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Comparative Analysis of Electrical Power Losses in Calabar Area

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***Abstract*:- Electrical Distribution system takes electric power from transmission section of power system and delivers a required quality and quantity needed to meet up customers demand. However, an important portion of the electric power generated is lost in the distribution network. These work is tend to compare the power losses in those feeders. Power losses in Esuk-Utan distribution network were computed from data obtained from Power Holding Company of Nigeria, Esuk-Utan Injection Distribution Substation for five year (January, 2016 to December, 2020). The data were analyses using MATLAB and the results are presented in tables. The results reveal that distribution losses in Esuk-Utan Injection Distribution Substation which includes Esuk-Utan feeder I, Federal Housing Feeder II and Feeder III as 8 mile feeder. When comparing the result of calculated average power loss it was revealed that Feeder III (8 Miles Feeder) recorded the highest power lost throughout the years. The percentage of power losses on Esuk-Utan feeder has a maximum loading of 3.0 MW, the percentages of power losses on those years involves are 12.79%, 16. 33 MW, 16.33%, 16.70% and 17.3% respectively. Federal Housing has its maximum loading of 4.8 MW, the percentages power loss are 18.5%, 18.75%, 19.2%, 19.0% and 20.4% respectively. For 8 Miles feeder its maximum loading is 5.8 MW. The percentages of power losses on those years are 27.63%, 27.9%, 28.0%, 31.53% and 36.44% respectively. Significantly it helps in making good decision on the following, Secure, stable and reliable power system effective planning, good maintenance schedule.**

Keywords: Power loss, power system, transmission lines, feeders, maximum loading.

1.0 INTRODUCTION

The economic development of a nations depends on the amount of energy the country can generate. With the diverse forms of energy in nature, the most important form for a nation growth and development is electrical energy. A modern and civilized society is so much relaying on the use of electrical energy. Activities relating to the generation, transmission and distribution of electrical energy have to be given the highest priority in the national planning process of any nation because of the usefulness of electrical energy to the economic and social development of the society. The greater the per capital consumption of electrical energy in a country, the higher the standard of living of its people. Therefore, the advancement of a country is measured in terms of it per capital consumption of electrical energy. Power plants, planning in a way to meet the power network load demand, is one of the most important and essential issues in power systems. Since transmission lines connect generating plants and distribution in power network, the analysis, computation and reduction of losses in these power networks are of great interest to engineers [12, 15]. Many research works have been carried out on the above listed aspects. Electrical energy is the most important form of energy in the present world. It is an energy that drives the economy of any society or country and makes the common citizen happy. Electricity that is been generated from the power station, needs to be transmitted to the end users, through transmission and distribution lines. This transmitted energy is not without losses. Nigeria transmission of electricity is through a national grid, which either in 330 kv or 132 kv. Transmission grid is a network that consists of conductors carried on steel towers in between transformer stations, which conveys generated power from power stations to major load centre, band linking all power stations to form a strong network that is easy to access to all load centres [1]. In electricity supply to final consumers, losses refer to the total aggregate injected into the transmission and distribution grids that are not paid for by users. The level or extent of these losses is a measure of the efficiency of the electric power networks. In virtually every electric power network either in a developing country or developed ones, losses in the electricity supply network is inevitable. Over the years, electrical engineers have explored several engineering techniques aimed at minimizing these losses [20, 24]. This study therefore explores the comparative analysis of losses in Esuk utan injection substation which comprises of three feeders that is Esuk-Utan feeder I, federal housing feeder II and 8 Miles Feeder III and the strategy to minimize it. The aim of this study is to bring to reality that losses occur in the electricity distribution network in Calabar areas and to propose a strategy to reducing the losses. Its main objectives here is to provide a solution that will be used for effective planning of electricity distribution in Calabar area.

- To formulate a better model that will be used to calculate the power losses in Calabar
- To compared the losses in different feeder in the area and the cause

2.0 METHODOLOGY AND MODEL FORMULATION

Method of load factor and load loss factor are used in these work. Losses in transformer are combination of the power dissipated by the cores magnetizing inductance (iron loss) and winding impedance (copper loss) [6]. These losses are generally classified into three as given below [16]:

I. No Load Losses (W_{NL}): These comprise of hysteresis losses and eddy current losses in the core. It is always constant irrespective of the load.

