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Electrical Load, Facility Audit and Estimation of Monthly Energy Consumption in Federal University of Agriculture, Abeokuta, Ogun State, Nigeria

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ABSTRACT

Electrical loads and facilities audits are carried out within the Federal University of Agriculture, Abeokuta, Ogun State, Nigeria. Measurements of consumption are taken for a period of five days with the aid of a clamp meter. Monthly electric energy consumption data from January 2008 to February 2013 are also obtained from the Works and Services Department of the University. Facilities audit reveals that the University has 20 functional generators with a total capacity of 6130kVA and 22 transformers comprising 20 distribution transformers and 2 power transformers. The study shows that load and facility audit is essential in carrying out load forecasting. Therefore, energy storage should be incorporated to the power network to cater for sudden increase in energy demand.

Keywords: *Electrical load, load audit, facility audit, energy consumption*

INTRODUCTION

An electrical ‘load” is the required power for a closed circuit system to be functioning (Chang, 2015). The required power for a closed or functioning circuit is the electrical load. The electrical load for a building or facility may be represented by the total current (I) measured in ampere (A). Current (I) is the flow of the electrical charge for a given time period (Chang, 2015). According to Chang (2015), load (L) is the power consumed in a closed circuit system. The “average load” is an average value of the power consumed in the system during a specific time period. The “maximum load” is the maximum value of the energy consumed during the same time period under all conditions. The “demand load” is the required power to satisfy an adequate operation of a device or a circuit system (Guyer, 2010). Chang (2015) also states that the electrical energy is the capacity or strength of an electrical system, such as the electrical circuits or the electrical devices and the “electrical power” is the input to this system.

Nevertheless, there are factors that influence load calculations. These are demand factor, coincidence factor, diversity factor and load factor. Factors for load calculations and analysis, according to Guyer (2010), refer to some equations or ratios.

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Therefore, demand factor is the ratio of the maximum demand load to the total load connected. When the power input is connected to a circuit, whether the switch is closed or open, the maximum demand load should always be equal or smaller than the connected load because of a system loss and various other reasons (Chang, 2015). Mathematically, demand factor is calculated as:

$$\text{Demand Factor (DF)} = \frac{\textit{Maximum Demand Load}}{\textit{Total Load Connected}} \qquad \text{(Guyer, 2010)}$$

While Guyer (2010) sees the coincidence factor as the ratio of the maximum demand of a system, or part under consideration, to the sum of the individual maximum demands of the subdivisions, Chang (2015) sees it as the maximum system demand divided by the sum of individual maximum demand. The equation for the calculation of coincidence factor according to Guyer (2010) is as follows:

$$\text{Coincidence Factor (CF)} = \frac{\text{Maximum System Demand}}{\text{Sum of individual maximum demands}}$$

The diversity factor is the sum of individual maximum demands (nominator) divided by the maximum system demand (denominator) (Chang 2015). Thus, the power plan is generally more effective for a greater "Diversity Factor" because the value of nominator is fixed but the value of denominator or the maximum system demand changes with different designs of the power plans. This is why Guyer (2010) states that the diversity factor is the reciprocal of the coincidence factor or

$$\text{Diversity Factor (DiF)} = \frac{\text{Sum of individual maximum demands}}{\text{Maximum system demand}}$$

The load factor is the ratio of the average load over a designated period of time, to the maximum load occurring in that period (Guyer 2010). Load Factor is the ratio of the average load to the maximum load (Chang 2015). The maximum load should occur under the "Worst Case Load Event" (White, 2010). The average load, according to Chang (2015), should always be less than the maximum load. Guyer (2010) hypothesizes the equation for the calculation of load factor as:

$$\text{Load Factor (LF)} = \frac{\text{Average load}}{\text{Maximum load}}$$

Hence, load audit becomes an important activity in which an organization wishes to control energy and utility costs (Aiyedun, Adeyemi and Bolaji, 2008). A load audit is an inspection and analysis of energy flow for efficiency in a building or system to reduce the amount of energy input into the system without negatively affecting the outputs (Suresh, 2012). It assists in evaluating energy consumption and provides guidelines on how to improve energy efficiency. Power efficiency (E) is a ratio of the power output from an electrical system to the power input into the system (Chang 2015). There is a "system loss" from input to output. The system loss for a building, which is about 6%, has been established (Rosenberg, 2011 as cited in Chang 2015).

