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ANALYSIS OF POWER LOSSES IN ELECTRICITY DISTRIBUTION SYSTEMS: A CASE STUDY OF IBADAN ELECTRICITY DISTRIBUTION COMPANY (IBEDC), NIGERIA

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ABSTRACT

In recent years, electric power demand has increased drastically due to superiority of electric energy to all other forms of energy. A distribution system is used to convey electric power from a transmission system to customers to serve their needs. However, a significant portion of the electric power is lost in the distribution process. Power losses in Ibadan Electricity Distribution Network were computed from the data obtained from Sagamu Business Hub, for two years (January, 2016 to December, 2017). The results revealed that distribution losses in Sagamu are due to technical and non-technical losses. The technical losses are due to resistance and reactance of the conductors and faults while non-technical losses are caused by theft of power, meter tampering among many others. Transformer leakage current, aged transformer, damage accessories, inadequate size of conductors were discovered to have attributed to power losses in Sagamu. Suggestions have been made in order to reduce power losses in Sagamu distribution network.

1. INTRODUCTION

Electric power plays the most vital role in the economic growth, progress, and development, as well as poverty eradication and security of any nation (Navani, 2012). The process of making electricity available to the users start from the power generating station, where energy is generated from available sources like gas, hydro, thermal, solar, wind etc., at a reasonable voltage level that is further stepped up for onward transmission. It is eventually transformed into power at a voltage level compatible with customer or consumer requirements via the distribution substations that received the energy from transmission stations (Omorogiuwa and Elechi, 2015). During the process, power losses are experienced at four stages that include; (1) transmission of energy from the generating station to the transmission station at a high voltage, (2) transportation of energy from the transmission station to the distribution substations (injection substations) at medium voltage level, (3) distribution of energy from the injection substation to various distribution transformers on the 11KV feeders, (4) connection of customers at the point of low voltage line at various customer's premises (Alumona, 2014).

Power losses occur in distribution networks due to joule's effect which can account for as much as 13% of the generated energy (Onohaebi and Kuale, 2007). Such non-negligible amount of losses has a direct impact on the financial issues and the overall efficiency of distribution utilities (Hachimenum et al., 2016). Therefore, methods for losses reductions, that optimally allocated scarce financial resources and maximize firm value, are essential for achieving the financial goals of distribution companies. Losses reduction initiatives in distribution systems have been activated due to increasing cost of supplying electricity, the shortage in fuel with ever increasing cost to produce more power, and global warning concerns (Gupta, 2008). These losses comprise technical and non-technical. Technical losses consist of naturally occurring losses associated with the heat dissipation in electricity system components such as transformers, distribution lines and measurement systems while non-technical losses on the other hand, are generally associated with electricity theft arising from commercial, administrative, and non-payment losses (Glover et al., 2001). All these losses translate to high operating cost as well as huge revenue losses and consequently they result in high cost of electricity (Nagi et al, 2008).

There are quite a handful of approaches that can be employed in estimating the technical losses of distribution networks. This research employs the use of loss factor to compute the technical losses in primary distribution network of IBEDC, Sagamu Business Hub in Sagamu, Ogun State using sampled network data. In Adesina and Ademola (2016), the power system network aggregate losses, technical losses and non-technical losses (commercial and collection losses) have been fully described. Various causes of technical as well as non-technical losses including their effects are clearly presented. Details of Newton-Raphson power flow method to determine the technical losses as well as other parameters were stated. Also, in Adegboyega et al., (2014) power line losses analysis on Ekpoma distribution network was carried out.

The aim of this research work is to determine and analyse the power losses in Sagamu distribution substation and to proffer possible ways for reducing the losses to the minimal.

2. MATERIALS AND METHODS

2.1. Study Location

Sagamu Business Hub has eight undertaken service hubs under it which includes Igbobi 1 service hub, Igbobi 2 service hub, Odogbolu service hub, Ogijo service hub. Sabo service hub, Owode service hub, Mowe service hub, Ibafo service hub, Magboro service hub, Iperu service hub and Eyita service hub. Each service hub has feeders it controls.

2.2. Data Collection

Data were collected on the following feeders: Sagamu 33KV feeder, Celpass 33KV feeder, Babcock 33KV feeder, Real 33KV feeder, Metafrique 33KV feeder. Also, the following were collected on each feeder. Monthly return loading of 33Kv, Feeder route length, Cable type, All Aluminium conductor (AAC) of size 150mm^2 with resistivity of 2.8×10^{-8} Ωm was used for both feeder and distribution lines.