II. Load Losses (W_L): These take place in the winding part and it is load dependent. It is subdivided into (I^2R) loss and stray losses. The stray losses are as a result of eddy currents that produce stray electromagnetic flux in the winding core, core clamps, magnetic shield and other parts of the transformer

III. Other Losses (W_{other}): These are dielectric losses, load unbalance loss, oil leakage loss, loss of life, lack of maintenance, improper up keep of distribution boxes and joint loose connections. Other Losses (W_{other}) is negligibly small (most of time less than 1%) and as such W_{NL} and WL are most important losses considered in this work. In calculating the technical losses of the power transformer, the method of load factor and load loss factor can be employed. Loss Factor (Lf) is the ratio of average power consumed during a designated period to maximum demand occurring in the same period [18]. Mathematically:

$$L_f = \frac{KVA_{average}}{KVA_{MaxDemand}} \quad (3.1)$$

Load Loss Factor (L_{lf}) describes the average electrical energy losses for electricity distributed during a designated period. Load Loss Factor is presented mathematically as:

$$L_{lf} = \frac{\text{Actual Loss During A Period (Kwh)}}{\text{Loss At Maximum Current (Kwh)}} \quad (3.2)$$

The relationship between Load Factor and Load Loss Factor is

$$L_{lf} = k * L_f + 1-k * (l_f)^2 \quad (3.3)$$

Where k is co-efficient of loading, as per loading.

$$K = \frac{\text{Minimum Demand } (KVA_{min})}{\text{Maximum Demand } (KVA_{max})} \quad (3.4)$$

The Total power loss in the transformer (WT_{Loss}) in KW is given as:

$$WT_{Loss} = \{\text{Load Loss } W_L + \text{No Load Loss } W_{NL}\} * 10^{-3} \quad (3.5)$$

$$W_{TL} = \{W_C (KVA_{MD}/KVArating)^2 * L_{lf} \quad (3.6)$$

W_C is full load copper loss KVA_{MD} is maximum KVA Demand in a period.
KVA_{Rating} is the KVA rating of the transformer
W_C and W_{NL} can be obtained from standard losses table for transformers available.
Combining (5) and (6) yields (7) below:

$$W_{TL} = \{W_C (KVA_{MD}/KVArating)^2 * L_{lf} + W_{NL} \quad (3.7)$$

When current passes through line of feeders, feeder load loss results due to imperfection of the conductors of the lines. The load losses of feeders. Feeder losses were computed using maximum return on loading of feeders without considering the place of loss factor. The value of the current at all times is less than the maximum current. Due to this, the computation of feeder losses in this work employs the loss factor approach. The power loss on a feeder (P_{LOSS}) is given as;

$$P_{LOSS} = I_L^2 R \quad (3.8)$$

When considering loss factor, (8) becomes:

$$P_{LOSS} = I_L^2 R * (\text{Loss Factor}) \quad (3.9)$$

Where Loss Factor is

$$\text{Loss } Factor = 0.3 * Load\ Factor + 0.7 * (Load\ Factor)^2 \quad (3.10)$$

And,

$$Load\ Factor = Averag\ Load / Peak\ Load \quad (3.11)$$

The maximum current (I_L) in Ampere, drawn from feeder is expressed as:

$$\text{Current drawn from feeder} \qquad (I_L) = \frac{P}{\sqrt{3}V\cos\theta} \quad (3.12)$$

$$\text{Resistance of line } (\Omega) \qquad R = \frac{\ell L}{A} \quad (3.13)$$

$$\text{Power losses (MW)} \qquad P = I_L^2 \cdot R \quad (3.14)$$

Where P is Power in Mega Watts, V is voltage in Volts, ℓ is resistivity in Ω-m, R is resistance in Ω, A is cross sectional area in , L is route length of the feeder Power loss = R

Hence, power loss is power received less power consumed. For this work equation 3.12 and equation 3.14 are used for the calculations of losses. Hence there are the model equations for these work. The data use for the analysis process and the matlab programing are shown below as

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Esuk-Utan Feeder (I) Maximum loading = 3.0 MW, Line voltage (V) = 11 kV, Power factor (p.f) = 0.8, Cross sectional area of conductor =150 mm^2, Route length (L) =8 km, Resistivity ℓ = 1.504 Ω.m, Current drawn from feeder (I_L) =196.83 A, Power loss P_L = 0.244 MW

Federal Housing Feeder (II): Maximum loading = 4.8 MW, Route length (L) = 10 km, Current drawn from feeder (I_L) = 314.83 A, Resistance = 1.88, Power loss = P = 2.18 MW III- 8-Miles Feeder (III): Maximum loading = 5.9 MW, Route length (L) = 15 km, Current drawn from feeder (I_L) = 387.10 A, Resistance = 2.82, Power loss = P = 2.18 MW

The data collected are presented in appendix 1, which are the losses recorded in the three feeders of Calabar area 1. The data is for the period of five years which is used for analysis and its results are shown below.

