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# Electrical Load Flow Analysis for improved power supply to Opolo Community in Bayelsa State using ETAP

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***Abstract***
***Background:*** *Electrical load flow studies were conducted in Opolo community which is fed from Opolo feeder. This is necessary for an improved performance and efficient distribution by addressing the problems of overloading and losses thereby reducing unstable power distribution in community. The objective of this paper is to determine distribution losses and over loading of the system, investigate power system performance (transformer distribution line) under steady condition, carry out load flow analysis using Electrical Transient Analyzer Program software (ETAP).*
***Materials and Methods:*** *Materials used were collected at the Port Harcourt Electricity Distribution Company (PHEDC), Single Line Diagram of 33KV. Load flow equations were formulated, applying Newton Raphson algorithm. The line diagram was drawn to solve the Newton Raphson algorithm using ETAP.*
***Results:*** *The result shows that the transformer at market square was at critical condition with 101.4% operation, while Alamieseigha, Community Estate 1, Gloryland Hospital, Famgbe and Paulca buses were marginally operating at 97.1%, 97.5%, 97.6%, 97.2% and 97.2% respectively. Optimal Capacitor Placement was used to improve the lines. The total losses reduced from 82.8MW and 124.4MVar to 64.5MW and 96.8 MVar resulting in the load flow simulation of the network to be in normal operation.*
***Conclusion:*** *This data will help the engineer during operation and future work expansion of the network.*
***Key word:*** *Losses, load flow analysis, Newton Raphson,Optimal Capacitance Placement, ETAP, power network overloading,*

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## I. Introduction

Electricity Power is an essential commodity because it drives the economy of a nation and sustains her developmental growth [1]. Electricity supply is made up of the generating system, transmission system and distribution systems. Power generation involves the conversion of mechanical energy from various sources to electrical energy. Power transmission system is conveying a higher amount (stepped up voltage) of the generating energy (132KV or 330KV) over a long distance from the point of generation to the distribution unit. Electricity distribution involves the transfers of electrical power from the transmission system to the point of consumption. Every distribution system involves the following elements: Sub-transmission lines (primary distribution), primary distributors (feeders), substation and equipment, service area, service wire (secondary distribution), service transformer (distribution transformers), and load centers. The analysis of the impact of electricity and customers' dissatisfaction proved that the distribution system is more important and deserved a serious attention because power generated and transmitted cannot be stored.

The demand for electrical power always exceeds the supply especially in the developing countries like Nigeria, resulting to undesirable power sharing thereby causing wasteful power supply system. Generally, in Nigeria, factors contributing to inefficient and unreliable power supply apart from low power generation may include poor or ineffective voltage control system, poor transmission networks, Highly overloaded transmission feeders due to lack of planning, faulty distribution system on the part of the electrical suppliers, voltage drop along the line and from the distribution system due to the flow of current and load variations on the consumer end, damage to substation, transmission and distribution network, short circuit or overloading of electrical mains, and tripping of power system. These shortcomings over the years have resulted to unreliable and spurious voltage variations and frequent power outages. An efficient power supply system is one that seeks to overcome the above shortcomings and delivered better quality of power to local consumers and industrial users. For distribution system the power flow analysis is a very important and fundamental tool. Its results play the major role during the operational stages of any system for its control and economic schedule, as well as during expansion and design stages.

The major challenges facing power distribution in Nigeria by extension in Opolo community are: Inefficient planning of the distribution network, increase in demand due to growth and expansion without corresponding adjustment in the supply chain, attitude of power companies, losses, faults, lengthen distribution line, bad workmanship, feeder face: current & load balancing, inadequate conductors size, transformer size and selection, unequal load distribution, installation of distribution line away from load center, overloading of the substations & feeders, Abnormal condition of operation transformers, low voltage at consumers terminal causing higher drawn of current by the indicative loads. The distribution section accounts for 50% of all fault and losses in the power sector [2]. It is a known fact that the distribution system account for 75% to 80% of the unavailability and reliability problems of consumers [3].

The stability of electricity of any country is usually assessed on the system performance of her distribution sector. The generating and transmission units have tremendous impact on power availability while the distribution section is of important in power supply satisfaction and profitability. For an improved and satisfactory power supply, the power companies must have an up till date load flow analysis of their network as operational and planning tool. The distribution system power supply adequacy, standardization and reliability is determined by load flow conformity of the network because over loading of the system network leads to system breakdown.

Load flow analysis is an important exercise for the system operation. It’s use to analysis power system [4]. Load flow analysis concentrates on the power factor, that is, the phase angle of the voltage, magnitude of the voltage, the real and reactive power in each of the buses and line. These four quantities determine the load flow in distribution power system. To improve the power distribution system, there is need to maintain the balance between production and consumption. There must be an improvement in load distribution which translates to less breakdown, losses and fault elimination, availability of power to consumers. Having the fact and figure of load flowing in the network is one of the sure ways to lead power improvement hence load flow analysis serves as a planning tool for system operators. Load flow determines the stability & reliability of power system. It quantifies and mitigates losses. It’s an indicator of the system performance. Load flow analysis gives us the sinusoidal steady state condition of the full system voltage, real power and reactive power generated /consumed as well as line losses. Since the load is a static quantity of the power system, it is the complex power that flows across the transmission lines [5]. This study helps us to analyze the voltage magnitudes and angles at each bus.[6-11]. It also assists in deducing the difference between real and reactive power flows in the sending and receiving ends. The losses in a particular line can also be computed using MATLAB programming in the load flow, the real and reactive power flow constantly of each line. Furthermore, from the line flow we can also determine the over and under load conditions. The steady state power and reactive power supplied by a bus in a power network are expressed in terms of nonlinear algebraic equations.