2.3. Methods

Classical method was applied in this work. In the classical method, route length and route resistance vis a vis the load type (resistive, inductive and capacitive) were considered. Load losses result from load currents flowing through the transformer. Winding losses are the power lost in the high and low voltage windings of the transformer due to winding resistance present when the transformer is unloaded (load dependent). The three components of the load losses are ohmic heat losses sometimes referred to as copper losses, eddy current losses and stray losses (Anazia et al., 2017). Load losses can be reduced by increasing the conductor cross sectional area and complying with the manufacturer's guideline as regards temperature.

Hence, a total loss in a transformer is equal to iron loss or no-load loss (P1) plus effective copper loss or load loss (P0). Many transformers work off constant-voltage mains, so P0 is a constant. Therefore,

$$\textit{Total loss} = \textit{constant} + \textit{effective resistance} \times I^2 \tag{1}$$

To calculate the power losses, the following parameters were used:

Number of the feeders attached to Sagamu Business Hub, total maximum loading on each feeder in Megawatt (MW), power factor (P.F) = 0.8, cross sectional area (CSA) of conductor wire (A) = 150mm^2 route length (L) of each feeder (km), resistivity (e) = 2.82 x 10^{-8} ohm meter, current drawn from each feeder (I_L), resistance (R) of the conductor wire (ohm), current drawn from feeder (I_L).

$$(I_L) = \frac{P}{\sqrt{3}x\ V\ x\ P.F} \tag{2}$$

The line resistance is given as:

$$R = \frac{eL}{A} \tag{3}$$

Where, P = power in Megawatts (MW); V = voltage in volts (V); e = resistivity in Ωm^{-1}; A = cross sectional area in mm^2; L is route length of the feeder.

Hence:

$$\text{Power loss} = I^2_L \text{ x } R \tag{4}$$

Using the collected data in Equations 2, 3 and 4, the current drawn and power losses for the six feeders attached to Sagamu Business Hub for both year 2016 and 2017 was calculated with the aid of Maltab Simulink.

3. RESULTS AND DISCUSSION

This research presents the result of the total power losses on each feeder. Data on monthly Electrical power loading were collected for the year 2016 and 2017. Table 1 shows the total power loadings in MegaWatts (MW) for each month of the year 2016 and Table 2 presents the total power loadings for year 2017.

Table 1: Power loadings in MW for the year 2016

Months	Sagamu 33KV	Real 33KV	Babcock 33KV	Celpass 33KV	Metafrique 33KV
January	15.0	16.0	2.0	4.0	1.0
February	13.0	0.1	2.0	4.0	0.1
March	18.0	10.0	3.0	4.0	1.0
April	12.0	10.0	3.0	4.0	0.1
May	13.0	10.0	3.0	4.0	1.0
June	14.0	10.0	3.0	4.0	2.0
July	16.0	6.0	2.0	3.0	1.0
August	18.0	10.0	1.5	4.0	0.1
September	15.0	9.0	2.0	3.0	0.1
October	13.5	0.1	2.0	3.0	0.1
November	12.5	9.0	2.5	3.0	3.0
December	12.0	8.0	2.0	0.0	3.0
Total	172.0	98.2	28.0	40.0	12.5

Table 2: Power loadings in MW for the year 2017

Months	Sagamu	Real	Babcock	Celpass	Metafrique
January	12.0	9.0	2.0	3.0	9.0
February	13.0	6.0	2.5	4.0	9.0
March	12.0	7.0	2.0	4.0	8.0
April	13.0	5.0	2.5	4.0	0.5
May	12.0	6.0	2.0	3.0	0.1
June	13.0	5.0	2.0	4.0	0.1
July	12.0	10.0	2.0	3.0	0.1
August	12.0	1.0	1.0	3.0	0.1
September	12.0	0.1	2.0	3.0	0.1
October	13.0	9.0	2.0	4.0	0.1
November	13.0	5.0	2.0	3.0	0.1
December	12.0	0.1	0.1	3.0	0.1
Total	149.0	63.2	22.1	41.0	27.3

The data collected and presented in Table 1 and Table 2 shows the Sagamu 33KV having the most power loading of all the feeders studies. Figure 1 presents the graph of the average maximum loading (average power loading) of all the feeders under the Sagamu Business Hub. The Sagamu, Real and Babcock 33KV feeders had decrease in the average maximum loading from 2016 to 2017.

The power losses in Mega Watts for all the five feeders in the Sagamu Business Hub for the years 2016 and 2017 were calculated using Equation 4. The calculated power losses for years 2016 and 2017 are presented in Table 3 and Table 4 respectively. The results show the Sagamu 33KV feeder having the most power losses per year which is due to it having the most feeder route length.

