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# Improvement of Electrical Power Reliability for Afam Community in Rivers State, Nigeria

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***ABSTRACT:*** *The reliability assessment was conducted for Afam Power Distribution System, in Oyigbo Local Government Area, Rivers State, for the purpose of adequate power supply evaluation and future expansion. For this study, 2-years period of data was acquired for this research. The Electrical Transient Analyser Program (ETAP) software was employed to model and simulate the network for validation of analysis conducted. By calculation and use of the reliability module of ETAP Software, evaluation of the 3-basic indices showed that the 11kV NEPA line as well as the Ndoki 1 (33kV line) does not experience overloading, and rate of failure is very minimal, but the Ndoki 2 (33kV line) experiences high rate of interruption compared to the other lines. The average interruption rate of the system was observed to be as low as 0.7489f/yr for Ndoki1, 0.7510f/yr for Ndoki2 and 0.7104f/yr for NEPA; the SAIFI value obtained was 0.7138f/yr after improvement was implemented on the network. However, the improvement followed method of Static VAR Compensator to improve the reactive power of the network that made the system reliable. This paper recommends addition of power transformers to the network and also the integration of Static VAR Compensator (SVC), alternatively.*

***KEYWORDS –****Electrical Power System Reliability; Distribution System Network; Static VAR Compensator; Reliability Assessment*

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## I INTRODUCTION

Electrical energy when produced is conveyed to electricity users in cities through transmission line and reliable distribution networks. Reliable power supply is of great importance in the electrical power system network. Reliability Indices suchSAIFI, CAIFI, SAIDI, CAIDI, ASAI, ASUI etc. are used to quantify the reliability of a system such as power distribution network system.These indices are statistical collections of reliability data, used as way to assess and evaluate the effectiveness of the power distribution system to supply power to the customer adequately and continually [1].

The study envisages determining the Load Point Indices and System Indices; the Load Point Indices measure the impact on the individual consumer while the System Indices measure the overall reliability of the system. For this reason, it becomes necessary to have indices that can express system failure events for a quantitative evaluation. The 3-basic indices are the failure rate ($\lambda$), outage duration ($\mu$) & annual outage time (r). These indices allow the measure of reliability at each load point to be quantified and the consumer interruption indices, which are SAIFI, CAIFI, SAIDI, CAIDI, ASAI, and ASUI to be found. These indices reflect the adequacy of overall system to supply and also indicate the system behaviour and response. Reliable electric power supply is essential for modern society, which Nigeria can be said to be one. The dependency to use of electricity has led to a high susceptibility to power failures. In line with this, reliability of power supply has gained attention and is considered highly important for electric power system planning and operation. In this paper, a state of the art technique in analytical power system reliability assessment is presented and used for a case study.

## II RELATED WORKS

Research as shown and statistics has proven, that the distribution network of a power system account for 75% to 80% of the unavailability of power and reliability problems of the system; therefore, improving the distribution network system is a vital step towards improving reliability and availability of electric power to consumers [2]. The distribution network system is relatively cheap compared to generation and transmission system; and power outages resulting from failures in the operations of the distribution network system have a much-localized effect [3-4]. On the other hand, the analysis of consumer failure statistics shows that distribution systems make the greatest impact on individual by contributing to the unavailability of consumer power supply [5-6]. Electric energy produced is delivered practically on real time and there is no convenient method to readily store in large quantity this electric energy produced, this makes it necessary to maintain a continuous and almost instantaneous balance between production and consumption of electricity in power systems [7-8].

Reliability models for distribution network considering different features such as the network equivalent, the protective devices in the network etc. [9-12] have been investigated upon. There have been works in recent time on reliability of distribution network system employing distributed generation [13-15].

Also, more recently, is the application of machine intelligent/ artificial intelligent (AI) to reliability studies of distribution network system using different forms of algorithm [16-18] to achieve more robust reliability analytical tools and systems.

## III METHODOLOGY

The methodology applied in this work is of analytical methods and simulation. Analytical technique was so employed in this work to evaluate the mean value of a wide range of system reliability indices. By means of mathematical modelling and evaluation of the reliability indices using the analytical technique, direct mathematical solutions were obtained. Due to low computation cost, short time solution in evaluating the reliability indices of the power system network of distribution, the analytical technique was selected. Adequacy in performance and reliability of the system is obtained as a result from application of this technique.

