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Modelling Of The Annual Cost Of Diesel Consumption And Running Of Diesel Generators For A University Campus

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Abstract— **In this paper, modelling of the annual cost of diesel consumption and running of diesel generators for a University campus is presented. The focus in this paper is to present the case study data and analytical approach for computation of the total number of days in a year without electricity supply from the national grid, annual running cost of diesel generator(s) and the cost estimation of supplying power to the case study University campus solely from the diesel generators. The study considered the occasions when the school is in session and when the school is not in session. Case study dataset from 2018 to 2022 was used and Holt Winter's forecast model was used to forecast the cost of diesel for a period of six years, from 2023 to 2028. The results show that a total of 104 days of power outage from the national grid occurred in a year. The results also show that the annual cost of diesel in 2018 is 49,373,272.00 Naira and it increased to 164,794,448.00 Naira in 2028 which is about 233.8 % increment. Also, the annual cost of diesel per litre in 2023 is 828.82 Naira per litre and it increased to 1537.72 Naira per litre in 2028 which is about 85.5 % increment over the period of 5 years. The model forecast results show that the annual cost of diesel without electricity supply from the national grid in 2023 is 695,794,390.00 litres and it increased to 1,294,452,696.00 litres in 2028 which is about 86.0 % increment over the period of 5 years. Similarly, the forecasted annual cost of diesel with partial electricity supply from the national grid in 2023 is 198,253,744.00 litres and it increased to 367,822,624.00 litres in 2028 which is about 85.5 % increment over the period of 5 years. The ideas presented in this study is essential for cost benefit analysis of power generation source selection and power system planning**.

Keywords — Power System Planning, Annual Cost of Diesel Consumption, Holt Winter's Forecast Model, Running of Diesel Generators, Cost Benefit Analysis, Power Generation Source Selection

1. INTRODUCTION

The power sector in Nigeria has had perennial challenges of meeting the burgeoning energy demand in the country [1,2,3]. This power supply problem has affected many of the Universities across nation. In many cases, the Universities rely on diesel energy generating systems for their energy need [4,5,6]. This has resulted in high cost of running the universities as the cost of diesel is eating deep into the budget of these institutions [7,8,9].

In recent time, some institutions have started installing solar power systems [10]. Also, other energy mix plans are being put in place in view of the rising cost of diesel and the need for environmentally friendly energy mix [11,12]. Besides, most universities are still expanding in their programmes, in the students' intake, in their infrastructure and in other ways. These expansions will require additional power supply and power system planning. The present quest for energy mix require cost benefit analysis. Accordingly, the present study presents the modelling of the annual cost of diesel consumption and running of diesel generators for a university campus. The essence of the study is to provide the requisite cost information for the power system expansion planning in such institution based on the prevailing diesel consumption dataset and the diesel generators and accessories used in the power supply system for the institution.

2. METHODOLOGY

The focus in this paper is to present the case study data and analytical approach for computation of total number of days without electricity supply in a year, annual running cost of diesel generator(s) and the cost estimation of supplying power to the campus solely from the diesel generators. The case study is a campus in a Nigerian University.

2.1 Determination of Total Number of Days without Electricity Supply in a Year

The following power supply data were acquired for the case study campus;

(i) the period of break that is when school is not in session and when school is in session in a year were found,

(ii) the ratio of days of electrical power supply from the national grid to the University campus to days with no electrical power supply from the national grid.

a) When school is in session:

Number of days when there was electrical power supply when school is in session (N_{DES}) was computed using Equation 1 and Equation 2 as:

$$N_{DES1} = \frac{R_{WES} \times D_{TSS}}{T_R} \quad (1)$$

$$N_{DNES1} = \frac{R_{WNES} \times D_{TSS}}{T_R} \quad (2)$$

where, N_{DNES1} is number of days when there was no electrical power supply when school is in session, R_{WES} is the ratio of days with electrical power supply, D_{TSS} is the total number of days when school is in session, T_R is the total ratio of days with and without electricity power supply and R_{WNES} denotes the ratio of days with no electrical power supply.

b) When school is not in session:

Number of days when there was electrical power supply when school is not in session (N_{DES2}) is calculated using Equation 1 whereas number of days when there was no electrical power supply when school is not in **session** (N_{DNES2}) is calculated using Equation 2. Finally, the total number of days when there was no electrical power supply (N_{DNES3}) both when school is in session and when school is not in session in a year is calculated using Equation 3.

