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Characterization And Forecasting Of The Off-Peak And Peak Hours Electrical Load Of A University Campus

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***Abstract*— In this paper, the characterization and forecasting of the off-peak and peak hours electrical load of a university campus is presented. Basic information such as the annual electric energy consumption and the amount of diesel consumed in litres per certain period for a case study university campus in Nigeria were gathered and used to determine the electrical energy consumption during off-peak and peak hours in the case study site. The periods were divided into 4 segments, namely: peak hour load in kVA during school session (PH-DS), off peak hour load in kVA during school session (Off-PH-DS), peak hour load in kVA when school is not in session (PH-NS) and off-peak hour load in kVA when school is not in session. (Off-PH-NS). With these data, electrical load ratio (ER) was also determined for each of the four periods. The Holt Winter's model was then used to model and forecast the off-peak and peak hours electrical load for the university campus. The computation for electrical load consumption ratio (ER) values yielded ER of 0.778 for PH-DS, ER of 0.074 for Off-PH-DS, ER of 0.074 for PH-NS, and ER of 0.074 for Off-PH-NS. The Holt Winter's forecasting model smoothing parameters and prediction performance for the PH-DS load forecast are as follows: α = 0.501, β = 0.001, γ = 0.001, MASE = 0.354, SMAPE = 0.199%, MAE = 42,167.73 kW-h and RMSE = 54,9606.77 kW-h. Similarly, the Holt Winter's forecasting model smoothing parameters and prediction performance for the PH-DS load forecast are as follows: α = 0.501, β = 0.001, γ = 0.001, MASE = 0.354, SMAPE = 0.199%, MAE = 40,015.97 kW-h and RMSE = 5,200.64 kW-h. In all, the load modelling is vital for estimating the energy cost, the diesel consumptions and the planning of the power supply system for the case study university campus.**

Keywords— Electric Load Forecast, Holt Winter's Model, Off-Peak Electrical Load, Power Supply System Planning, Peak Hours Electrical Load

1. INTRODUCTION

Over the years many academic institutions in Nigeria have been struggling with energy supply challenges [1,2]. In practice, a major objective for an electric power system is to keep a continual balance between the supply and demand for electricity [3,4]. This will require appropriate power system planning prior to the installation of a new power system or expansion of the existing power system [5,6].

Meanwhile, given the rising population and building structures in many academic institutions, across Nigeria, there is need for electrical power expansion in those institutions [7,8,9]. For instance, in the University of Uyo, Permanent Site, Nsukara Offot, Uyo, students' population is on the increase, building structures are erected to accommodate those faculties that have relocated and would relocate from Town Campus to Permanent Site. Hence, applying extra electrical load in excess on the existing power infrastructure mam lead to breakdown of the power system [10,11,12]. Besides, cost of electrical power generation, supply and distribution in the school may be so exorbitant [13,14,15]. If there is no proper planning meant for electrical power generation, supply and distribution, it may be difficult to have any information in future for possible expansion.

Notably, proper power planning is based on effective energy demand modelling and forecasting [16,17]. Accordingly, this study presents the characterization and forecasting of the off-peak and peak hours electrical load for University of Uyo, Permanent Site. The study is based on the dataset obtained from the case study institution over a given period.

2. METHODOLOGY

2.1 Electrical Load Estimation during Off-Peak and Peak Hours from 2018- 2022

Basic information (for example transformers and generators' ratings and amount of diesel consumed in litres per certain period in a given faculty) relating electrical energy consumption during off- peak and peak hours were gathered. These periods were divided into 4 segments, namely: peak hour load in kVA during school session (PH-DS), off peak hour load in kVA during school session (Off-PH-DS), peak hour load in kVA when school is not in session (PH-NS) and off-peak hour load in kVA when school is not in session. (Off-PH-NS). With these data, electrical load or diesel consumption ratio (E_R), annual PH-DS load, annual Off-PH-DS load, annual PH-NS load and annual Off-PH-NS load were computed using Equation 1 and Equation 2, respectively. Furthermore, chart showing annual electrical load for 2018 to 2022 was plotted.

$$E_R = \frac{\text{Each load in respective hours in litres of diesel consumed}}{\text{Sum of the load in litres of diesel consumed}} \quad (1)$$

$$Z_p = E_{RX} \times E_{Aee} \quad (2)$$

where, Z_p is annual PH-DS, Off-PH-DS, PH-NS and Off-PH-NS, E_{RX} is E_R for PH-DS, Off-PH-DS, PH-NS and Off-PH-NS for a particular year (kW-h) and E_{Aee} means annual electrical energy consumption (kW-h).