Load flow analysis has been widely examined [12-18]. The planning, design operation and future expansion of the Opolo community power network require load flow analysis.

## II. Materials and Methods

### A. Materials

The materials used were collected at the Port Harcourt Electricity Distribution Company (PHEDC), Single Line Diagram of 33KV [16]. The Opolo feeder (33KV) is fed from the 95MVA transformer inside the 132KV transmission station in Gbarantoru. As at present, the Opolo feeder has over 204 substations and is of 37KM length. Opolo community has about 34 substations that distribute power to the community.

### B. Methods

The transformers and buses considered on the network were used to calculate the actual impedance and the admittance of each feeder on the network. The power flow equation was solved using the Newton Raphson method. ETAP was used to analyze the network. The voltage magnitude and phase angle on each substation were also analyzed.

### C. Newton-Raphson’s Method

The Gauss-Seidel iterative algorithm (technique) is very simple but convergence becomes increasingly slow as the system size grows. The Newton-Raphson’s (N.R) technique converges fast in less than four to five iterations irrespective of system size. In this thesis Newton-Raphson’s, Method will be applied in the load flow analysis

The N.R method solves the polar form of the power flow equation until the $\Delta P$ and $\Delta Q$ mismatches in all the buses fall within specified tolerance. From the knowledge of circuit theory that is Taylor’s series expansion for a function of two or more variables is the basis for the N.R method for solving the power flow problem. Starting the discussion by taking a problem involving only two equations and two variables, and then extend the analysis to the solution of power flow equation afterwards. Considering the equation of a function $h_1$ of two variables $X_1$ and $X_2$ equal to a constant $b_1$ given as

$$g_1(x_1, x_2, u) = h_1(x_1, x_2, u) - b_1 = 0 \qquad 1$$

$$g_2(x_1, x_2, u) = h_2(x_1, x_2, u) - b_2 = 0 \quad 2$$

Where,
$b_1$ and $b_2$ are constants and U is the independent control and also a constant. $g_1$ and $g_2$ are introduced for convenience to discuss the difference between the calculated the values of $h_1$ and $h_2$ and their respective specified value $b_1$ and $b_2$

For a specified value of U, we can estimate the solution of these equations to be $X_1^{(0)}$ and $X_2^{(0)}$. The zero superscripts indicate the initial estimates, $X_1^{(1)}$ and $X_2^{(1)}$ actual solution. $\Delta X_1^{(0)}$ and $\Delta X_2^{(0)}$ are the correction values to be added to $X_1^{(0)}$ and $X_2^{(0)}$ to yield the corrected solution $X_1^{(1)}$ and $X_2^{(1)}$ so that equations 1 and 2 becomes

$$g_1(X_1^1, X_2^1, U) = g_1(X_1^{(0)} + \Delta X_1^{(0)}, X_2^{(0)} + \Delta X_2^{(0)}, U) = 0 \quad 3$$

$$g_2(X_1^1, X_2^1, U) = g_2(X_1^{(0)} + \Delta X_1^{(0)}, X_2^{(0)} + \Delta X_2^{(0)}, U) = 0 \quad 4$$

The problem is to solve $\Delta X_1^{(0)}$ and $\Delta X_2^{(0)}$ and it is achieved by expanding Equations 23 and 24 in Taylor's series about the assumed solution to give

$$g_1(X_1^1, X_1^1, U) = g_1(X_1^{(0)}, X_1^{(0)}, U) + \Delta X_1^{(0)} \frac{\partial g_1}{\partial x_1} + \Delta X_2^{(0)} \frac{\partial g_1}{\partial x_2} + \ldots = 0 \quad 5$$

$$g_2(X_1^1, X_1^1, U) = g_2(X_1^{(0)}, X_1^{(0)}, U) + \Delta X_1^{(0)} \frac{\partial g_2}{\partial x_1} + \Delta X_2^{(0)} \frac{\partial g_2}{\partial x_2} + \ldots = 0 \quad 6$$

Neglecting the partial derivatives of the order greater than 1, the term $\frac{\partial g_2}{\partial x_1}$ indicates that the partial derivatives is evaluated at $X_1^{(0)}$ and $X_2^{(0)}$.