The operating life of distribution system may be represented by simple 2-state model. Service process and Repair process (λ – failure frequency & μ – repair rate). The probability of the system failure seems to be of utmost importance quality for distribution reliability. Long-run failure probability is also known as the Unavailability of the system $U_0$.

Therefore,

$$U_0 = \frac{\sum downtime}{(\sum downtime + \sum uptime)} \qquad (1)$$

Expressing the Unavailability of the system as in Equation 1 in terms of failure and repairs frequency, we have:

$$U_0 = {}^{\lambda}/_{(\lambda + \mu)} = {}^{r}/_{(m+r)} \qquad (2)$$

With $(m + r) = T$ the left hand of Equation 2 becomes:

$$r/T = F/\mu \qquad (3)$$

Where,

λ :- Failure rate = (1/$m$); μ :- Repair rate = (1/$r$); m :- failure mean time = (1/λ); r :- Repair mean time = (1/μ);
T :- Mean cycle time (m +r); F :- Cycle frequency = (1/T).

Thus from Equation 3, we have: $U_0 = F/\mu\,; \quad or F = \mu . U_0$ (4)

For Availability $U_1 of$ the system, we have:

$$U_0 = \frac{\sum uptime}{(\sum downtime + \sum uptime)} \qquad (5)$$

then,

$$U_1 = {}^{\mu}/_{(\lambda + \mu)} = {}^{m}/_{(m+r)} \qquad (6)$$

With $(m + r) = T$ the left hand of Equation 6 becomes: $U_1 = m/T = F/\lambda\,; or F = \lambda . U_1$ (7)

Where, $U_0$ – Unavailability of component (down state)
$U_1$ – Availability of component (up state)
$F$ – Cycle frequency (up or down)

It's necessary having indices that expresses system failure event on probability and frequency basis. The three basic indices, failure rate (λ), outage duration (r) and average annual outage time (U), permits a measure of reliability at each load point to be quantified and allow subsidiary indices such as the customer interruption indices to be found. Table 1 present the historical data of the system under case study.

**Table 1: Historical Data of the Sample System**

| Load Point | Cumulative Failure | Annual Downtime(hrs) | Annual Uptime(hrs) | No. of Costumers | Load Sector | Peak/Average Load (mw) |
|---|---|---|---|---|---|---|
| **NEPA** | 199 | 750 | 8010 | 667 | Residential | 1.8/1.5 |
| **NDOKI 1** | 238 | 893 | 7867 | 6783 | Residential | 2/1.9 |
| **NDOKI 2** | 257 | 3200 | 5560 | 3212 | Residential | 20/19.2 |

The case study is a radial system, therefore the reliability indices basic equation for the calculation at the various load point Y are as written:

### 3.1 Load Point Indices Calculation

**Ndoki 1 (33KV)**:
Cumulative Failure $\sum F = 238$ (for 2-yrs)
Total annual downtime $\sum T_0 = 893$
Operating time$T = (365\ days \times 24hrs) = 8760hrs.$

**Load Point Failure Rate**
To determine the failure frequency of the line, we have;

$$\boldsymbol{\lambda} = \sum {}^{F}/_{T} = {}^{238}/_{8760} = 0.0272\ (\boldsymbol{f/yr}) \quad (8)$$

**Load Point Repair Rate**
For the Repair rate of the network;

$$\boldsymbol{\mu} = {}^{T_0}/_{(\sum T_0/\sum F)} = {}^{8760}/_{(893/238)} = {}^{8760}/_{3.75} = 2334.7(\boldsymbol{repair/yr}) \quad (9)$$

**Annual Outage Duration**
To calculate the duration of the annual outage;

$$\boldsymbol{\mu_y} = {}^{\sum T_0}/_{T} = {}^{893}/_{8760} = 0.102(\boldsymbol{hr/yr}) \quad (10)$$