$$N_{DNES3} = N_{DNES1} + N_{DNES2} \quad (3)$$

2.2 Determination of Annual Running Cost of Diesel Generator(s)

The amount of diesel consumed in a day in the entire study area is determined as sum of the amount of diesel used during the day time by the Faculty of Engineering, the Faculty of Science and the Central Administration building, as well as the amount of diesel used during night the time by the Faculty of Engineering which is represented by X_1. Thereafter, the annual cost of diesel (X_4) is computed using Equation 4 from the 2018 to 2022 dataset.

$$X_4 = (X_1)\ (X_2)\ (X_3) \quad (4)$$

where, X_1 is litres of diesel consumed/ day and night, X_2 denotes cost of diesel /litre and X_3 is the number of days without electricity power supply in a year. The case study data on the cost of Diesel /Litre, X2 (Naira per Litre) is presented in Figure 1.

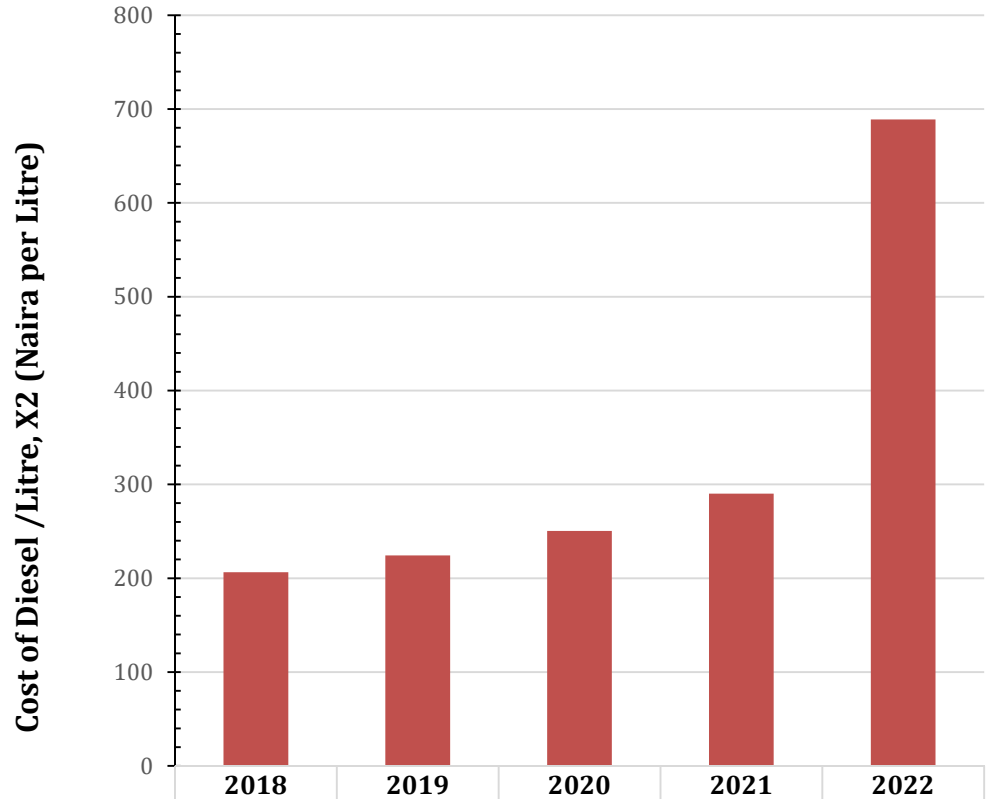

Figure 1 The case study data on the cost of Diesel /Litre, X2 (Naira per Litre)

Then value of the number of days without electricity power supply in a year, X3 is computed using Equation 3 using the information acquired concerning the power supply in the case study campus. For the computation of the number of days without electricity power supply in a year, it was assumed that:

(i) Period of break that is when school is not in session is 12 weeks (84 days in a year) and the remaining period when school is in session is 40 weeks (280 days) in a year.

(ii) The national grid is able to supply the case study campus with electrical power for 5 days in a week. This implies that the ratio of days of electrical power supply to days with no power supply is 5: 2.

