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ENHANCEMENT OF ELECTRIC POWER SUPPLY TO ABULOMA COMMUNITY IN PORT HARCOURT FOR IMPROVED PERFORMANCE

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ABSTRACT

The improved electrical power supply to Abuloma community in Port Harcourt is a research conducted, that is necessary for the planning, operation, future expansion and improvement of the power supply via the utility in charge of electrical distribution to the area under consideration. The analysis was conducted to tackle and solve the problem of overload/over independence of transmission line station, power outages in the zone (study area), system failures and deviation between energy generating capacity and energy demand to the receiving end. A detailed survey was conducted, from which the line and bus data, transformer capacities and loadings, and the short circuit capacity of the injection substation feeding the area were obtained. The network was modeled and simulated in Electrical Transient Analyzer Program (ETAP) using Fast Decoupled Load Flow Method (FDLFM) for the purpose of improved power quality. The modeled simulated result show that buses 20, 26 and 35 in the network flagged overload marginal. Addition of appropriately sized 3800Kvar capacitor to the violated buses in other to supply the system with more reactive power. This enhances the voltage stability limits, thus drastically improving the power quality in study area. Simulation result showed that the power injected into the network via buses 1 and 2 are 0.501MVA and 0.494MVA respectively, which then increased to 0.663MVA and 0.674MVA at buses 1 and 2 respectively after the introduction of the adequately sized 3800Kvar capacitor to the violated buses.

Key word: Capacitor bank, Distribution network, Losses, Transformer, Voltage profile,

1.0 INTRODUCTION

Conventional electric power system is usually a complex infrastructure whose availability and reliability is critical to socio-economic and industrial development of any society. The major challenge facing powers system operators is Voltage instability. To a large extend, forced outages or voltage collapse experienced by operators is caused by voltage instability. According to the Nigerian National Grid (NNG) report 2018, for the past ten years, an average of thirty-five (35) forced outage or system collapse occurs in every year. Due to the constant interlinking of bulk supply occasioned by economics and environmental pressure, the power system infrastructure now currently operates closer to its stability limit. This has led to the growing concern of the challenges associated with power system dynamics stability assessment. The importance of conducting research on the dynamics of voltage collapse in power system cannot be overemphasized. This is because voltage collapse or forced outage is a result of challenge associated with power system dynamic response. Voltage collapse in power system occurs when system is over loaded occasioned by gradual decrease in voltage magnitude until it goes beyond the statutory limit or operating point. According to Amesi

(2016) voltage collapse in power system is the gradual decrease in voltage due to system over load. The aftermath is forced outage and system collapse. This has led to numerous challenges of poor power supply experienced by consumers (Sunday, 2010).

1.1 Statement of Problem

The dwelding state of transmission network (132KV up to the study case of 11KV) due to insufficient supply of power from the generating station particularly from Afam power station to the source Abuloma substation required necessary attention, on the view to conduct analysis for upgrading the transmission and distribution networks, which if not properly handled, the consequences are:

i. Overloading/over dependence of the facility
ii. Persistent Power outages in the zone (study area)
iii. System failures (generally)
iv. Deviation between energy generating capacity and energy demand to the receiving end.

1.2 Aim of Study

This research is aimed at improving the electrical power supply system to Abuloma in community, Port Harcourt. It is also targeted at providing overview of cause and effect of voltage drop experienced with a view of minimizing the effect.

1.3 Objectives of Study

The step-by-step approach in the actualization of this project shall be:

i. To acquire preliminary data from utility company (PHED)
ii. To use the data collected for modeling of the network in ETAP 12.60 software.
iii. To analyze and run simulations using Fast Decoupled Load Flow Method (FDLFM), thereby obtaining steady state operational values of the existing network.
iv. To infect an optimization technique for the improvement of the network.