3.0 RESULT PRESENTATION

The results are gotten from the calculated power losses.

Table 3.1 Calculated Power Losses (Mw) On Esuk-Utan 11 Kv Feeder (F 1)

MO NTH	2016	2017	2018	2019	2020
JAN	0.37	0.47	0.49	0.47	0.49
FEB	0.37	0.47	0.49	0.47	0.49
MAR	0.37	0.47	0.41	0.47	0.49
APR	0.37	0.47	0.49	0.49	0.49
MAY	0.37	0.49	0.50	0.48	0.53
JUN	0.37	0.49	0.51	0.55	0.55
JUL	0.41	0.47	0.49	0.47	0.49
AUG	0.37	0.47	0.49	0.49	0.49
SEP	0.37	0.53	0.47	0.53	0.47
OCT	0.36	0.49	0.49	0.49	0.49
NOV	0.37	0.47	0.49	0.55	0.59
DEC	0.37	0.49	0.49	0.50	0.59
TOTAL	4.52	5.82	5.85	6.00	6.20
Average Power Losses	0.38	0.49	0.49	0.50	0.52

Table 3.2: Calculated Power Losses (Mw) On Federal Housing 11kv Feeder (F II)

	YEARS				
MONTH	2016	2017	2018	2019	2020
JAN	0.86	0.91	0.89	0.81	1.11
FEB	0.86	0.89	1.04	1.01	1.18
MAR	0.86	0.96	1.01	0.96	1.11
APR	1.01	0.86	0.89	1.01	1.11
MAY	0.86	0.84	0.89	0.96	1.11
JUN	0.89	1.09	1.04	0.89	0.96
JUL	0.89	0.89	1.01	0.89	0.96
AUG	0.86	0.67	1.01	0.96	0.96
SEP	0.86	0.89	0.91	0.94	0.89
OCT	0.79	0.96	0.91	1.09	0.94
NOV	0.79	0.86	0.91	0.96	0.91
DEC	1.11	0.99	0.49	0.48	0.47
TOTAL	10.66	10.81	11.00	10.96	11.72
Average Power Losses	0.89	0.90	0.92	0.91	0.98

Table 3.3: Calculated Power Losses (Mw) On 8-Miles 11kv Feeder (F III)

MONTH	2016	2017	2018	2019	2020
JAN	1.67	1.44	1.67	1.67	2.15
FEB	1.67	1.52	1.67	1.59	2.15
MAR	1.70	1.59	1.70	1.74	2.07
APR	1.67	1.63	1.67	1.74	2.04
MAY	1.67	1.63	1.63	1.81	2.15
JUN	1.67	1.55	1.63	1.92	2.15
JUL	1.70	1.70	1.70	1.89	2.15
AUG	1.67	1.67	1.59	1.48	2.44
SEP	1.59	1.59	1.63	2.11	2.15
OCT	1.59	1.74	1.67	2.07	2.07
NOV	1.52	1.70	1.63	2.11	2.11
DEC	1.52	1.63	1.63	2.15	2.18
TOTAL	19.61	19.39	19.80	22.28	25.79
Average Power Losses	1.63	1.62	1.65	1.86	2.15

4.0 DISCUSSION OF RESULTS

The results is shown in table 3.1, 3.2 and 3.3. These shows the calculated power loss in the three feeders in the area (i.e Esuk-Utan feeder, federal housing feeder and 8 miles feeder). Table 3.1 is the calculated power loss on Feeder I (Esuk-Utan feeder) for the period of five years. In 2016 the calculated power loss on the feeder in January to June is about 0.37 MW and July the loss increases by 0.04 MW thereby returned back and further reduced. In 2017 the losses increases by 0.10 MW in January and it has the highest power loss at September of 0.53 MW, and it lowest power loss of 0.47 MW on the month of January, February, march and April. In 2018 it has its calculated lowest power loss of 0.41 MW on the month of March and it highest power loss of 0.51 MW on the month of June. In 2019 it calculated lowest power loss is 0.55 MW on the month of June and November with t highest power loss of 0.58 MW on the month of February and July. In 2020 it calculated lowest power loss is 0.47 MW on the month of November and December and it calculated highest power loss of 0.59 MW on the month of September.