The days of power supply and days of no power supply when school is in session are computed as follows;

Number of days when there was electrical power supply (N_{DES1}) from the national grid is computed as:

$$N_{DES1} = \frac{5 \times 280}{7} = 200 \text{ days}$$

Number of days when there was no electrical power supply (N_{DES1}) from the national grid is computed as:

$$N_{DNES1} = \frac{2 \times 280}{7} = 80 \text{ days}$$

The days of power supply and days of no power supply when school is not in session are computed as follows;

From $N_{DES1,\ the}$ number of days when there was electrical power supply (N_{DES2}) is computed as:

$$N_{DES2} = \frac{5 \times 84}{7} = 60 \text{ days}$$

Then, from N_{DNES1}, the number of days when there was no electrical power supply (N_{DES2}) is computed as:

$$N_{DNES2} = \frac{2 \times 84}{7} = 24 \text{ days}$$

The total number of days when there was no electrical power supply (N_{DNES3}) both during school session and when school was not in session is computed as;

$X3 = N_{DNES3} = N_{DNES1} + N_{DNES2} = 80 + 24 = 104$ days in a year

In the case study campus, the amount of diesel consumed in a day equal sum of amount of diesel used during the day time by the Faculty of Engineering (700 litres), Faculty of Science (700 litres), Central Administration (700 litres) and night time by Faculty of Engineering (200 litres), that is 2300 litres per day.

2.3 Cost Estimation of Running Generators Only

Firstly, data on past and present cost of running diesel generators were collected and used in computing annual cost of diesel per litre between 2018 and 2022. From these data, annual cost of diesel per litre (X_2) between 2023 and 2028 was forecasted using the Holt Winter's forecasting model. Then, the annual costs of diesel (X_4) from 2023 to 2028 were computed using Equation 5.

$$X_{C4} = X_1 \times X_{C2} \times X_3 \quad (5)$$

where, X_1 is litres of diesel consumed/ day and night and X_{G3} is no. of days in a year.

3. RESULTS AND DISCUSSIONS

3.1 Number of Days without Electricity Supply in a Year

The results on the number of days without electricity supply in a year is presented in Table 1and it show that a total of 104 days of power outage from the national grid is experienced in a year.

Table 1: The number of days without electricity supply in a year.

Status on School	R_{WES}	R_{WNES}	T_R	D_{TSS} (days)	N_{DES1} (days)	N_{DNES1} (days)
School in Session	5	2	7	280	200 days	80
	R_{WES}	R_{WNES}	T_R	D_{TSS} (days)	N_{DES2} (days)	N_{DNES2} (days)
School not in Session	5	2	7	84	60	24
					N_{DNES3}	104

Where, N_{DES1}= no. of days when there was electrical power supply during school on session, N_{DNES1} = no. of days when there was no electrical power supply during school on session, N_{DES2}= no. of days when there was electrical power supply when school NOT in session, N_{DNES2} = no. of days when there was no electrical power supply during school NOT in session, N_{DNES3} =total no. of days when there was no electrical power supply both during school session and when school not in session, R_{WES}= ratio of days with electrical power supply, D_{TSS} = total no. of days during school in session, T_R = total ratio of days with and without electricity power supply and R_{WNES}= ratio of days with no electrical power supply

3.2 The results on the annual running cost of diesel generator(s) alongside electricity supply from the national grid

The results on the annual running cost of diesel generator(s) alongside electricity supply from the national grid for year 2018 to 2022 are shown in Table 2. The results show that the annual cost of diesel in 2018 is 49,373,272.00 Naira and it increased to 164,794,448.00 Naira in 2028 which is about 233.8 % increment.

Table 2: Past and present running cost of diesel generator(s).

Year	Litres of Diesel Consumed/ Day and Night (X_1)	Cost of Diesel /Litre (N per Litre) (X_2)	No. of Days without Electricity Power Supply in a Year (X_3)	Annual Cost of Diesel (N) (X_4)
2018	2300	206.41	104	49,373,272.00
2019	2300	224.35	104	53,664,520.00
2020	2300	250.45	105	60,483,675.00
2021	2300	290.07	104	69,384,744.00
2022	2300	688.94	104	164,794,448.00

Note: $X_4 = X_1 \times X_2 \times X_3$; and 105 days for leap year.

3.3 The result of the forecast of annual cost of diesel consumption from 2022 to 2028

The results of the Holt Winter's model forecast of the annual cost of diesel consumption from 2022 to 2028 are displayed in Figure 2. The Holt Winter's forecasting model smoothing parameters values are; alpha [α =0.250], beta [β =0.001] and gamma [$\gamma = 0.000$]). The model performance values are; MASE (0.964), SMAPE (0.307%), MAE (N 27, 802,407.48) and RMSE (N 31, 921,255.48).