The data on the annual electrical energy consumption of the University campus used as the case study is presented in Figure 1 while Table 1 provided further basic information relating energy consumption during off-peak and peak hours for the case study campus. Based on the data items in Figure 1 and Table 1, some sample computations are performed for the electrical load consumption ratio (E_R) and annual load consumption for PH-DS, Off-PH-DS, PH-NS and Off-PH-NS scenarios.

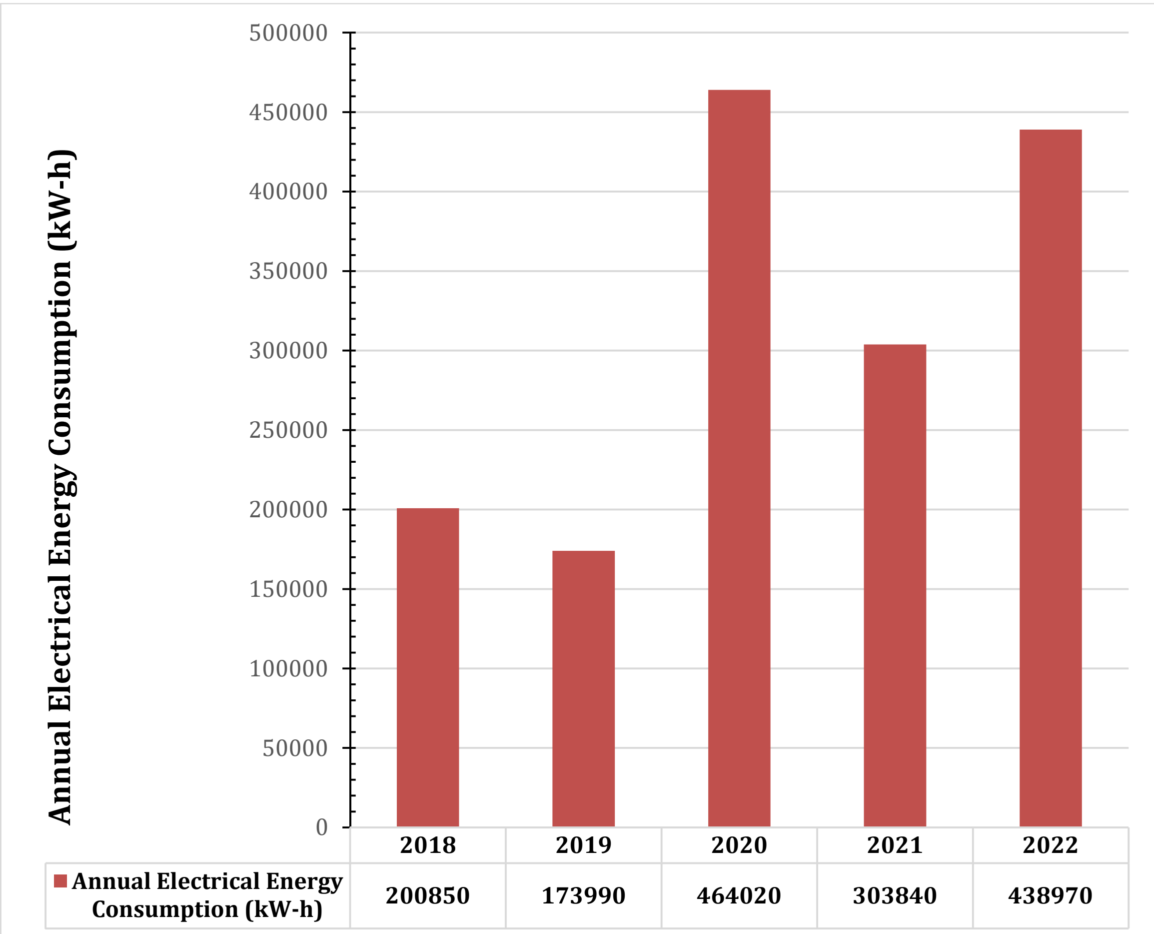

Figure 1 Case study data on the annual electrical energy consumption

Table 1 Basic information relating energy consumption during off-peak and peak hours.