Figure 2 shows the Babcock, Celplas and Metafrique 33KV feeders having significant increase in the average power losses for the year 2016 compared to the year 2017, while the Sagamu and Real 33KV feeders had an improvement in efficiency by having a decrease in the average power losses from 2016 to 2017. The average power losses on the five feeder for each year 2016 and 2017 are shown in the Figure 2.

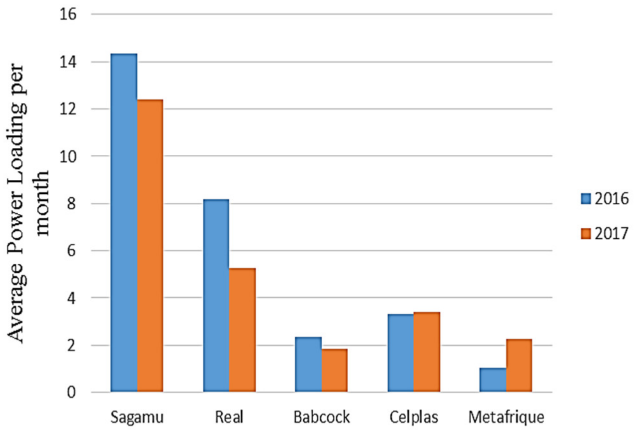

Figure 1: The average maximum loading (MW) on all feeders

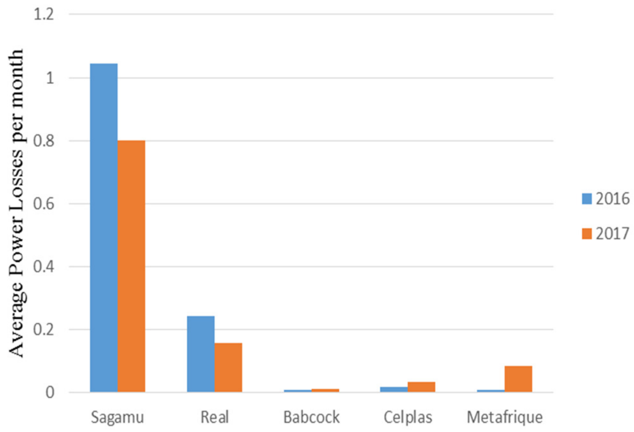

Figure 2: The average power losses (MW) on all feeders

Table 3: Calculated power losses (MW) of all the five feeders for the year 2016

Months	Sagamu	Real	Babcock	Celpass	Metafrique
January	1.11700	1.05700	0.00551	0.01470	0.00400
February	0.84000	0.00003	0.00551	0.01470	0.00004
March	1.62000	0.14300	0.01240	0.01470	0.00440
April	0.72200	0.14300	0.01240	0.01470	0.00004
May	0.84200	0.14300	0.01240	0.01470	0.00440
June	0.97700	0.14300	0.01240	0.01470	0.02000
July	1.27800	0.14800	0.00551	0.08310	0.00440
August	1.60000	0.14300	0.00310	0.01470	0.00004
September	1.12300	0.33400	0.00551	0.00831	0.00004
October	0.90800	0.00003	0.00551	0.00831	0.00004
November	0.78300	0.41300	0.00862	0.00831	0.03970
December	0.72200	0.26000	0.00551	0.00000	0.03970
Total	12.53200	2.92706	0.09438	0.21093	0.11680

Table 4: Calculated power losses (MW) of all the five feeders for the year 2017

Months	Sagamu	Real	Babcock	Celpass	Metafrique
January	0.72200	0.33400	0.00551	0.00831	0.35300
February	0.84200	0.14800	0.00862	0.01470	0.35300
March	0.72200	0.20200	0.00862	0.01470	0.29700
April	0.84200	0.10200	0.10200	0.01470	0.00100
May	0.72200	0.14800	0.00551	0.00837	0.00004
June	0.85800	0.10200	0.00551	0.01470	0.00004
July	0.73600	0.41000	0.00550	0.08310	0.00004
August	0.73800	0.00004	0.00137	0.08310	0.00004
September	0.74200	0.00003	0.00551	0.08310	0.00004
October	0.80200	0.33400	0.00551	0.00831	0.00004
November	0.86600	0.10200	0.00551	0.00831	0.00004
December	1.03400	0.00003	0.00001	0.08310	0.00004
Total	9.62600	1.88210	0.15918	0.45450	1.00432

Table 5 and Table 6 present data showing the relationship of each of the feeder route length with the average maximum power loadings, average power losses, percentage of average power losses and average power consumed of all the five (5) feeders studied for 2016 and 2017 respectively. The Sagamu 33KV has the highest percentage of the average power losses of 7.28% and 6.46% for year 2016 and 2017 respectively occurring among all the five (5) feeders.