The matrix form of Equations 5 and 6 is as follow;

$$\begin{bmatrix} \frac{\partial g_1}{\partial x_1} & \frac{\partial g_2}{\partial x_2} \\ \frac{\partial g_2}{\partial x_1} & \frac{\partial g_2}{\partial x_2} \end{bmatrix} \begin{bmatrix} \Delta X_1^{(0)} \\ \Delta X_2^{(0)} \end{bmatrix} = \begin{bmatrix} 0 - g_1(X_1^1, X_2^1, U) \\ 0 - g_2(X_1^1, X_2^1, U) \end{bmatrix} = \begin{bmatrix} b_1 - h_1(X_1^{(0)}, X_2^{(0)}, U) \\ b_2 - h_2(X_1^{(0)}, X_2^{(0)}, U) \end{bmatrix} \quad 7$$

Equation 3.7 indicates square matrix called Jacobian, the zero superscript indicates the initial estimate $X_1^{(0)}$ and $X_2^{(0)}$ which is used to compute the numerical values of the partial derivatives. The mismatch $\Delta g_1^{(0)}$ is the specified value of $g_1$ minus the calculated value of $g_1$

$$J^{(0)} \begin{bmatrix} \Delta X_1^{(0)} \\ \Delta X_2^{(0)} \end{bmatrix} = \begin{bmatrix} \Delta g_1^{(0)} \\ \Delta g_2^{(0)} \end{bmatrix} \quad 8$$

We determine $\Delta X_1^{(0)}$ and $\Delta X_2^{(0)}$ by solving the mismatch equation either by triangular factorization of the Jacobian or by finding its inverse (for very small problem). However since we truncated the series expansion, these values added to our initial guess do not determine the correct solution and we must try again by assuming new estimates $\Delta X_1^{(1)}$ and $\Delta X_1^{(2)}$ where.

$$X_1^{(1)} = X_1^{(0)} + \Delta X_1^{(0)} \quad 9$$

$$X_2^{(1)} = X_2^{(0)} + \Delta X_2^{(0)} \quad 10$$

The process is repeated until the corrections become so small in magnitude that satisfy a chosen precision index $\varepsilon > 0$ i.e $|\Delta X_i|$ & $|\Delta X_2|$ are less than $\varepsilon$.

The general non-linear algebraic equations of power flow are transformed into a set of linear algebraic equations relating the changes in power (i.e. error in power) to the change in real and reactive components of bus voltages with the help of the Jacobian matrix. To apply N.R method to the solution of power flow equations, we express bus voltages and admittances in polar form. When n (i.e. no of buses) is set equal to 'I' and the corresponding terms are separated from the summations, we have

$$P_i = |V_i|^2 G_{ii} + \sum_{\substack{K=1 \\ K \neq 1}}^{N} |V_i V_k V_{ik}| \cos(\theta_{ik} + \partial_k - \partial_1)$$

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$$Q_i = -|V_i|^2 B_{ii} + \sum_{\substack{K=1 \\ K \neq 1}}^{N} |V_i V_k V_{ik}| \sin(\theta_{ik} + \partial_k - \partial_1) \qquad 12$$

$B_{ii}$ and $G_{ii}$ are the conductance and susceptance of a line joining two transmission stations. Since transmission lines connect bus (i) to another bus k which has its admittance expressed as $y_{ik}$ .

$$y_{ik} = |y_{ik}| \angle \theta_{ik} = |Y_{ik}| (\cos \theta_{ik} + j \sin \theta_{ik}) \qquad 13$$

$$Y_{ik} = G_{ik} + JB_{ik} \qquad 14$$

This gives the voltage at a particular bus (k) to be

$$V_i = |V_i| \angle \partial_i = |V_i| (\cos \partial_1 + j \sin \partial_1) \qquad 15$$

So that

$$G_{ii} = |Y_{ii}| (\cos \theta_{ii}) \qquad 16$$

$$B_{ii} = |Y_{ii}| (\sin \theta_{ii}) \qquad 17$$

$$Y_{ii} = G_{ii} + jB_{ii} \qquad 18$$

$$\partial_k = \partial_i = 0 \qquad 19$$

For i=k

For a slack bus having specified values of $V_i$ and $\delta_i$, at each of the non-slack buses, the estimated values of $V_i$ and $\delta_i$ corresponding to the estimate $\Delta X_1^{(0)}$ and $\Delta X_2^{(0)}$ in the proceeding section corresponds to the mismatch. The complex power mismatches for a typical bus (i) is giving thus;

$$\Delta P_i = P_{i,sch} - P_{i,calc} \qquad 20$$

$$\Delta Q_i = Q_{i,sch} - Q_{i,calc} \qquad 21$$

For real power P we have,

$$\Delta P_i = \frac{\partial P_i}{\partial \delta_2} \Delta \delta_2 + \frac{\partial P_i}{\partial \delta_3} \Delta \delta_3 + \frac{\partial P_i}{\partial \delta_4} \Delta \delta_4 + \frac{\partial P_i}{\partial |V_2|} \Delta |V_2| + \frac{\partial P_i}{\partial |V_3|} \Delta |V_3| + \frac{\partial P_i}{\partial |V_4|} \Delta |V_4| \qquad 22$$

$$where \quad P = j(\partial_2, \partial_3, \partial_4, V_2, V_3, V_4) \qquad 23$$

The last 3-terms can be multiplied and divided by their respective voltage magnitude without altering their values, and we obtain,

$$\Delta P_i = \frac{\partial P_i}{\partial \delta_2} \Delta \delta_2 + \frac{\partial P_i}{\partial \delta_3} \Delta \delta_3 + \frac{\partial P_i}{\partial \delta_4} \Delta \delta_4 + |V_2| \frac{\partial P_i}{\partial |V_2|} \frac{\Delta |V_2|}{|V_2|} + |V_3| \frac{\partial P_i}{\partial |V_3|} \frac{\Delta |V_3|}{|V_3|} + |V_4| \frac{\partial P_i}{\partial |V_4|} \frac{\Delta |V_4|}{|V_4|} \quad 24$$