**Outage Duration Average**
The load point indices;

$$\boldsymbol{r_y} = {}^{\mu_y}/_{\lambda_y} = {}^{0.102}/_{0.0272} = 3.75(\boldsymbol{hrs}) \quad (11)$$

**Mean Time Before Failure**
The MTBF is determined;

$$MTBF = \sum \frac{T}{F} = \sum \frac{8760}{238} = 36.81\ hrs \quad (12)$$

**Mean Time To Repair**
We shall determine the MTTR using;

$$\boldsymbol{MTTR} = \sum \frac{T_0}{F} = \frac{893}{238} = 3.75\ hrs \quad (13)$$

**Mean Time To Failure**
For the MTTF, we have;

$$\boldsymbol{MTTF} = {}^{1}/_{\lambda} = {}^{1}/_{0.0272} = 36.76\ yr \quad (14)$$

**Ndoki 2 (33KV)**:
Cumulative Failure $\sum F = 257$ (for 2-yrs)
Total annual downtime $\sum T_0 = 3200$
Operating time$T = (365\ days \times 24hrs) = 8760hrs.$
Following same procedures as Equation (8-14), we obtain the parameters for **Ndoki 2**(33**KV**) line as;
$\lambda = 0.0293\ (\boldsymbol{f/yr})$; $\mu = 703.54\ (\boldsymbol{repair/yr})$; $\mu_y = 0.3653\ (\boldsymbol{hr/yr})$
$r_y = 12.47\ \boldsymbol{hrs}$; ***MTBF*** = 34.09 **hrs**; ***MTTR***= 12.45 **hrs**; ***MTTF*** = 34.13 **yr**

**NEPA (11KV)**:
Cumulative Failure $\sum F = 199$ (for 2-yrs)
Total annual downtime $\sum T_0 = 750$
Operating time$T = (365\ days \times 24hrs) = 8760hrs.$
Following same procedures as Equation (8-14), we obtain the parameters for **Ndoki 2**(33**KV**) line as;
$\lambda = 0.0227\ (\boldsymbol{f/yr})$; $\mu = 2323\ (\boldsymbol{repair/yr})$; $\mu_y = 0.0856\ (\boldsymbol{hr/yr})$
$r_y = 3.77\ \boldsymbol{hrs}$; ***MTBF*** = 44.02 **hrs**; ***MTTR***= 3.77 **hrs**; ***MTTF*** = 44.05 **yr**
Summary of the obtained calculated values in the above equations are given in Table 2.

**Table 2: Load Point Indices of the Sample System**

| Load Point | $\lambda_T(f/yr)$ | $r_T(hr)$ | $\mu_T(hr/yr)$ |
|---|---|---|---|
| NEPA | 0.7104 | 7.97 | 5.6654 |
| NDOKI 1 | 0.7289 | 8.10 | 5.9050 |
| NDOKI 2 | 0.7310 | 8.44 | 6.1678 |

The Global Indices: SAIFI, CAIDI, SAIDI and ASAI, are the common utility for the System Indices and can also be calculated using the Local Indices (failure rate, outage duration and annual outage duration). Table 3 gives the obtained calculated values of the Global Indices.

**Table 3: Global Indices of the System**

| Index | Value | Units |
|---|---|---|
| **SAIFI** | 0.6942 | f/cust-yr |
| **SAIDI** | 5.5576 | Hr/cust-yr |
| **CAIDI** | 8.006 | Hr/cust-int |
| **ASAI** | 99.93 | (%) |
| **ASUI** | 0.0007 | Pu |

The Cost WorthIndices: EENS, ECOST and AENS are the common distribution system reliability indices and can be calculated using the Local Indices at the load point are presented in Table 4.

**Table 4:Cost Worth Indices of the System Sample**

| Load Point | EENS (Mwh/Cust-Yr) | ECOST ($/yr) | AENS |
|---|---|---|---|
| **NEPA** | 8.4981 | 37202.02 | 0.051 |
| **NDOKI 1** | 11.2195 | 25874.57 | 0.0035 |
| **NDOKI 2** | 120.2721 | 272610.60 | 0.018 |
| **Total** | **139.9936** | **335687.19** | **0.014** |

### 3.2. Experimental details and data

The Electrical Transient Analyser Program (ETAP) software was used to model the distribution network of the Afam community. The reliability assessment module of ETAP was simulated to calculate, produce and generate output reports of the reliability indices i.e. the load point indices, the system indices and the cost worth indices. ETAP was used to run the reliability assessment of the Afam distribution network that is under study as shown in Figure 1. The Transformer T1 highlighted in pink indicating an overloaded.