Structure	PH-DS	Off-PH-DS	PH-NS	Off-PH-NS
Faculty of Engineering	**500 + 630 kVA for electricity supply or 700 litres of diesel is consumed from 9.00 am to 4.00 pm. Offices / laboratories use many appliances; hence, more electrical load is expected.**	**Between 4.00 pm to 12.00 mid night, load is reduced, hence, only 200 kVA or 200 litres of diesel is used to provide electrical power in hostels and lightings for security purpose.**	**During broad day light, there would not be internally generated electrical power through generators, except the one that comes from PHCN through 200 kVA, transformer / generator.**	**Between 6.30 pm – 12.00 mid night, 200 kVA or 200 litres of diesel is used to provide lighting for security purpose.**
Central Administration	**Same as Faculty of Engineering**			
Faculty of Science	**Same as Faculty of Engineering**			
Electrical Load / Litres of Diesel Consumption	**3 ×700 litres = 2100 litres**	**200 litres**	**200 litres**	**200 litres**
Electrical Load / Diesel Consumption Ratio	$\frac{2100\,L}{2700\,L} = 0.778$	$\frac{200\,L}{2700\,L} = 0.074$	$\frac{200\,L}{2700\,L} = 0.074$	$\frac{200\,L}{2700\,L} = 0.074$

Note: PH-DS = peak hour load in kVA during school session, Off-PH-DS = off peak hour load in kVA during school session, PH-NS = peak hour load in kVA when school is not in session and Off-PH-NS = off peak hour load in kVA when school is not in session.

The computation for electrical load consumption ratio (ER) values are shown in Table 1 row 6 which yielded ER = 0.778 for PH-DS, ER = 0.074 for Off-PH-DS, ER = 0.074 for PH-NS, and ER = 0.074 for Off-PH-NS. Then, by using the values of the ER obtained in Table 1 and the annual electrical energy consumption in Figure 1, the computations for the 2018 annual load consumption for PH-DS, Off-PH-DS, PH-NS and Off-PH-NS scenarios are presented as follows;

Annual PH-DS for 2018 (that is, the annual peak hour load in kW-h during school session for 2018) =

Load ratio for 2018 PH-DS × 2018 annual electrical energy consumption

0.778 × 200850 kW-h = 156216.67 kW-h

Annual Off-PH-DS for 2018 (that is, annual off-peak hour load in kW-h during school session for 2018) =

Load ratio for Off-PH-DS 2018 × 2018 annual electrical energy consumption

0.074 × 200850 kW-h = 14877.78 kW-h

Annual PH-NS (that is, annual peak hour load in kW-h when school is not in session for 2018) =

Load ratio for PH-NS 2018 × 2018 annual electrical energy consumption

0.074 × 200850 kW-h = 14877.78 kW-h

Annual Off-PH-NS (that is, annual off-peak hour load in kW-h when school is not in session for 2018) =

Load ratio for Off-PH-NS 2018 × 2018 annual electrical energy consumption

0.074 × 200850 kW-h = 14877.78 kW-h

The sum of each of these results gives 200850 kW-h in 2018.

2.2 Projection of Electrical Energy Consumption (kW-h) Beyond 2022

The Holt Winter's model is used to characterize the Off-Peak and Peak Hours energy consumptions. The Holt Winter's model is based on the additive and multiplicative seasonality whereby the level component, L_t is defined for the additive seasonality as (Aishwarya, 2020):

$$L_t = \alpha\,(Y_t \,/\, S_{t-m}) + (1\text{-}\alpha)\,[L_{t-1} + T_{t-1}] \quad (3)$$

Also, for the multiplicative seasonality, L_t is given as (Aishwarya, 2020):

$$L_t = \alpha (Y_t / S_{t-m}) + (1-\alpha) [L_{t-1} + T_{t-1}] \quad (4)$$

where, Y_t denotes the historical data, α denotes the level smoothing parameter which value is $0 \leq \alpha \leq 1$, Y_t - S_{t-m} denotes the seasonality adjusted observation and T_{t-1} denotes the trend component computed in the previous time step.