A similar mismatch equation can be written for reactive power Q,

$$\Delta Q_i = \frac{\partial Q_i}{\partial \delta_2} \Delta \delta_2 + \frac{\partial Q_i}{\partial \delta_3} \Delta \delta_3 + \frac{\partial Q_i}{\partial \delta_4} \Delta \delta_4 + |V_2| \frac{\partial Q_i}{\partial |V_2|} \frac{\Delta |V_2|}{|V_2|} + |V_3| \frac{\partial Q_i}{\partial |V_3|} \frac{\Delta |V_3|}{|V_3|} + |V_4| \frac{\partial Q_i}{\partial |V_4|} \frac{\Delta |V_4|}{|V_4|} \quad 25$$

Equations 24 and 25 can be put into matrix form to produce the Jacobian matrix as seen in equation 26

$$\begin{bmatrix} \Delta P_2 \\ \vdots \\ \Delta P_4 \\ \cdots \\ \Delta Q_2 \\ \vdots \\ \Delta Q_4 \end{bmatrix} = \begin{bmatrix} \frac{\partial P_2}{\partial \delta_2} & \cdots & \frac{\partial P_2}{\partial \delta_4} & \vdots & \frac{\partial P_2}{\partial |V_2|} & \cdots & \frac{\partial P_2}{\partial |V_4|} \\ \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots \\ \frac{\partial P_4}{\partial \delta_2} & \cdots & \frac{\partial P_4}{\partial \delta_4} & \vdots & \frac{\partial P_4}{\partial |V_2|} & \cdots & \frac{\partial P_4}{\partial |V_4|} \\ \cdots & \cdots & \cdots & \vdots & \cdots & \cdots & \cdots \\ \frac{\partial Q_2}{\partial \delta_2} & \cdots & \frac{\partial Q_2}{\partial \delta_4} & \vdots & \frac{\partial Q_2}{\partial |V_2|} & \cdots & \frac{\partial Q_2}{\partial |V_4|} \\ \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots \\ \frac{\partial Q_4}{\partial \delta_2} & \cdots & \frac{\partial Q_4}{\partial \delta_4} & \vdots & \frac{\partial Q_4}{\partial |V_2|} & \cdots & \frac{\partial Q_4}{\partial |V_4|} \end{bmatrix} \begin{bmatrix} \partial \delta_2 \\ \vdots \\ \partial \delta_4 \\ \cdots \\ \Delta |V_2| \\ \vdots \\ \Delta |V_4| \end{bmatrix} \quad 26$$

In short form, equation 26 can be written as;

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_{11} & J_{12} \\ J_{21} & J_{22} \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \Delta [V] \end{bmatrix} \quad 27$$

This can also be written as

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} H & N \\ M & L \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \Delta [V] \end{bmatrix} \quad 28$$

The diagonal and the off-diagonal elements of are $J_{11}$

$$\frac{\partial P_i}{\partial \delta_i} = \sum_{\substack{K=1 \\ K \neq 1}}^{N} |V_i||V_k||Y_{ik}| \sin(\theta_{ik} + \delta_k - \delta_i) \quad 29$$

$$\frac{\partial P_i}{\partial \delta_k} = -|V_i||V_k||Y_{ik}| \sin(\theta_{ik} + \delta_k - \delta_i) \quad 30$$

$$k \neq i$$

The diagonal and the off-diagonal elements of are $J_{12}$

$$\frac{\partial P_i}{\partial |V_i|} = 2|V_i||Y_{ii}| \cos \theta_{ii} \sum_{\substack{K=1 \\ K \neq 1}}^{N} |V_i||V_k||Y_{ik}| \sin(\theta_{ik} + \delta_k - \delta_i) \quad 31$$

$$\frac{\partial P_i}{\partial |V_k|} = |V_i||Y_{ik}| \sin(\theta_{ik} + \delta_k - \delta_i) \quad 32$$

$$k \neq i$$

The diagonal and the off-diagonal elements of are $J_{21}$

$$\frac{\partial Q_i}{\partial \delta_i} = \sum_{\substack{K=1 \\ K \neq 1}}^{N} |V_i||V_k||Y_{ik}| \sin(\theta_{ik} + \delta_k - \delta_i) \quad 33$$

$$\frac{\partial Q_i}{\partial \delta_k} = -|V_i||V_k||Y_{ik}| \sin(\theta_{ik} + \delta_k - \delta_i) \quad 34$$

$$k \neq i$$

The diagonal and the off-diagonal elements of are $J_{22}$

$$\frac{\partial Q_i}{\partial |V_i|} = -2|V_i||Y_{ii}| \sin \theta_{ii} \sum_{\substack{K=1 \\ K \neq 1}}^{N} |V_i||V_k||Y_{ik}| \sin(\theta_{ik} + \delta_k - \delta_i) \quad 35$$

$$\frac{\partial Q_i}{\partial |V_k|} = -|V_i||Y_{ik}|\sin(\theta_{ik} + \delta_k - \delta_i) \qquad k \neq i \tag{36}$$