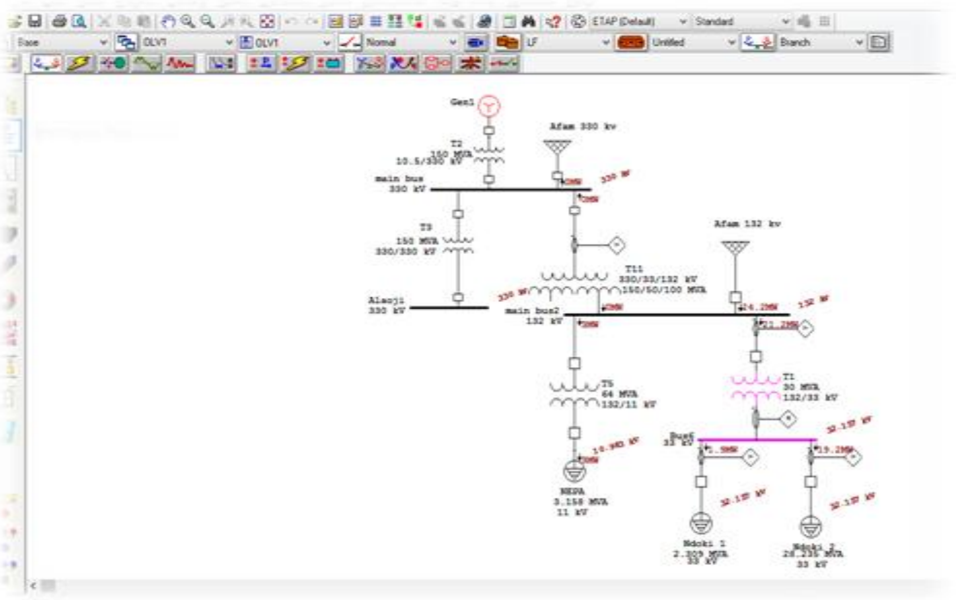


**Figure 1: Afam Community Power Distribution Network Model using ETAP**

## IV RESULTS AND DISCUSSIONS

With simulations,Figure 1 presents a network with transformer T1 been overloaded as it delivers power to Ndoki 1 and Ndoki 2 feeders. To diminish the overloading effect on the transformer system, the Static VAR Compensator is integrated into the network to compensate for the losses, and improve the reactive power of the network as shown in Figure 2.

For load point indices analysis, the basic parameters: failure rate, outage duration and average annual outage time were determined. The failure rate average of each load point is determined, and the NEPA (11kV) is the load point that offers the least failure rate, followed by Ndoki 1 (33kV). The Ndoki 2 (33kV) has the highest failure rate average, which means that Ndoki2 experiences the highest level of interruption as compared to others. This affected the cumulative failure of the line as calculated for 2-yrs. Table 5,shows the load point indices result for all load point before SVC integration into the network.

**Table 5: Load Point Output Report**

| Bus ID | Load Sector | Connected Bus ID | Avg. Interruption Rate f/yr | Avg. Outage Duartion hour | Annual Outage Duration hr/yr | EENS MWOhr/yr | ECOST $/yr | IEAR $/kW hr |
|---|---|---|---|---|---|---|---|---|
| Bus 5 | N/A | | 0.7104 | 7.97 | 5.6654 | 16.9969 | 37202.03 | 2.189 |
| Bus 6 | N/A | | 0.6939 | 8.01 | 5.5558 | 122.2251 | 268377.30 | 2.196 |
| Main Bus 2 | N/A | | 0.6597 | 3.00 | 1.9778 | 0.0000 | 0.00 | 0.000 |
| Ndoki 1 | Residential | Bus6 | 0.7289 | 8.10 | 5.9050 | 11.8080 | 25874.57 | 2.191 |
| NEPA | Residential | Bus5 | 0.7104 | 7.97 | 5.6654 | 16.9969 | 37202.02 | 2.189 |
| Ndoki 2 | Residential | Bus6 | 0.7310 | 8.44 | 6.1678 | 123.3564 | 272610.60 | 2.210 |
| Afam 132kV | None | Main Bus2 | 0.6460 | 2.22 | 1.4360 | 0.0000 | 0.00 | 0.000 |