2.0 LITERATURE REVIEW

The Distribution system is the last stage of power supply system and also the most noticeable segment of the power system by end-users. According to Okereafor, Idoniboyeobu, and Bala (2017) optimal delivery of uninterrupted power to the end users is a huge task. Because the distribution system is regularly faced with a high demand for power thereby is prone to system instability such as over loading. The distribution system consist of three main segments namely; primary, secondary and tertiary distribution and their voltage level are 33kV, 11kV and 0.415kV respectively. Amesi (2016)

Navpreet (2014) took a study in which a new method was eventually proposed. It was actually based on newly emerging concept of artificial intelligence principles such as the ant colony applied in achieving optimal capacitor allocation in distribution system planning. In the proposed technique, limitations such as capacitor switching transients were extensively considered and solution obtained for a system of feeders. They noted that the system capacity was release and reductions in losses are obtained.

Srividya (2013) presented a techniques used for improvement of voltage profile and loss reduction. He noted that loss sensitivity factor was used for computing the bus most suitable for capacitor placements. Similarly Dijkstra algorithm was utilized in ascertaining the true capacitor rating.

According to Legha (2013) noted that the power loss in distribution system corresponds to about 70% of total losses in electric power systems. However, he pointed out that installation of shunt capacitor banks on primary feeders of the distribution systems can improve the power factor, improve the voltage profile of the feeder, reduces system loss and increase the available capacity of feeders.

3.0 RESEARCH METHODOLOGY

The research methodology includes the following

i. Obtaining the Load and line data
ii. Representation of the Abuloma community distribution network in a single line diagram
iii. Simulation of the Abuloma community distribution network in ETAP Power station software

3.1 Data Collection

The data used for this study were collected from Port Harcourt Electricity Distribution Company (PHED).

Table:1 Load Bus Data

Substation Nominal Data				**I_R**	**I_Y**	**I_B**	**I_N**	**Calculated Load**	
Bus No	**Bus Name**	**KVA**	**kV**	**(A)**	**(A)**	**(A)**	**(A)**	**I_L (A)**	**S (KVA)**
1	King David street	500	11	250	208	200	40	232.667	167.241
2	Micheal street	500	11	198	118	208	70	198.000	142.323
3	Ozuboko road	500	11	265	352	414	128	386.333	277.697
4	Pearl avenue	300	11	415	360	450	102	442.333	317.950
5	Obinna street	300	11	410	384	512	150	485.333	348.858
6	King Jesus street	300	11	472	420	464	48	468.000	336.399
7	Emmanuel Street	500	11	304	310	308	50	324.000	232.89
8	St. Mathew street	500	11	290	280	275	35	293.333	210.848
9	Omenle Street	500	11	270	285	265	20	280.000	201.264
10	Charles Road	500	11	280	274	270	32	285.333	205.098
11	Potters Estate	300	11	290	280	275	55	300.000	315.640
12	Somitel Street	500	11	270	285	265	50	290.000	208.452
13	Omunakwa Street	500	11	280	274	270	62	295.333	212.286
14	Okabie Street	500	11	100	110	125	45	126.667	91.048
15	Amadi Street	500	11	315	360	350	75	366.667	263.560
16	Ideogu Street	500	11	198	118	208	70	198.000	142.323
17	Bakery Road	500	11	265	252	214	88	273.000	196.233
18	Osimini Street	500	11	310	384	312	100	232.667	167.241

Source: Port Harcourt Electricity Distribution Company (PHEDC)

Table 2: Line Data

Line ID	From Bus	To Bus	Impedance (Z)
1	King David street	Micheal street	0.35+j0.037
2	Micheal street	Ozuboko road	0.37+j0.039
3	Ozuboko road	Pearl avenue	0.36+j0.038
4	Pearl avenue	Obinna street	0.39+j0.041
5	Obinna street	King Jesus street	0.33+j0.035
6	King Jesus street	Emmanuel Street	0.30+j0.031
7	Emmanuel Street	St. Mathew street	0.38+j0.040
8	St. Mathew street	Omenle Street	0.37+j0.039
9	Omenle Street	Charles Road	0.32+j0.033
10	Charles Road	Potters Estate	0.35+j0.037
11	Potters Estate	Somitel Street	0.38+j0.040
12	Somitel Street	Omunakwa Street	0.33+j0.035