However, power efficiency is always less than 1 or below 100 percent (Chang 2015). Hence, the connected load or the required power for the circuit system has to be more than the specified power input (Chang 2015).

Power supply is becoming more complex as a result of increasing population, expansion, and improper planning by government and individuals. A device which utilizes electrical energy is called a load (Suresh, 2012). The load may be resistive, inductive, capacitive or a combination of all (Suresh, 2012). These depend on the qualities and capacities of the devices and equipment used. Based on the purpose for which electrical power is consumed, the electrical voltage of a circuit can be changed from low to high and vice versa, through a transformer. Transformer is a machinery to transform (change) electrical power from one circuit to another (Chang 2015). There are different types of transformers. Empirically, there are distribution and power transformers in Federal University of Agriculture, Abeokuta, Ogun State, Nigeria.

The common types of electrical power, according to Chang (2015), consist of single-phase and three-phase circuits. Phase is a wave of alternating current in a sinusoidal form. This type of sine wave moves in a series of 360^{o} cycles (Chang, 2015). A single phase circuit has only one sine-wave, alternating current flow; while a three phase circuit consists of three, sine-wave, alternating current flows. The three different waves are displaced in 120 degrees from each other (Chang, 2015). The three phase power is more efficient and often used in commercial and industrial facilities. The single phase power has a lower voltage and is often used for domestic purposes (Chang 2015).

$P = SCos\theta$ $Q = SSin\theta$ $P = IVCos\theta$ $Q = IVSin\theta$

Hence, this study is designed to evaluate the Electrical Load. In addition, facility audit and estimation of monthly energy consumption in Federal University of Agriculture, Abeokuta, Ogun State, Nigeria are conducted. The load audit was carried out round the campus for 5 days using a clamp meter to measure the current on each phase (red, blue, and yellow).

Load Audit Calculation

Power (P) is an input to the electrical circuit or a circuit system. It is the rate of electrical energy delivered to the circuit system (Chang, 2015). Mathematically, P = VI, or P = IR2 (Cathey and Nasar, 1997). Power is expressed in the unit of watt (W). The power demand for electrical components is given by equation (4):

$$S = IV \quad (2)$$

(3)

(4)

(5)

Where

P = Real Power (watts)

Q	=	Reactive Power
S	=	Complex Power or Apparent power
I	=	Measured Current (Amperes)
V	=	Voltage Supplied (volts). Voltage is the work that causes the current to flow. It is the required work to move a charge from one point to another point of an electrical circuit (Chang 2015).

The conversion of power in horse power (hp) to watt is demonstrated on table 1.

Table 1: Electric energy consumption by FUNAAB from January 2008-February 2013 (1hp =746 watt)

S/N	Year	Unit consumed (kwh)	**Amount ($)**	Amount (₦)
1	2008	1271749	89,478.18	13,845,853.57
2	2009	1184742	51,512.03	7,970,971.52
3	2010	1798000	78,809.10	12,194,920.13
4	2011	1297030	85,719.26	13,264,198.29
5	2012	1726210	279,091.99	43,186,694.53
6	2013	430780	47,530.89	7,354,929.92
Total		**7708511**	**632141.45**	**97,817,567.97**

The US dollar to Naira rate of 154.74 was used as accessed on 04/04/13 from CBN archive

Table 2: Electric load demand in FUNAAB in five days

S/N	Date	Day	Time	Load (kw)	kVA
1	22/03/13	1	12 noon-2.30 pm	1363	1704
2	25/03/13	2	12 noon-2.30 pm	1442	1802
3	26/03/13	3	12 noon-2.30 pm	1426	1783
4	27/03/13	4	12 noon-2.30 pm	1223	1529
5	28/03/13	5	12 noon-2.30 pm	1282	1603