The term $\Delta P_i^{(k)}$ and $\Delta Q_i^{(k)}$ are the difference between the scheduled and the calculated values, known as the power mismatch (residuals), given by

$$\Delta P_i^{(k)} = P_{i,sch} - P_{i,calc} \tag{37}$$

$$\Delta Q_i^{(k)} = Q_{i,sch} - Q_{i,calc} \tag{38}$$

Then the new estimates for the bus voltages are

$$\delta_i^{(k=1)} = \delta_i^{(k)} + \Delta\delta_i^{(k)} \tag{39}$$

A. $$|V_i^{(k=1)}| = |V_i^{(D)}| + \Delta|V_i^{(k)}|$$

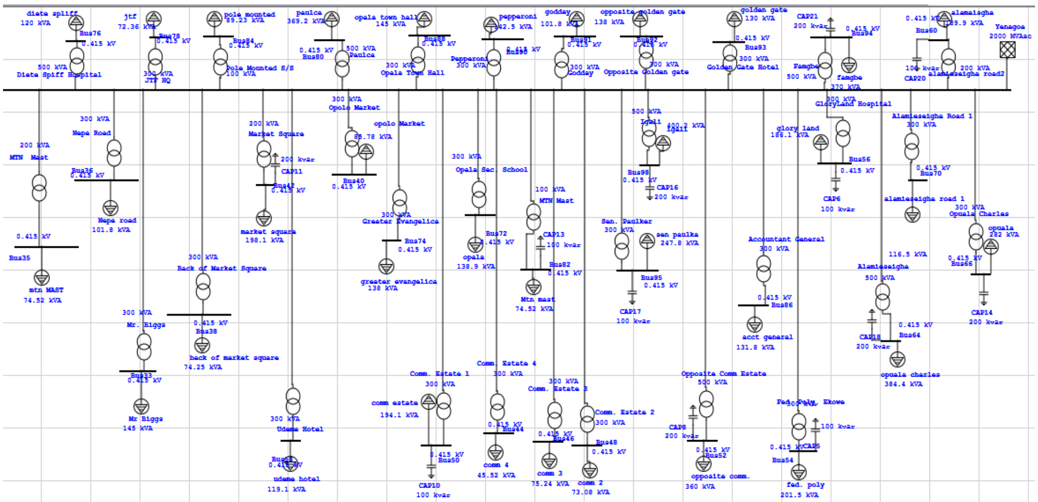

Figure 1: ETAP single line diagram for Opolo distribution line and their load capacities

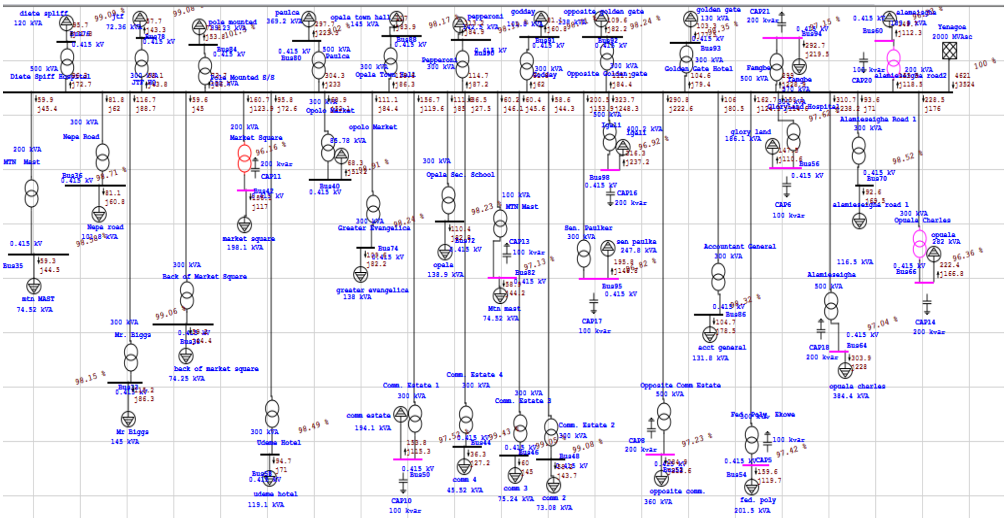

Figure 2: ETAP single line diagram for Opolo distribution line after load flow analysis

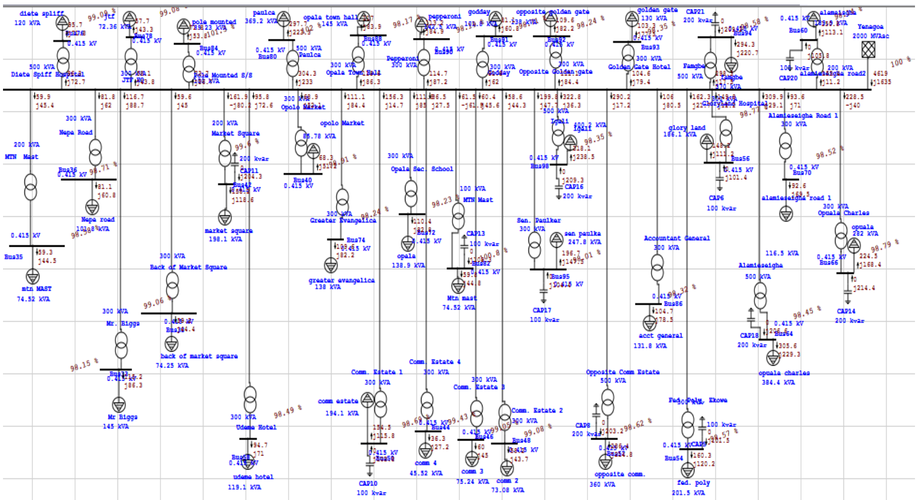

Figure 3: ETAP single line diagram for Opolo distribution line after compensation with capacitors