13	Omunakwa Street	Okabie Street	0.35+j0.037
14	Okabie Street	Amadi Street	0.34+j0.036
15	Amadi Street	Ideogu Street	0.32+j0.033
16	Ideogu Street	Bakery Road	0.35+j0.037
17	Bakery Road	Osimini Street	0.38+j0.040

Source: Port Harcourt Electricity Distribution Company (PHEDC)

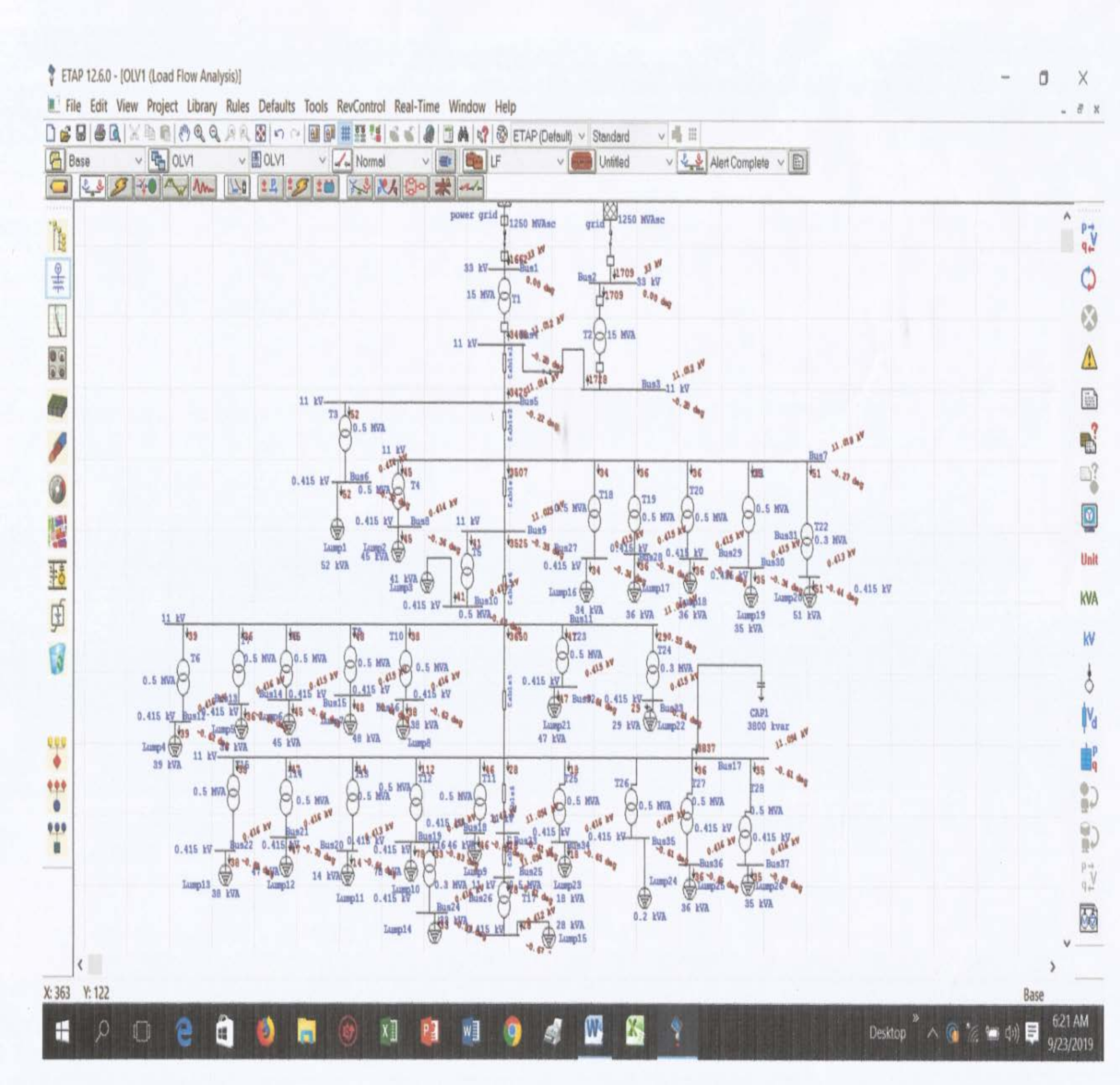

Figure 1: Abuloma community distribution network in a single line diagram

3.2 Mathematical Model

I. Determination of Load current

The average load current (I_L) is giving by

$$I_L = \frac{I_R + I_Y + I_B + I_N}{3} \tag{1}$$

Where

I_R is current in the red phase
I_Y is current in yellow phase
I_B is current in the blue phase
I_N is current in neutral

II. Determination of Line Resistance,

The line parameters collected in the study case: Abuloma community which includes:
Thus, the per-kilometer resistance, R_0 given as:

$$R_0 = \frac{1000\,\ell}{A(m^2)} \tag{2}$$

Where;
$\ell =$ Resistivity for pure aluminum = 2.826 x 10^{-8}
$l =$ Length of cable
A = cross-sectional area
d = 220mm^2

III. Determination of Line Reactance

The per-kilometer reactance,X_o is given as;

$$X_o = 0.1445\, log_{10}\left(\frac{DGMD}{R}\right) + 0.0157\Omega/Km \tag{3}$$

Where;
DGMD = 1.100m
R = 0.5 Ω

IV. Determination of Line Capacitive Susceptance

The capacitance susceptance is given as;