Source: Fieldwork, 2014

Table 3: List of transformers and generators in FUNAAB

S/N	Equipment	Rating (kVA)	Type	Qty.
1	Transformer	2000	Power transformer	1
2	Transformer	2500	Power transformer	1
3	Transformer	500	Distribution transformer	16
4	Transformer	300	Distribution transformer	4
5	Generator	1000	Low voltage	1
6	Generator	800	Low voltage	1
7	Generator	500	Low voltage	4
8	Generator	250	Low voltage	5
9	Generator	200	Low voltage	3
10	Generator	100	Low voltage	3
11	Generator	60	Low voltage	3

Source: Fieldwork, 2014

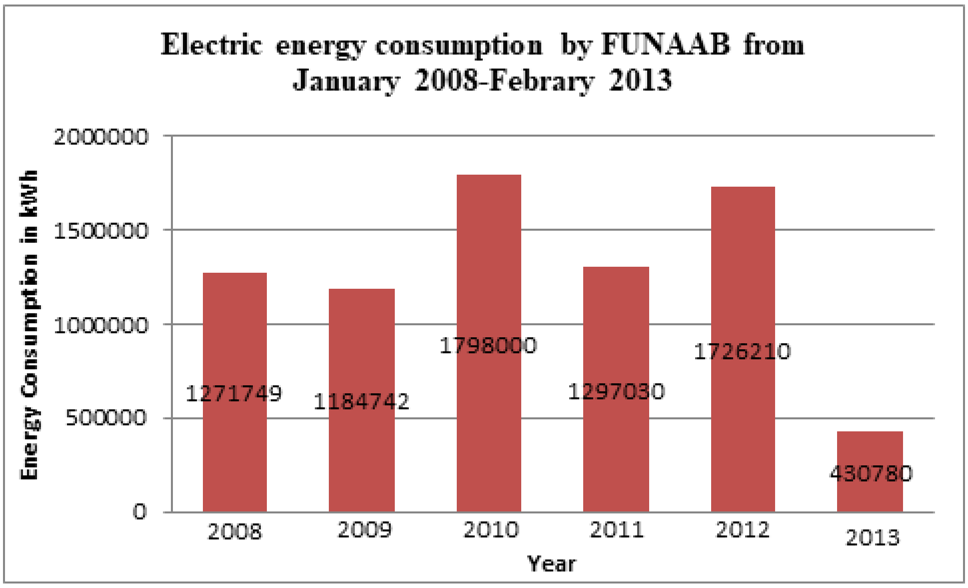

Figure 1: Electric energy consumption by FUNAAB from January 2008 to February 2013

