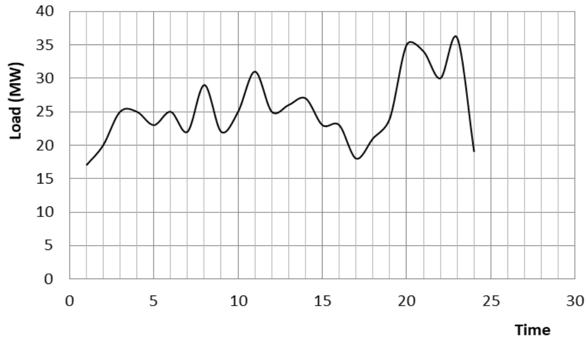

Figure 8. A 24-Hour load curve for Tuesday, December 19, 2017 for the study area.

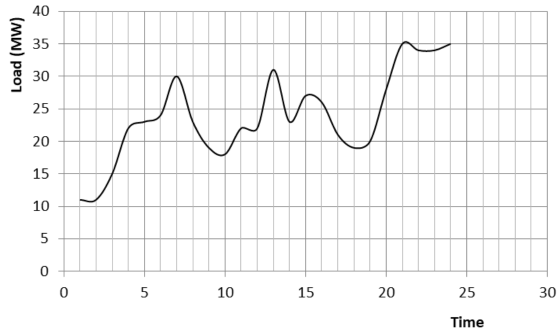

Figure 9. A 24-Hour load curve for Thursday, December 21, 2017 for the study area.

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