$$b_o = \frac{7.58}{log_{10}\left(\frac{DGND}{R}\right)} \times 10^{-6}\,\frac{1}{\Omega.\text{kmj}} \tag{4}$$

V. Determination of number of conductors per phase

$$\text{Number of conductor} = \frac{\text{Load current}}{\text{Current carrying capacity of conductor}} \tag{5}$$

VI. Determination of the voltage drop

$$V_{d_1} = \frac{\sqrt{3}\times(RCos\emptyset + \times Sin\emptyset) \times I_L \times Leng\,ht\ of\ line\ section}{No.of\ conductor\ /phase \times 100} \tag{6}$$

VII. Determination of the receiving end voltage

$$V_{R_1} = \text{Sending voltage (Vs) – Voltage drop } (V_{d_1}) \tag{7}$$

VIII. Determination of the percentage Voltage Regulation

$$\%\ \text{Voltage regulation} = \frac{V_S - V_{R_1}}{V_{R_1}} \times 100\% \tag{8}$$

XI. Newton Raphson Load Flow Method

Complex power at the *ith* node on the distribution line is given by

$$S_i = V_i I_i^* = P_i + jQ_i \tag{9}$$

$$I_i = \left(\frac{S_i}{V_i}\right)^* = \frac{P_i - jQ_i}{V_i^*}$$

(10)

$$I_i = \frac{P_i - jQ_i}{V_i^*} = \sum_{k=1}^{n} Y_{ik}\, V_k \tag{11}$$

$$P_i - jQ_i = V_i^*\left(\sum_{k=1}^{n} Y_{ik}\, V_k\right) \tag{12}$$

$$P_i - jQ_i = V_i^*\left(\sum_{k=1}^{n} Y_{ik}\, V_k \angle \delta_k + \theta_{ik} - \delta_i\right) \tag{13}$$

$$P_i - jQ_i = \sum_{k=1}^{n} |Y_{ik}||V_{\mathrm{i}}||V_{\mathrm{k}}| \left[\cos(\delta_k + \theta_{ik} - \delta_i) + j\sin(\delta_k + \theta_{ik} - \delta_i)\right] \tag{14}$$