Table 3.2 is the calculated power loss on feeder II (Federal Housing) for the period of five years. In 2016 the calculated peak power loss on the feeder is 1.11 MW on the month of December and it lowest power loss is 0.79 MW on the month of October and November. In 2017 calculated peak power loss is 1.09 MW on the month of June and it lowest power loss is 0.67 MW on the month of August. In 2018 the calculated peak power loss is 1.04 MW on the month of February and June ad it lowest power loss 0.92 MW are on the month October and November. In 2019 calculated peak power loss is 1.09 MW on the month of October and it lowest power loss of 0.48 MW on the month of December. In 2020 the calculated peak power loss is 1.18 MW on the month February and its lowest power loss is 0.47 MW on the month of December.

Table 3.3 is the calculated power loss on feeder III (8 Miles) for the period of five years. In 2016 the calculated peak power loss on the feeder is 1.70 MW on the month of March and July and it calculated lowest power loss is 1.52 MW on the month of November and December. In 2017 the least power loss is recorded on the month of January with the calculated power loss of 1.44 MW and its calculated peak power loss is on the month of October with the calculated power loss of 1.74 MW. In 2018 the least power loss are recorded on the months of May and June with the calculated power loss of 1.63 MW and its calculated peak power loss is on the month of July with the calculated power loss of 1.70 MW. In 2019 the least power loss is recorded on the month of March with the calculated power loss of 1.59 MW and its calculated peak power loss is on the month of September and November with the calculated power loss of 2.15 MW. In 2020 the least power loss is recorded on the month of April with the calculated power loss of 2.04 MW and its calculated peak power loss is on the month of December with the calculated power loss of 2.18 MW.

5.0 CONCLUSION

The comparative analysis performs on the losses in power system distribution network in Calabar Area 1(feeder I-Esuk-Utan, Feeder II- Federal Housing, Feeder III-8 Miles) has been carryout in this work. The programming results are obtained using MATLAB software. These research reveals that, 8 miles feeder has the highest power loss in the area, following by federal housing and then Esuk-Utan feeder. These highest power loss is as a result of high irregularities, excessive increase in on the network connections without considering the key factors such as supply voltages, maximum loading on the area. The involvement of none qualified personnel in the management (work force) of the feeder also contribute to the high losses recorded. The environmental factors such as the topographical area of the places involve, the types of customers and, the environs does not permit regular supervision in the area. When comparing the average power losses per year on the three feeders from 2013 to 2017, it was reveal that Esuk-Utan has the average loss of 0.38 MW, 0.49 MW, 0.49 MW, 0.50 MW and 0.52 MW respectively.

For Federal Housing the average power losses are 0.89 MW, 0.90 MW, 0.92 MW, 0.91 MW, and 0.98 MW respectively.

And 8 Miles has the power loss of 1.63 MW, 1.62 MW, 1.65 MW, 1.86 MW, and 2.15 MW respectively.

Esuk-Utan feeder has a maximum loading of 3.0 MW, with its average power loss per year the percentages of power losses on those years involves are 12.79%, 16. 33 MW, 16.33%, 16.70% and 17.3% respectively.

Federal Housing has its maximum loading of 4.8 MW, with its average power losses per. The percentages of power loss are 18.5%, 18.75%, 19.2%, 19.0% and 20.4% respectively.

For 8 Miles feeder its maximum loading is 5.8 MW. The percentages of power losses on those years involve are 27.63%, 27.9%, 28.0%, 31.53% and 36.44% respectively.

It is concluded that a high percentage of power is being loss every year in the area, which result to the loss of resources in the system. Timely or regular periodic supervision on the network in terms of illegal connection to those area if the management want to control the losses. The cable size should also be check when a contract on power system expansion is awarded, it should be giving to qualified personnel. Critically, a high sum of money is being wasted because of losses on the network. If the percentages of the power loss is converted to kilowatt and the amount involve is too much. In all there is a level of irregularities on the network which result to the high power loss in the area (all the feeders).

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