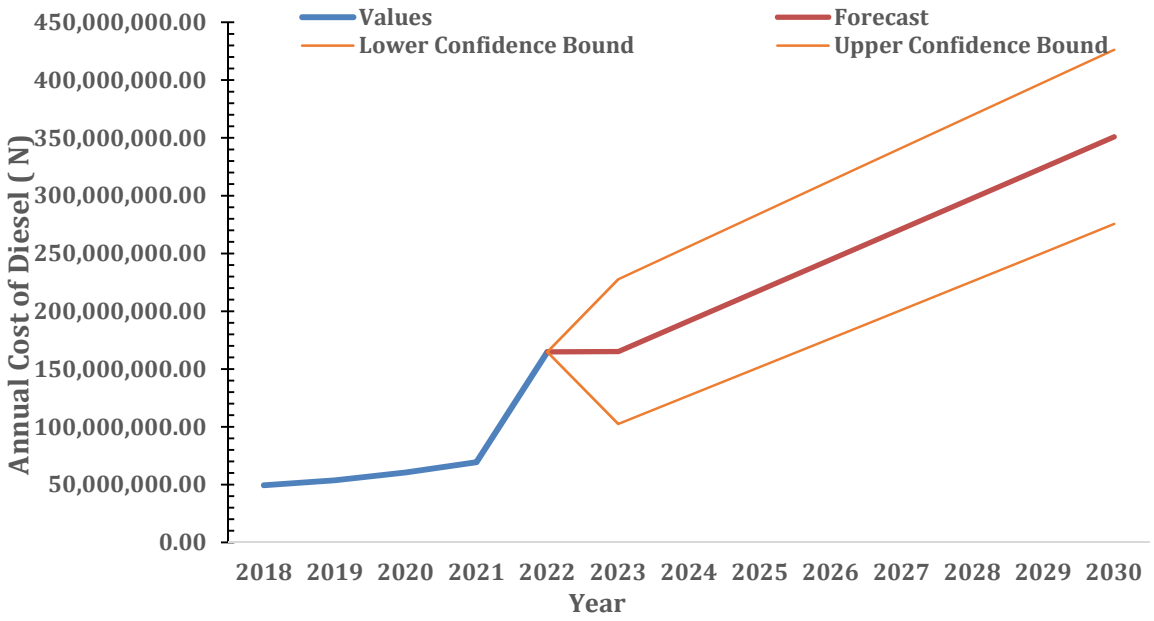

Figure 2: Forecast of annual cost of diesel consumption from 2022 to 2030.

3.4 Cost of Running Diesel Generator(s) Alone from 2022 to 2028.

The results of the Holt Winter's model forecasted cost of diesel per litre (N per Litre) from 2023 to 2028 is shown in Table 3 and Figure 3. The Holt Winter's forecasting model smoothing parameters values are; alpha α =0.900], beta [β =0.001] and gamma [$\gamma = 0.001$]). The model performance values are; MASE (0.851), SMAPE (0.272%), MAE (N105.971 per Litre) and RMSE (N132.913 per Litre). The results show that the annual cost of diesel per litre in 2023 is 828.82 Naira per litre and it increased to 1537.72 Naira per litre in 2028 which is about 85.5 % increment over the period of 5 years.

Table 3: Annual cost of diesel per litre from 2023 to 2028.

Year	Cost (N per Litre)	Forecast	Lower Confidence Bound	Upper Confidence Bound
2018	206.41	189.33		
2019	224.35	235.00		
2020	250.45	259.00		
2021	290.07	310.23		
2022	688.94	671.33		
2023	828.82	828.82	828.82	828.82
2024		968.82	708.32	1229.33
2025		1111.05	760.40	1461.69
2026		1253.27	831.17	1675.37
2027		1395.49	912.27	1878.72
2028		1537.72	1000.17	2075.27