Separating (7) into real and imaginary parts we have,

$$P_i = \sum_{k=1}^{n} |Y_{ik}||V_{\mathrm{i}}||V_{\mathrm{k}}| \cos(\delta_k + \theta_{ik} - \delta_i) \tag{15}$$

$$Q_i = -\sum_{k=1}^{n} |Y_{ik}||V_{\mathrm{i}}||V_{\mathrm{k}}| \sin(\delta_k + \theta_{ik} - \delta_i) \tag{16}$$

4.0 RESULT REPRESENTATION

Table 4.1: Active, Reactive Power (MW, MVAr, Voltage drop)

Bus ID	Power (MW)	Power (MVAR)	Voltage Drop
T1	0.429	-1.606	0.11
T2	0.436	-1.652	0.11
Cable1	0.363	-6.622	0.02
Cable 2	0.318	0.028	0.04
T3	0.044	-3.453	0.38
T4	0.613	0.024	0.07
T18	0.035	0.018	0.33
T19	0.029	0.019	0.25
T20	0.031	0.019	0.26
Cables4	0.03	0.019	0.26

Table 4.2: Active, Reactive Power (MW, MVAr, Voltage drop)

Bus ID	Power (MW)	Power (MVAR)	Voltage Drop
T5		-1.606	0.11
Cables5	0.436	-1.652	0.11
T6	0.363	-6.622	0.02
T7	0.318	0.028	0.04
T8	0.044	-3.453	0.38
T9	0.613	0.024	0.07
T24	0.035	0.018	0.33
Cable6	0.029	0.019	0.25
T11	0.031	0.019	0.26
T12	0.095	0.06	0.09