## III. Result

**Table 1:** Alert summary report

**(a) Critical report**

| Device Name | Type | Condition | Rating/Limit | Unit | Operating | %Operating | Phase Type |
|---|---|---|---|---|---|---|---|
| Market Square | Transformer | Overload | 0.200 | MVA | 0.203 | 101.4 | 3-Phase |

**(b) Marginal report**

| Device Name | Type | Condition | Rating/Limit | Unit | Operating | %Operating | Phase Type |
|---|---|---|---|---|---|---|---|
| Alamieseigha R2 | Transformer | Overload | 0.200 | MVA | 0.194 | 97.1 | 3-Phase |
| Market Square | Bus | Under voltage | 0.415 | kV | 0.40 | 96.2 | 3-Phase |
| Comm Estate 1 | Bus | Under voltage | 0.415 | kV | 0.40 | 97.5 | 3-Phase |
| Opposite Comm | Bus | Under voltage | 0.415 | kV | 0.40 | 97.2 | 3-Phase |
| Fed. Poly Ekowe | Bus | Under voltage | 0.415 | kV | 0.40 | 97.4 | 3-Phase |
| Gloryland Hospt | Bus | Under voltage | 0.415 | kV | 0.41 | 97.6 | 3-Phase |
| Alamieseigha R2 | Bus | Under voltage | 0.415 | kV | 0.40 | 96.3 | 3-Phase |
| Alamieseigha | Bus | Under voltage | 0.415 | kV | 0.40 | 97.0 | 3-phase |
| Opuala Charles | Bus | Under voltage | 0.415 | kV | 0.40 | 96.4 | 3-Phase |
| Paulca | Bus | Under voltage | 0.415 | kV | 0.40 | 97.2 | 3-Phase |
| MTN Mast II | Bus | Under voltage | 0.415 | kV | 0.40 | 97.1 | 3-Phase |
| PoleMounted SS | Bus | Under voltage | 0.415 | kV | 0.401 | 96.6 | 3-phase |
| Famgbe | Bus | Under voltage | 0.415 | kV | 0.40 | 97.2 | 3-Phase |
| Sen Paulker | Bus | Under voltage | 0.415 | kV | 0.40 | 96.8 | 3-Phase |
| Igali | Bus | Under voltage | 0.415 | kV | 0.40 | 96.9 | 3-Phase |
| Opuala Charles | Transformer | Overload | 0.300 | MVA | 0.29 | 96.1 | 3-Phase |