Table 5: Relationship between feeder route length, average maximum loadings, average power losses and average power consumed of all the feeders for the year 2016

Feeders	Sagamu 33KV	Real 33KV	Babcock 33KV	Celplas 33KV	Metafrique 33KV
FR_L (km)	55.500	30.620	15.150	10.150	32.300
$MLoad_{avg}$	14.333	8.183	2.333	3.333	1.042
$MLoss_{avg}$	1.044	0.244	0.008	0.018	0.010
% of $MLoss_{avg}$	7.284	2.982	0.343	0.540	0.960
$PCons_{avg}$ (MW)	13.289	7.939	2.325	3.316	1.032

Table 6: Relationship between feeder route lengths, average maximum loadings, average power losses and average power consumed of all the feeders for the year 2017

Feeders	Sagamu 33KV	Real 33KV	Babcock 33KV	Celplas 33KV	Metafrique 33KV
FR_L (km)	58.160	30.620	15.150	10.150	32.300
$MLoad_{avg}$ (MW)	12.417	5.267	1.842	3.417	2.275
$MLoss_{avg}$ (MW)	0.802	0.157	0.013	0.035	0.084
% of $MLoss_{avg}$	6.459	2.981	0.706	1.024	3.692
Pcons avg (MW)	11.615	5.110	1.828	3.381	2.191

*** FR_L = Feeder route length (km), $MLoad_{avg}$ = Average maximum loading (MW), $MLoss_{avg}$ = Average maximum losses (MW), $PCons_{avg}$ = Average power consumed (MW)

The probable cause of power losses in the 33kv feeder were due to Technical losses resulting from the following; lengthy distribution lines, unequal load distribution among three phases in L.T system causing high neutral currents, leaking and loss of power, over loading of lines, abnormal operating conditions at which power and distribution transformers are operated and low voltages at consumer terminals causing higher draw of currents by inductive loads (Adesina, et al., 2016). An inductive load pulls a large amount of current when first energized, then settle down to a full load running current after few seconds or cycles.

4. CONCLUSION

The results obtained showed that the power losses were more in the industrial area than in the residential area, and this is due to the large number of inductive loads like transformers, heavy motors, and chokes used in the industries. To reduce these losses, we recommend the replacement of old equipment. We also recommend the installation of low-loss transformers and operating transformers at efficiency-maximizing utilization rates.

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

REFERENCES

Adegboyega, G. A (2014). Determination of Electric Power Losses in Distribution Systems: Ekpoma, Edo State, Nigeria as a Case Study. *The International Journal of Engineering and Science (IJES),* 3(1), pp. 66-72.

Adesina, L.M. and Ademola, Abdulkareem (2016). Determination of Power System Losses in Nigerian Electricity Distribution Networks. *International Journal of Engineering and Technology,* 6(9), pp. 322-326.

Alumona, T. L., Nwosu, Moses O., Ezechukwu, A. O. and Chijioke, Jonah (2014). Overview of Losses and Solutions in Power Tranmission Lines. *Network and Complex Systems,* 4(8), pp. 24-31.

Anazia, E. A., Ugochukwu, E. S., Onuegu, J. C. and Onyedikachi, S. N. (2017). Design and Analysis of Losses in Power Transformer. *American Journal of Electrical and Electronic Engineering,* 5(3), pp.94 – 101.

Gupta, J. B. (2008). A course in power systems. *S.K. Kataria & Sons, New Delhi*

Glover, J. D., Sarma, M. S., Overbye T. J. and Pasly, N. P. (2001). Power System Analysis and Design. *Cangage Learning United States*.

Hachimenum N. Amadi, Ephraim N. C. Okafor and Fabian I. Izsuegbunam (2016). Assessment of Energy Losses and Cost Implications in the Nigerian Distribution Network. *American Journal of Electrical and Electronic Engineering,* 4(5), pp. 123-130.

Nagi, J., Mohammed, A., Yap, K., Tiong, S. and Ahmed, S. (2008). Non-technical loss analysis for detection of electricity theft using support vector machines. In: Proceedings of *2nd IEEE Int. Power and Energy Conf.*, pp. 907 – 912.

Navani, J.P. Sharma, N.K. and Sapra, S. (2012). Technical and Non-Technical Losses in Power System and Its Economic Consequence in Indian Economy. *International Journal of Electronics and Computer Science Engineering*, 1(2), pp. 757 – 761.

Omorogiuwa E. and Elechi P. (2015). Economic Effects of Technical and Non-Technical Losses in Nigeria Power Transmission System. *IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE),* 10(2), pp. 89 -100

Onohaebi O. S. and Kuale P. A. (2007). Estimation of Technical Losses in the Nigerian 330KV Transmission Network. *International Journal of Electric Engineering,* 1(4), pp. 402 – 409.