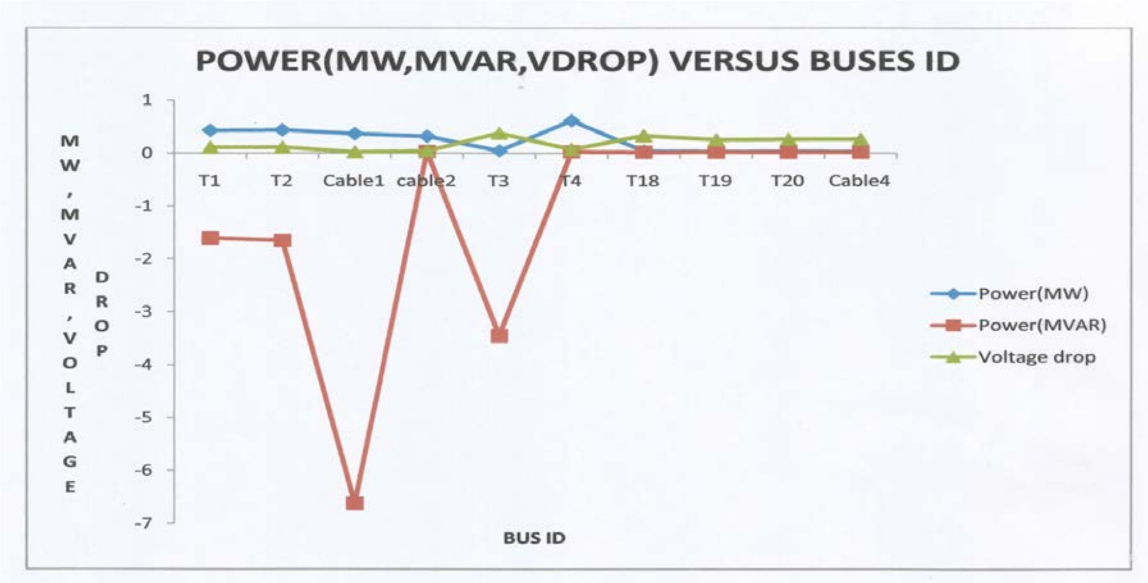

Figure 2: Plot of Active, Reactive Power (MW, MVAr, Voltage drop) for feeder 1

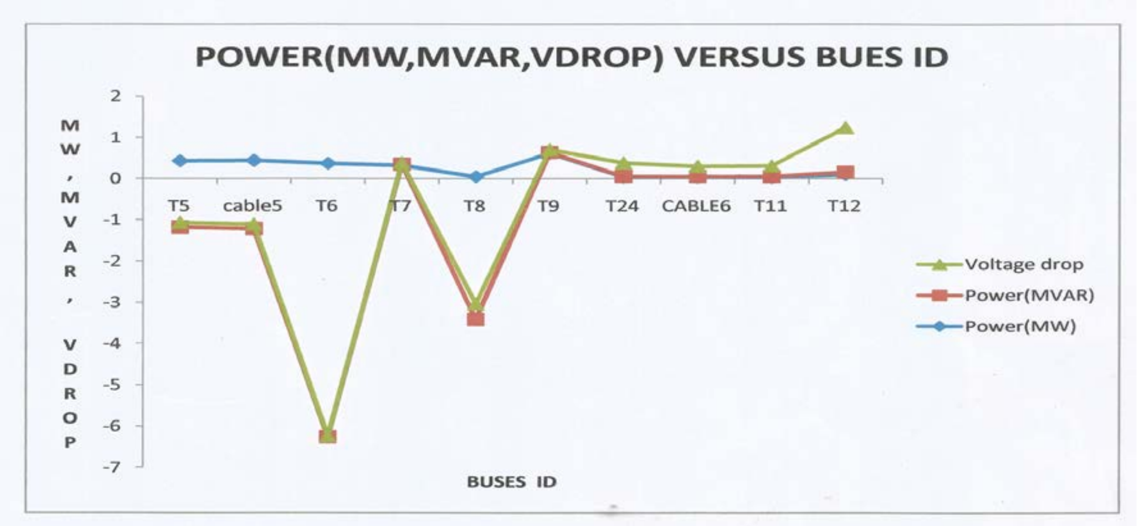

Figure 3: Plot of Active, Reactive Power (MW, MVAr, Voltage drop) for feeder 2

4.1 RESULT DISCUSSION

Power flow and voltage investigation has been carried out by modeling the existing study case at Abuloma 11KV distribution network for purpose of improved power quality. The modeled simulated results show that buses 20, 26 and 35 indicates overloads marginally which needed to be free from overload conductions.

The graph of figure 2 whose irregular believer of reactive (MVar) power supply that need to be compensated with power electronics controllers (capacitor bank with capacity 3800KVAr). While the active power flow (MW) represents some degree of irregular power to the 11KV distribution that required a support on the view of decongest some of the overloaded transformers. The voltage profile shows losses along the distribution network that needed to be minimized in order to improve power quality.

The graph of figure 3 power (MW, MVar, Vamp) Versus Bus-ID are plotted to show the distribution activities of active, reactive and voltage drop.

The voltage drop (Vdrop) profile followed the active power distribution lines. This means that excess power losses occurred on the line in a progressive, manner, that is over loaded on the network increases the need for active (MW) and reactive power (MAR) compensation which resulted into increasing voltage drop/losses.

5.0 CONCLUSION

The aim of this study is to conduct the analysis of electric power supply in Abuloma Port Harcourt Town using Power flow method, voltage equations. The network was analyzed in ETAP using the Fast-Decoupled Load Flow Method (FDLFM), from which the steady state operational values and losses were obtained. From analysis, it was seen that the problem encountered by the network were overload/over independence of transmission line station, power outages in the zone (study area), system failures and deviation between energy generating capacity and energy demand to the receiving end. Therefore, in other to optimize the performance efficiency of the 11KV distribution network system the following are recommended:

i. Addition of capacitor bank to the load buses of 20, 26 and 35 will enhance the voltage stability limits.
ii. Continually checking the load demand requirement to match existing capacity of the transformer in other to avoid overloading scenario will help the performance of the network under consideration.
iii. The reactive power load at buses 20, 26 and 35 should be increased by addition of 3800Kvar which will drastically improve the power quality in the study area.
iv. Pressure testing should be done on the feeders to correct all weak insulators, and a thorough inspection should also be done to figure all high resistance points which include all mechanical weak joints and terminations, so as to enhance proper maintenance to be done on the network.

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