The branch losses summary report before network improvement is found in table 2

**Table 2:** Branch Losses Summary Report

| | From-To-Bus Flow | | To-From Bus Flow | | Losses | | % Bus Voltage | | Vd |
|---|---|---|---|---|---|---|---|---|---|
| Branch Name | MW | Mvar | MW | Mvar | kW | Kvar | From | To | % Drop in Vmag |
| Accountant General | 0.106 | 0.081 | -0.105 | -0.079 | 1.3 | 2.0 | 100 | 98.3 | 1.68 |
| Alamn iseigha | 0.311 | 0.238 | -0.304 | -0.228 | 6.8 | 10.2 | 100 | 97.0 | 2.96 |
| Alamieseigha Road 1 | 0.094 | 0.071 | -0.093 | -0.069 | 1.0 | 1.5 | 100 | 98.5 | 1.48 |
| Alamieseigha Road 2 | 0.154 | 0.119 | -0.150 | -0.112 | 4.2 | 6.3 | 100 | 96.3 | 3.67 |
| Back of Market Square | 0.060 | 0.045 | -0.059 | -0.044 | 0.4 | 0.6 | 100 | 99.1 | 0.94 |
| Comm Estate 1 | 0.157 | 0.120 | -0.154 | -0.115 | 2.9 | 4.3 | 100 | 97.5 | 2.48 |
| Comm Estate 2 | 0.059 | 0.044 | -0.058 | -0.044 | 0.4 | 0.6 | 100 | 99.1 | 0.92 |
| Comm Estate 3 | 0.060 | 0.046 | -0.060 | -0.045 | 0.4 | 0.6 | 100 | 99.0 | 0.95 |
| Comm Estate 4 | 0.036 | 0.027 | -0.036 | -0.027 | 0.2 | 0.2 | 100 | 99.4 | 0.57 |
| Diette Spiff Hospital | 0.096 | 0.073 | -0.096 | -0.072 | 0.6 | 1.0 | 100 | 99.1 | 0.91 |
| Famgbe | 0.299 | 0.229 | -0.293 | -0.220 | 6.3 | 9.4 | 100 | 97.2 | 2.85 |
| Fed. Poly, Ekowe | 0.163 | 0.124 | -0.160 | -0.120 | 3.1 | 4.6 | 100 | 97.4 | 2.58 |
| Gloryland Hospital | 0.150 | 0.115 | -0.147 | -0.111 | 2.6 | 4.0 | 100 | 97.6 | 2.38 |
| Godday | 0.082 | 0.062 | -0.081 | -0.061 | 0.8 | 1.2 | 100 | 98.7 | 1.29 |
| Golden Gate Hotel | 0.105 | 0.079 | -0.103 | -0.077 | 1.3 | 1.9 | 100 | 98.3 | 1.65 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Greater Evangelica | 0.111 | 0.084 | -0.110 | -0.082 | 1.4 | 2.2 | 100 | 98.2 | 1.76 |
| Igali | 0.324 | 0.248 | -0.316 | -0.237 | 7.4 | 11.1 | 100 | 96.9 | 3.08 |
| JTF HQ | 0.058 | 0.044 | -0.058 | -0.043 | 0.4 | 0.6 | 100 | 99.1 | 0.92 |
| Market Square | 0.161 | 0.124 | -0.156 | -0.117 | 4.6 | 6.8 | 100 | 96.2 | 3.83 |
| Mr. Biggs | 0.117 | 0.089 | -0.115 | -0.086 | 1.6 | 2.4 | 100 | 98.2 | 1.85 |
| MTN Mast I | 0.060 | 0.045 | -0.059 | -0.044 | 0.6 | 0.9 | 100 | 98.6 | 1.42 |
| MTN Mast II | 0.060 | 0.046 | -0.059 | -0.044 | 1.3 | 1.9 | 100 | 97.1 | 2.87 |
| Nepa Road | 0.082 | 0.062 | -0.081 | -0.061 | 0.8 | 1.2 | 100 | 98.7 | 1.29 |
| Opala Sec School | 0.112 | 0.085 | -0.110 | -0.083 | 1.5 | 2.2 | 100 | 98.2 | 1.77 |
| Opala Town Hall | 0.119 | 0.086 | -0.117 | -0.084 | 1.6 | 2.4 | 100 | 98.2 | 1.83 |
| Opolo Market | 0.069 | 0.052 | -0.068 | -0.051 | 0.6 | 0.8 | 100 | 98.9 | 1.09 |
| Opposite Comm Estate | 0.291 | 0.223 | -0.285 | -0.214 | 6.0 | 8.9 | 100 | 97.2 | 2.77 |
| Opposite Golden Gate | 0.111 | 0.084 | -0.111 | -0.082 | 1.4 | 2.2 | 100 | 98.2 | 1.76 |
| Opuala Charles | 0.229 | 0.176 | -0.222 | -0.167 | 6.2 | 9.2 | 100 | 96.4 | 3.63 |
| Paulca | 0.298 | 0.228 | -0.292 | -0.219 | 6.3 | 9.4 | 100 | 97.2 | 2.84 |
| Pepperoni | 0.115 | 0.087 | -0.113 | -0.085 | 1.5 | 2.3 | 100 | 98.2 | 1.81 |
| Pole Mounted S/S | 0.072 | 0.056 | -0.070 | -0.053 | 1.8 | 2.8 | 100 | 96.6 | 3.45 |
| Sen Paulker | 0.200 | 0.154 | -0.196 | -0.147 | 4.7 | 7.1 | 100 | 96.8 | 3.18 |
| Udeme Hotel | 0.096 | 0.073 | -0.095 | -0.071 | 1.1 | 1.6 | 100 | 98.5 | 1.51 |
| Total | | | | | 82.9 | 124.4 | | | |

To improve the Opolo community distribution lines, the kVar capacities of the various capacitors required to carry out full compensation of the network were determined. The equation for capacitor improvement is as follows

$$MVar = (MW) * (Tan\ \phi_1 - Tan\ \phi_2) \quad (40)$$

Cos $\phi_1$ is the existing power factor

Cos $\phi_2$ is the required power factor

**Table 3:** Losses comparison after compensation

| | Losses before compensation | | Losses after compensation | |
|---|---|---|---|---|
| Branch Name | kW | kVar | kW | kVar |
| Accountant General | 1.3 | 2.0 | 1.3 | 2.0 |
| Alamieseigha | 6.9 | 10.2 | 4.3 | 6.4 |
| Alamieseigha Road 1 | 1.0 | 1.5 | 1.0 | 1.5 |
| Alamieseigha Road 2 | 4.2 | 6.3 | 2.6 | 3.9 |
| Back of Market Square | 0.4 | 0.6 | 0.4 | 0.6 |
| Comm Estate 1 | 2.9 | 4.3 | 1.8 | 2.7 |
| Comm Estate 2 | 0.4 | 0.6 | 0.4 | 0.6 |
| Comm Estate 3 | 0.4 | 0.6 | 0.4 | 0.6 |
| Comm Estate 4 | 0.2 | 0.2 | 0.2 | 0.2 |
| Diette Spiff Hospital | 0.6 | 1.0 | 0.6 | 1.0 |
| Famgbe | 6.3 | 9.4 | 4.0 | 5.9 |
| Fed. Poly, Ekowe | 3.1 | 4.6 | 2.0 | 3.0 |
| Gloryland Hospital | 2.6 | 4.0 | 1.7 | 2.5 |
| Godday | 0.8 | 1.2 | 0.8 | 1.2 |
| Golden Gate Hotel | 1.3 | 1.9 | 1.3 | 1.9 |
| Greater Evangelica | 1.4 | 2.2 | 1.4 | 2.2 |
| Igali | 7.4 | 11.1 | 4.7 | 7.0 |
| JTF HQ | 0.4 | 0.6 | 0.4 | 0.6 |
| Market Square | 4.6 | 6.8 | 3.6 | 5.4 |
| Mr. Biggs | 1.6 | 2.4 | 1.6 | 2.4 |
| MTN Mast I | 0.6 | 0.9 | 0.6 | 0.9 |
| MTN Mast II | 1.3 | 1.9 | 1.7 | 2.5 |
| Nepa Road | 0.8 | 1.2 | 0.8 | 1.2 |
| Opala Sec School | 1.5 | 2.2 | 1.5 | 2.2 |
| Opala Town Hall | 1.6 | 2.4 | 1.6 | 2.4 |
| Opolo Market | 0.6 | 0.8 | 0.6 | 0.8 |
| Opposite Comm Estate | 6.0 | 8.9 | 3.7 | 5.6 |
| Opposite Golden Gate | 1.4 | 2.2 | 1.4 | 2.2 |
| Opuala Charles | 6.2 | 9.2 | 4.0 | 6.0 |
| Paulca | 6.3 | 9.4 | 6.5 | 9.8 |
| Pepperoni | 1.5 | 2.3 | 1.5 | 2.3 |
| Pole Mounted S/S | 1.8 | 2.8 | 1.9 | 2.9 |
| Sen Paulker | 4.7 | 7.1 | 3.1 | 4.7 |
| Udeme Hotel | 1.1 | 1.6 | 1.1 | 1.6 |
| Total | 82.9 | 124.4 | 64.5 | 96.8 |