This indices measure the impact to the individual customers. The result of this work shows that Afam experiences a very low failure rate and for this reason, the costumers should be satisfied. By the integration of Static VAR Compensator into the network, the load point indices of the lines (Ndoki1, Ndoki2, and NEPA), all were improved.

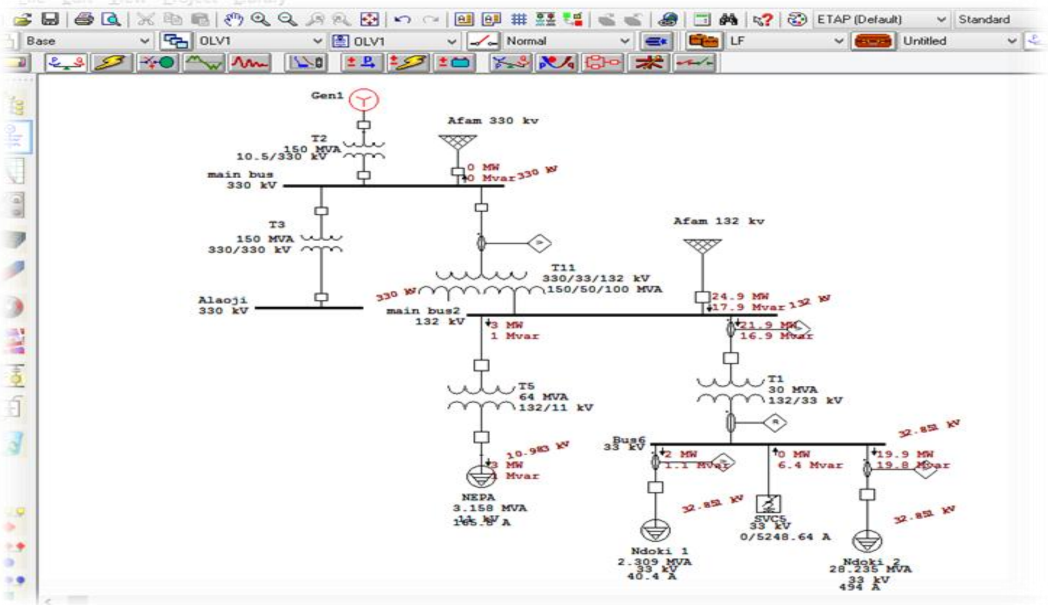


**Figure 2- An Improved Afam Community Power Distribution Flow Network using ETAP**

## V CONCLUSION

Increase in demand/consumption of electric power supply without a corresponding increase in maintenance, expansion of the network system causes setbacks economically and otherwise to the network. This work achieved the assessment and evaluation of the reliability of power distribution network system of Afam Community with the determination of the load point indices and the system indices of the network. The load point indices calculated and the result obtained showed that the Ndoki 2 (33kV) linewas more loaded than the other lines considered in the work, therefore experiences more interruption than the other lines. The system indices analysis indicated that the more the interruption, the more effect on the cost worth indices, either for every interruption, there is a cost. Result of the analysis also shows that more interruption is not healthy for our system economically. The modelled network showed that the 30MVA (T1) transformer was overloaded from analytical point of view, hence the Static VAR Compensator (SVC) was integrated into the network to compensate for the losses and improve the reactive power of the system; this improved the voltage profile of the network making the system more reliable. Both analytical method as well as simulation using ETAP gave similar results showing that Afam power distribution network could be considered reliable after the improvement has been made. The possible improvement methods therefore entail either integration of a reactive compensator, upgrade of the present transformer or addition of relief transformers to support the existing transformer in the network.

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