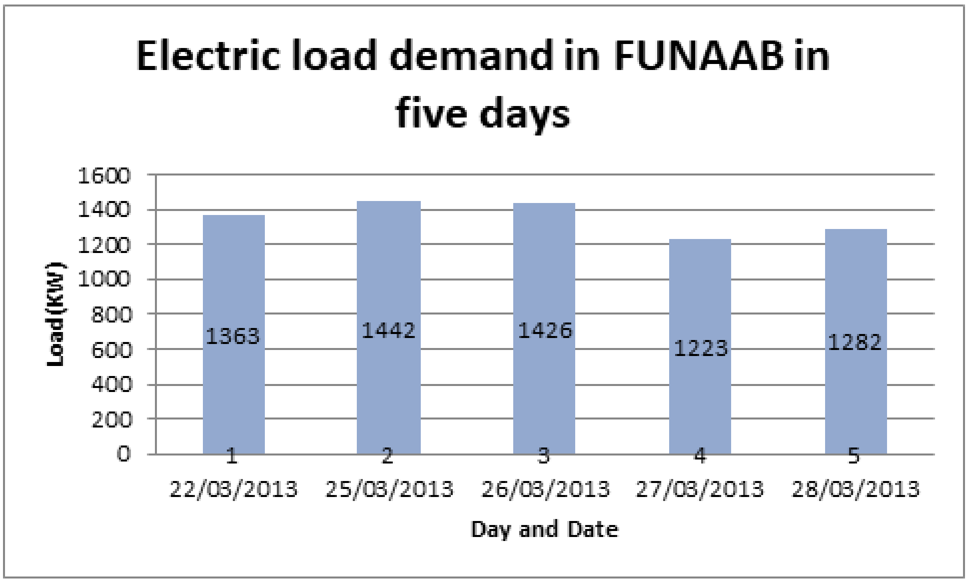

Figure 2: Five days electric load demand in FUNAAB

Electricity Network in Federal University of Agriculture, Abeokuta, Ogun State

Data in Federal University of Agriculture, Abeokuta, Ogun State show that 330kV is supplied from the National grid to Ikeja transmission station in Lagos State. Ikeja power station steps-down the voltage to 132kV and transmits to Papalanto substation in Ogun State. The voltage of 132kV is transmitted from Papalanto to Ojeere transmission station in Abeokuta where it is stepped-down to 33kV. This 33kV is supplied to the Federal University of Agriculture, Abeokuta, Ogun State from Ojeere

(FUNAAB feeder) and it is stepped-down to 11kV by a 2500kVA transformer at FUNAAB power house. The University currently has a total of 20 generators as shown in Table 3. The distribution transformers steps-down the 11 kV to 415V for distribution across the campus. However, according to information gathered from the power house of the University, it was learnt that the distribution network has suffered overloading, erratic supply especially when operating on generator(s) and from utility providers due to ageing of the equipment. It was learnt that this has resulted in massive shedding of load and decentralization of generating station across the campus. The ratings of the generators currently available in the University are given in Table 3. The 1000kVA generator provides 415V but it is stepped-up by the 2000kVA transformer at FUNAAB power house. Also, some colleges have generators ranging from 60kVA to 500kVA in an attempt to decentralize the university's power house supply. The reasons for this, are erratic power supply, easy fault tracing, to prevent overloading of generators at the power house and special programs administration.

Cost of Energy Consumed

The University paid the following amounts yearly to Power Holding Company of Nigeria (PHCN), as indicated in Table 1 from January 2008 to February 2013. The sum of ₦13,845,853.57 ($89,478.18) was paid for 1271749kwh of energy consumed in 2008, while ₦7,970,971.52 ($51,512.03) was paid for 1184742 kwh of energy consumed in 2009 and the sum of ₦12,194,920.13 ($78,809.10) was paid for 1798000 kwh of energy consumed in 2010. Also paid was the sum of ₦13,264,198.29 ($85,719.26) for 1297030 kwh of energy consumed in 2011 and ₦43,186,694.53 ($279,091.99) for 1726210 kwh of energy consumed in 2012. In 2013, the sum of ₦7,354,929.92 ($47,530.89) was paid for 430780 kwh of energy consumed in the University campus. The total amount paid for 7708511 kwh of energy consumed in the University within 5 years and 2 months, from January and February of 2013, was ₦97,817,567.97 ($632.141.45) (Table 1). The observed variation in the cost may be attributed to irregular supply of power, increment in tariff, faults on the network, University breaks and strike. For instance, in July to October 2009, there was ASUU (Academic Staff Union of Nigeria Universities) strike and likewise in November 2012 to January 2013. From the load audit carried out, the following results were obtained: 1363kw (1704kVA), 1442kw (1802kVA), 1426kw (1783kVA), 1223kw (1529kVA) and 1282kw (1603kVA), these were indicated in Tables 2 and Figure 2. It shows that the Federal University of Agriculture Abeokuta, Ogun State has a total number of 22 functional transformers, one step-down transformer, one step-up transformer and 20 distribution transformers as well as 20 functional low voltage generators as shown in Table 3.

CONCLUDING REMARKS

Electrical loads and facilities audit was carried out with visits to the available facility locations, and measurements were taken with the help of Clamp meter. Some parameters such as frequency, ratings, and phase were observed and consumption for the period of five days were obtained. It was discovered that there are 20 functional low voltage generators (6130kVA) that are under-utilized and 20 distributing transformers (8200kVA), 1 step-up power transformer (2000kVA) and 1 step-down transformer (2500kVA). Power Holding Company of Nigeria (PHCN) monthly energy consumption by Federal University of Agriculture, Abeokuta, Ogun State was obtained from January 2008 to February 2013. The study shows that electricity load and facility audit is essential in carrying out load forecasting. Energy storage should be incorporated to the power network to cater for sudden increase in energy demand.

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