**Table 4:** Voltage drop comparison after improvement

| Branch Name | Vd<br>% Drop in Vmag before compensation | Vd<br>% Drop in Vmag after compensation |
|---|---|---|
| Accountant General | 1.68 | 1.68 |
| Alamn iseigha | 2.96 | 1.55 |
| Alamieseigha Road 1 | 1.48 | 1.48 |
| Alamieseigha Road 2 | 3.67 | 1.86 |
| Back of Market Square | 0.94 | 0.94 |
| Comm Estate 1 | 2.48 | 1.31 |
| Comm Estate 2 | 0.92 | 0.92 |
| Comm Estate 3 | 0.95 | 0.95 |
| Comm Estate 4 | 0.57 | 0.57 |
| Diette Spiff Hospital | 0.91 | 0.90 |
| Famgbe | 2.85 | 1.42 |
| Fed. Poly, Ekowe | 2.58 | 1.43 |
| Gloryland Hospital | 2.38 | 1.23 |
| Godday | 1.29 | 1.29 |
| Golden Gate Hotel | 1.65 | 1.65 |
| Greater Evangelica | 1.76 | 1.76 |
| Igali | 3.08 | 1.65 |
| JTF HQ | 0.92 | 0.92 |
| Market Square | 3.83 | 0.40 |
| Mr. Biggs | 1.85 | 1.85 |
| MTN Mast I | 1.42 | 1.42 |
| MTN Mast II | 2.87 | 0.75 |
| Nepa Road | 1.29 | 1.29 |
| Opala Sec School | 1.77 | 1.77 |
| Opala Town Hall | 1.83 | 1.83 |
| Opolo Market | 1.09 | 1.09 |
| Opposite Comm Estate | 2.77 | 1.38 |
| Opposite Golden Gate | 1.76 | 1.76 |
| Opuala Charles | 3.63 | 1.21 |
| Paulca | 2.84 | 1.96 |
| Pepperoni | 1.81 | 1.81 |
| Pole Mounted S/S | 3.45 | 1.31 |
| Sen Paulker | 3.18 | 1.99 |
| Udeme Hotel | 1.51 | 1.51 |

## IV. Discussion

Table 1 also shows the buses that are experiencing under voltage and over voltage. This is shown in the table 1(a) where transformer in the market square shows the alert report being critical. The implication of the critical nature of the transformer is that if nothing is done, it will breakdown thereby putting the residents of the area in darkness. Table 1(b) shows the buses and transformer in marginal alert condition. The buses are in under voltage condition while the transformer is in over voltage condition. As a result of these conditions, compensation of the network needs to be carried out; this should put the network under working operation.

Table 3 is the losses comparison after the network improvement. The buses that were in both the marginal and critical situation losses were improved after the buses were compensation. This reduced the total losses from 82.8MW and 124.4MVar to 64.5MW and 96.8 MVar resulting in the load flow simulation of the network to be in normal operation.

The voltage drop comparison is shown in table 4 after the network has been compensated. The buses that were in both the marginal and critical situation voltage drops were improved after the buses were compensation.

## V. Conclusion

Opolo community is partly connected to Opolo feeder (33KV) and Imiringi feeder 2 (33KV). The Opolo feeder (33KV) is fed from the 95MVA transformer inside the 132KV transmission station in Gbarantoru. As at present, the Opolo feeder has over 204 substations and is of 37KM length. Opolo community has about 34 substations that distribute power to the community. Power flow analysis which is the backbone of power system analysis and design and which is necessary for planning, operation, economics scheduling and exchange of power between utilize was sued to analyze the power distribution system of the Opolo community. Power flow analysis is required for many other analyses such as transient stability, optimal power flow and contingency studies. The principal information of power flow analysis was to find the magnitude and phase angle of voltage at each bus and the real and reactive power flowing in each transmission lines. A Newton-Raphson iterative technique was employed in analyzing the power distribution of the community. Capacitor compensation was applied in correcting the low voltage as a result of the load on the buses and transformer.

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