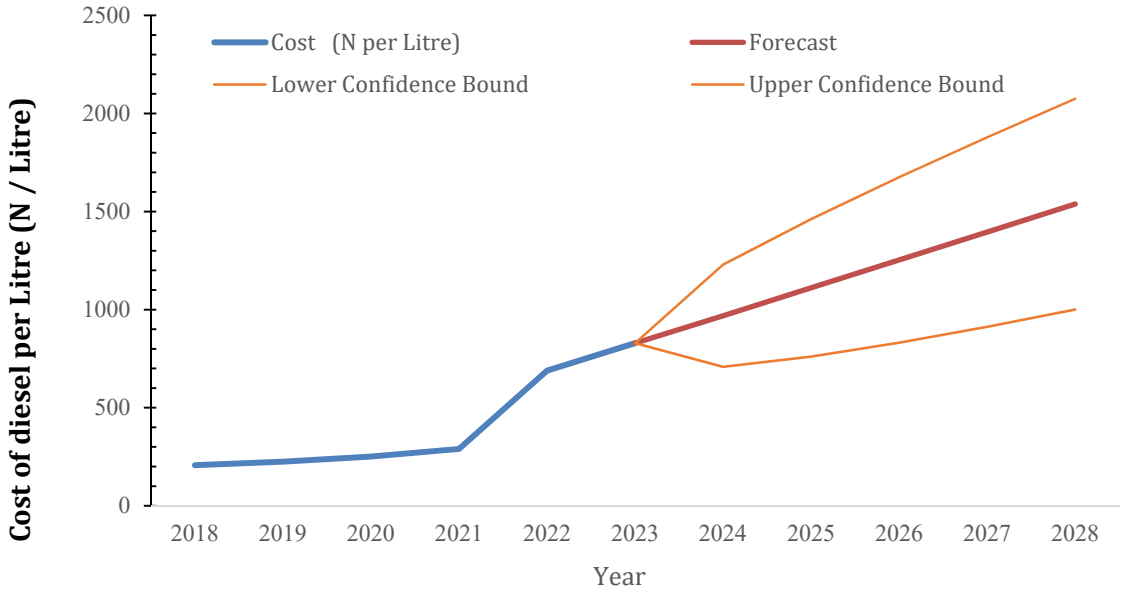

Figure 3: Predicted annual cost of diesel per litre (N per Litre) from 2023 to 2028.

The results of the Holt Winter's model forecasted annual cost of diesel from 2023 to 2028 without electricity supply from the national grid is presented in Table 4. The forecast results show that the annual cost of diesel without electricity supply from the national grid in 2023 is 695,794,390.00 litres and it increased to 1,294,452,696.00 litres in 2028 which is about 86.0 % increment over the period of 5 years.

Similarly, the results of the Holt Winter's model forecasted annual cost of diesel from 2023 to 2028 with electricity supply from the national grid is presented in Table 5. The results show that the annual cost of diesel with partial electricity supply from the national grid in 2023 is 198,253,744.00 litres and it increased to 367,822,624.00 litres in 2028 which is about 85.5 % increment over the period of 5 years.

Table 4 : The Holt Winter's model forecasted annual cost of diesel from 2023 to 2028 without electricity supply from the national grid

Year	Litres of Diesel Consumed/ Day and Night (X_1)	Cost of Diesel /Litre (N per Litre) (X_2)	No. of Days (X_{G3})	Annual Cost of Diesel (N) (X_4)
2023	2300	828.82	365	695,794,390.00
2024	2300	968.82	366	815,552,676.00
2025	2300	1111.05	365	932,726,475.00
2026	2300	1253.27	365	1,052,120,165.00
2027	2300	1395.49	365	1,171,513,855.00
2028	2300	1537.72	366	1,294,452,696.00

Note: $X_4 = X_1 \times X_2 \times X_{G3}$

Table 5 : The Holt Winter's model forecasted annual cost of diesel from 2023 to 2028 with electricity supply from the national grid

Year	Litres of Diesel Consumed/ Day and Night (X_1)	Cost of Diesel /Litre (N per Litre) (X_2)	No. of Days-Without Electricity Power Supply in a Year (X_3)	Annual Cost of Diesel (N) (X_4)
2023	2300	828.82	104	198,253,744.00
2024	2300	968.82	104	231,741,744.00
2025	2300	1111.05	104	265,763,160.00
2026	2300	1253.27	104	299,782,184.00
2027	2300	1395.49	104	333,801,208.00
2028	2300	1537.72	104	367,822,624.00

Note: $X_4 = X_1 \times X_2 \times X_{G3}$

4. CONCLUSION

The paper presented analytical approach to determine the annual cost of diesel used in power supply to a University campus. The requisite data on the energy supply from the national grid, the days without power supply from the grid, the unit cost of diesel were obtained for the case study University campus in Akwa Ibom State, Nigeria. The study considered the occasions when the school is in session and when the school is not in session. It also considered the diesel cost for supplying the power solely from the diesel generator and also by using a combination of the national grid and the diesel generator. In addition Holt Winter's forecast model was used to forecast the cost of diesel for a period of six years from 2023 to 2028. The study is essential for cost benefit analysis of power generation source selection and power system planning.

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