Again, the Holt Winter's trend model is defined at time step (t) and seasonal value at t-m step which for the additive seasonality S_t is given as (Aishwarya, 2020):

$$S_t = \gamma(Y_t - L_t) + (1-\gamma) S_{t-m} \quad (5)$$

Also, for the multiplicative seasonality, S_t is given as (Aishwarya, 2020):

$$S_t = \gamma(Y_t / L_t) + (1-\gamma) S_{t-m} \quad (6)$$

Then, the Holt Winter's forecasting model is defined as:

$$\hat{Y}_t = (\{\alpha (\frac{Y_t}{S_{t-m}}) + (1-\alpha) [L_{t-1} + T_{t-1}]\} + \{\beta (L_t - L_{t-1}) + (1-\beta) T_{t-1}\}) (\gamma(Y_t / L_t) + (1-\gamma) S_{t-m}) \quad (7)$$

where, β denotes the trend smoothing factor which value is $0 \leq \beta \leq 1$, t denotes the trend at any period. T_t denotes the trend component calculated in the previous time step. The (γ) denotes the seasonal smoothing variation factor which value is: $0 \leq \gamma \leq 1$.
The Holt Winter's forecasting model is used to forecast the electrical energy consumption for the off-peak and peak hours. The load periods considered include PH-DS, Off-PH-DS, PH-NS (kW-h) and Off-PH-NS (kW-h).

3. RESULTS AND DISCUSSIONS

3.1 Results of Electrical Load Estimation during Off-Peak and Peak Hours

Results of electrical loads during off-peak and peak hours when school is not in session and when school is in session are presented using the data from the following three units in the case study university campus: Faculty of Engineering, Central Administration and Faculty of Science. The results of the electrical energy consumption during off-peak and peak hours from 2018 to 2022 are shown in Table 2 and the bar chart in Figure 2.

Table 2 Electrical energy consumption during off-peak and peak hours from 2018 to 2022.

Year	2018	2019	2020	2021	2022
PH-DS (kW-h)	156216.67	135325.56	360904.44	236320.00	341421.11
Off-PH-DS (kW-h)	14877.78	12888.15	34371.85	22506.67	32516.30
PH-NS (kW-h)	14877.78	12888.15	34371.85	22506.67	32516.30
Off-PH-NS (kW-h)	14877.78	12888.15	34371.85	22506.67	32516.30
Annual Electrical Energy Consumption (kW-h)	200850.00	173990.00	464020.00	303840.00	438970.00

Note: Sum of PH-DS, Off-PH-DS, PH-NS and Off-PH-NS gives total electrical energy consumed for the year

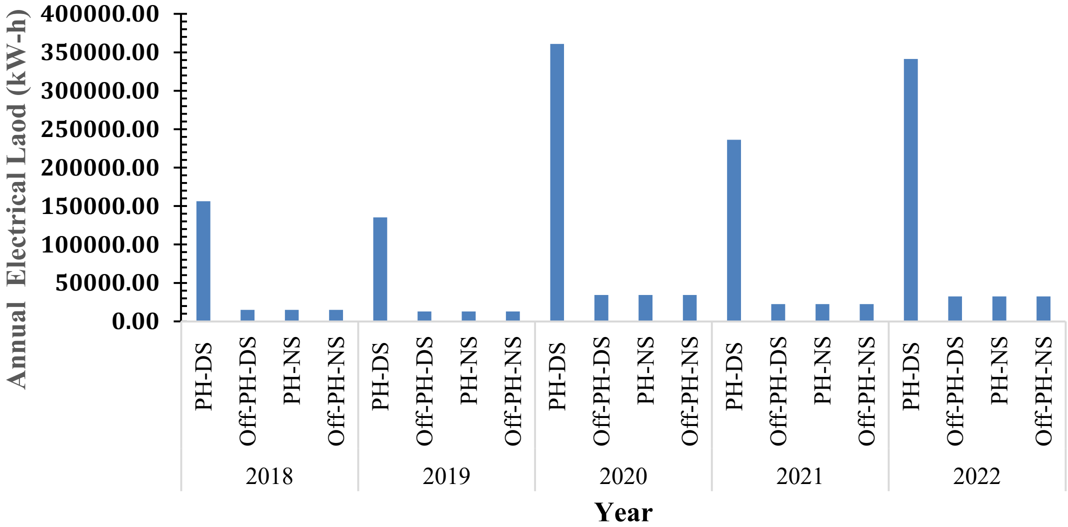

Figure 2: Bar chart showing annual electrical energy consumption during off-peak and peak hours from 2018 to 2022.

3.2 Results of the Forecast of the Electrical Energy Consumption (kW-h) Beyond 2022

The results of the actual and the projected annual electrical energy consumption for the PH-DS load (that is, the peak hours load when school is in session) are presented in Table 3 and Figure 3. Projections of yearly electrical energy consumption (kW-h) including off-peak and peak hours beyond 2022 are shown in Figure 3 and Figure 4 The Holt Winter's forecasting model smoothing parameters and prediction performance for the PH-DS load forecast are as follows: α = 0.501, β = 0.001, γ = 0.001, MASE = 0.354, SMAPE = 0.199%, MAE = 42,167.73 kW-h and RMSE = 54,9606.77 kW-h.

Table 3 The actual and the projected annual electrical energy consumption for the PH-DS load (that is, the peak hours load when school is in session)

Timeline	Values	Forecast	Lower Confidence Bound	Upper Confidence Bound
2018	156,216.67	143,236.17		
2019	135,325.56	139,315.16		
2020	360,904.44	342,999.20		
2021	236,320.00	240,220.10		
2022	341,421.11	341,421.11	341,421.11	341,421.11
2023		295,001.85	187,974.55	402,029.16
2024		461,483.03	341,726.98	581,239.07
2025		383,651.09	252,307.18	514,995.01
2026		550,132.27	408,143.05	692,121.48
2027		472,300.33	320,333.92	624,266.75
2028		638,781.51	477,453.76	800,109.26
2029		560,949.58	390,706.44	731,192.71
2030		727,430.75	548,716.43	906,145.07

Note: PH-DS load (that is, the peak hours load when school is in session)

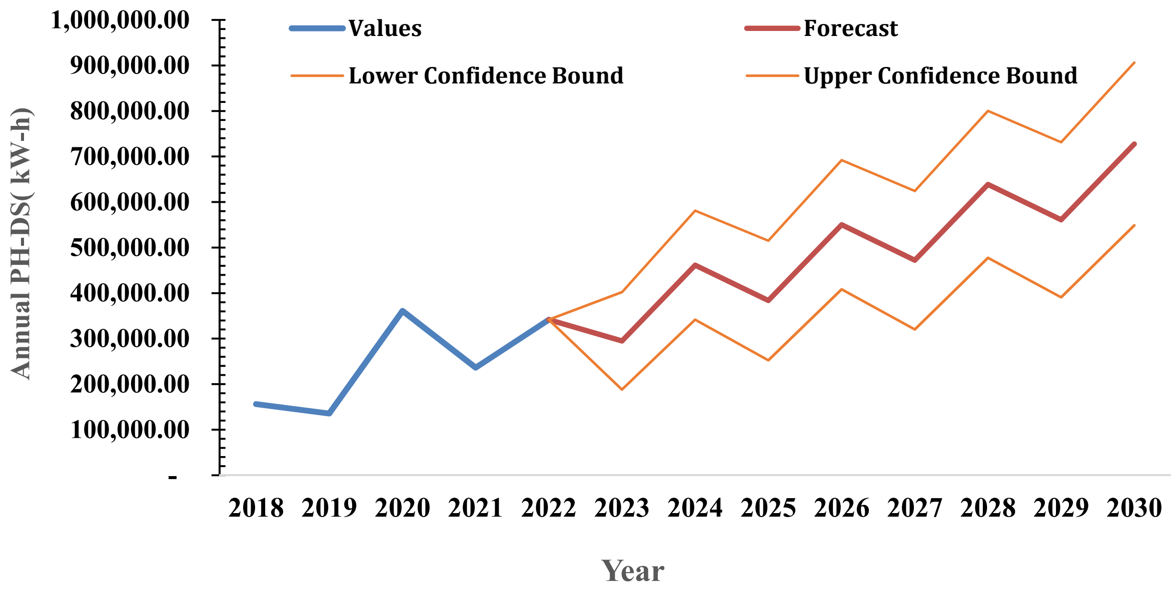

Figure 3: The annual PH-DS load (that is, the peak hours load when school is in session) from 2022 to 2030.

Also, the results of the actual and the projected Off-PH-DS load (that is, the off peak hours load when school is in session) are presented in Table 4 and Figure 4. The Holt Winter's forecasting model smoothing parameters and prediction performance for the PH-DS load forecast are as follows: α = 0.501, β = 0.001, γ = 0.001, MASE = 0.354, SMAPE = 0.199%, MAE = 40,015.97 kW-h and RMSE = 5,200.64 kW-h.

Table 4 The actual and the projected Off-PH-DS load (that is, the off peak hours load when school is in session)

Timeline	Values	Forecast	Lower Confidence Bound	Upper Confidence Bound

2018	14,877.78	13,988.65		
2019	12,888.15	13,675.43		
2020	34,371.85	32,222.33		
2021	22,506.67	24,332.00		
2022	32,516.30	32,516.30	32,516.30	32,516.30
2023		28,095.42	17,902.35	38,288.49
2024		43,950.77	32,545.44	55,356.10
2025		36,538.21	24,029.27	49,047.15
2026		52,393.56	38,870.78	65,916.33
2027		44,980.99	30,508.01	59,453.98
2028		60,836.34	45,471.80	76,200.88
2029		53,423.78	37,210.15	69,637.41
2030		69,279.13	52,258.72	86,299.53

Note: Off-PH-DS load = off-peak hours load when school is in session, PH-NS = peak hours load when school is not in session. Off-PH-NS load (that is, off-peak hours load when school is not in session)

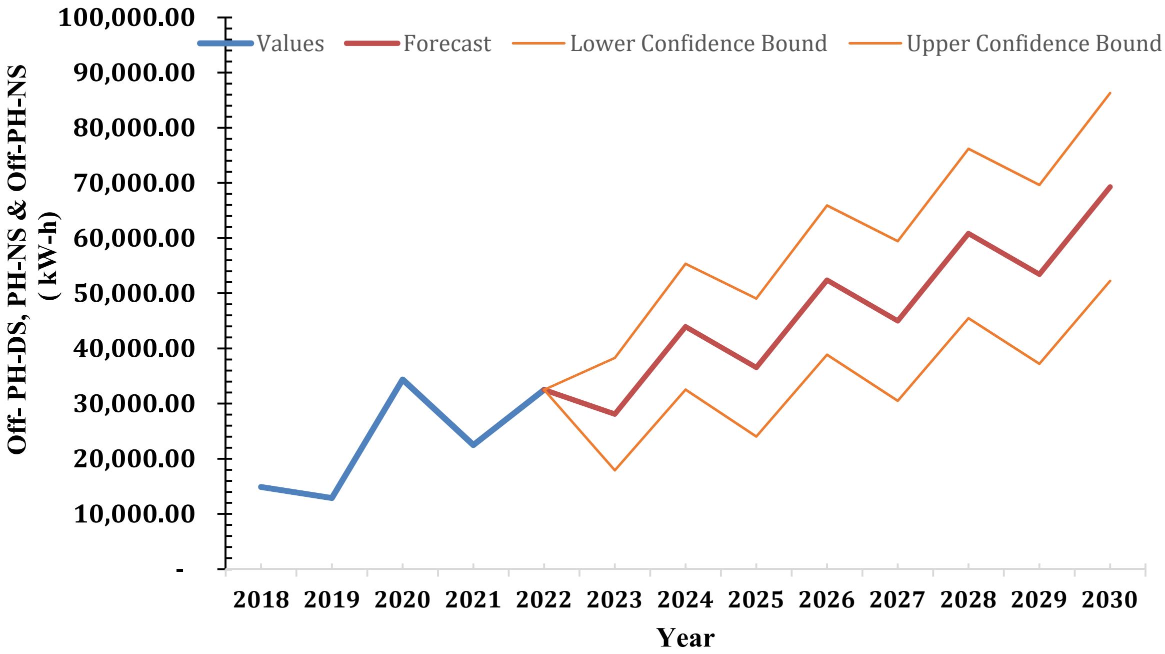

Figure 4: The annual Off-PH-DS load (that is, the off peak hours load when school is in session) from 2018 to 2030.

4. CONCLUSION

The paper modelled the electrical load estimation during off-peak and peak hours for a University campus. The model was used to forecast the off-peak and peak hours electrical loads of the campus when the school is in session and when the school is not in session. The Holt Winter's model was used for the study and the case study off-peak and peak hours electrical load estimation dataset was used to determine the smoothing parameters of the Holt Winter's model. The Holt Winter's model was then used to forecast the off-peak and peak hours electrical load for additional 8 years. The load modelling is vital for estimating the energy cost, the diesel consumptions and the planning of the power supply system for the case study university campus.

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