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Analysis of Electrical Power Distribution Network in Tai Local Government Rivers State, for Improved Distribution.

D.C. Idoniboyeobu[1] S.L. Braide[2] D.O Amadi[3]
[1, 2&3] *(Department of Electrical Engineering, Rivers State University, Nigeria)*
Corresponding Author: Divine Amadi

ABSTRACT*: It is observed that sufficient amount of electrical power loss and low voltage profile is connected in electrical power system network particularly in the primary and secondary distribution system of electrical power supply. Distribution system is frequently in a radial configuration with long distance of feeder line and several loads connected to it. The challenges limiting distribution feeders operation are poor power factor at load end, over-loading of feeder transformers, deficient sizing of conductors, deficient power distribution from grid, etc. In this research work: Analysis of Electrical Power Distribution Network in Tai Local Government, Rivers State, for Improved Distribution, will produce possible applications in handling the above challenges. This analysis establishes that decent placement of Distributed Generation (DG), optimal location, and sizing of DG units was examined and adopted. The method utilised here is a load flow techniques and electrical distribution network under analysis is modelled in ETAP 12.6, simulation software competent of modelling and simulating power system network. The analysis is in various scenarios with results: base case load flow and formation of priority list for power loss and voltage profile; the base case without DG is 1265KW, 1957KVar; with optimal placement of DG recorded 456KW, 1059KVar; the least bus voltage recorded from the base case is 23.14KV of 33KV; and DGs at optimal placement recorded 32.54KV. There was power loss reduction from 1265KW to 456KW and a voltage improvement from 23.14KV to 32.55KV as the least voltage on a 33KV bus.*

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I. INTRODUCTION

The background of electrical energy development in Nigeria can be traced back to the end of the 19th century when the first generating power plant was installed in the city of Lagos in 1898. From this period of time to 1950, the perceptual structure of electricity development was in the form of individual electricity power undertaking, occurring all over the towns.[1]

Some of the few occurring were federal Government bodies under the public works department some by the Native Authorities. In the early 1960s, the Niger Dam Authorities (NDA) and Electricity Corporation amalgamated to become Electricity Corporation of Nigeria (ECN). [2]

The Port Harcourt Electricity Distribution Company (PHED) is a private electric distribution company that provides power to over 14 million people in 4 states of Nigeria including Rivers State, Bayelsa State, Cross Rivers State, and Akwa Ibom State. Firstly it operated as a government owned enterprise before the privatization took place in 2013, [3].

Tai is a Local Government Area (LGA), of Rivers State in Nigeria. It cloaked an area of 159km^2 and during the 2006 census its population was 117,797. It is part of the constituency of the Nigerian State [4].

II. LITERATURE REVIEWS

In recent time there have been related works where the actualisation of electrical power distribution network has been improves through means of analysis. Among remarkable works done but not limited to those listed are reviewed below.

Over view of the Nigerian generation, transmission and distribution system. The total installed capacity of currently generating plant is 7,876MW but the presently installed available capacity is less than 4,000MW. Out of the fourteen generating stations only seven are above 20years in operation and less than 4,000MW are the average power generated daily which is below the present day installed infrastructures in Nigeria. [5]

In recent time voltage stability problem have been encountered by many electrical power utilities in Nigeria. Due to the important of the sectors, the authority in charge in 2017 declared a state of emergency in the electrical power sector thus dismissed bureaucracy in the power generation, transmission and distribution sectors. [6]

In Rivers State between the years 2005-2015 the State underwent tremendous positive changes in improving the electrical power distribution system. In a paper presented in [7] like others, the planned 500MW power generation capacity by Rivers State Government through the independent power project which will be installed in various locations in the state definitely require the frame work that will guarantee the realization and sustenance of an improved/optimal system operation of this plants in order to benefit the full potentials of their design and installed capacities.

III. MATERIALS AND METHODS

A proper design plans have to be made and even in construction for future expansion capability considering the continuous demand for electric power energy before embarking into the construction proper. To speed up the progress in the future of electrical power distribution expansion proper, the initial design need to accommodate all requirements of a current long-range system forecast to add Distribution Generation (DG) system considering the increase in population of an area under electrical power supply. The rate of increase in power demand which affect the initial capacity of the substations calls for modification of the entire facilities to accommodate the additional load demand. This implies that there should be some form of flexibilities in the mechanism of the various system typically electrical distribution networks is expected to deliver power continuously and retain favourable flexibility in every level of expansion. Thus after a very careful study of this feeder the methods employed here are based on the Newton-Raphson load flow with Electrical Transient Analyser Program (ETAP). ETAP is full spectrum analytical engineering software; specialize in the analysis simulation, monitoring, control, optimization, and automation of electrical power system.

Optimal Distributed Generation (DG) **Photovoltaic Array Information:** Manufacture**r**–Q Cell, Model -QQ. BBAASSEE215-230, Type poly-crystalline #of cell 60, Size -230 Vdc 1000. Units was utilised which ensures a notable improvement in voltage profile, loss minimization in the distribution network and improves the quality of electric power supply to the consumers. [7]

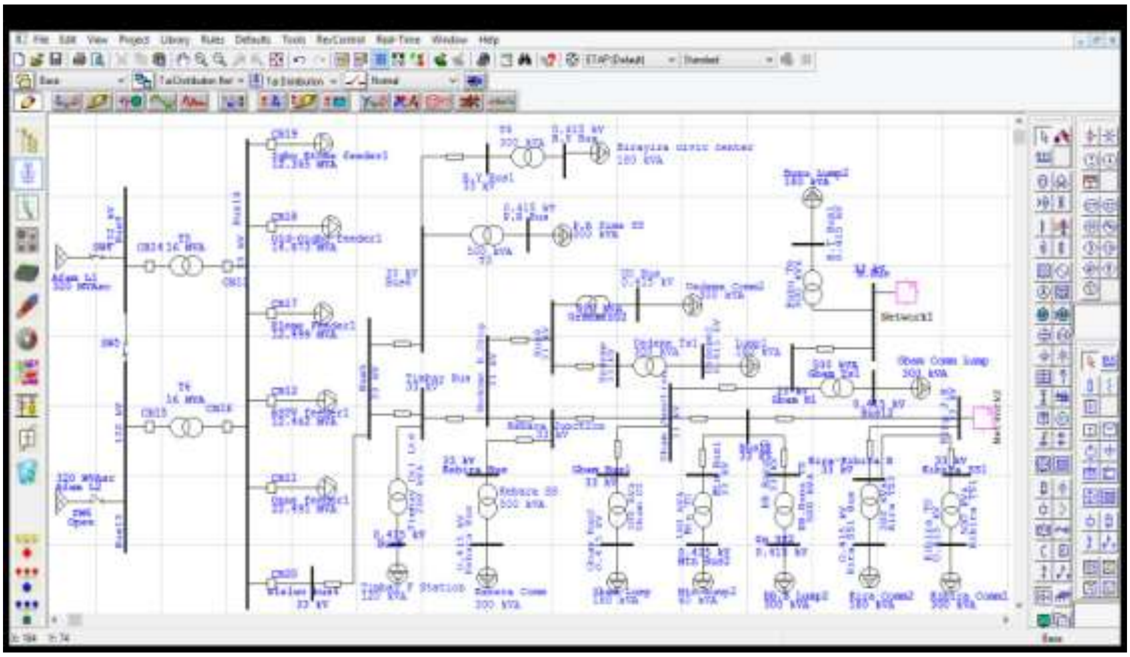


Fig 1 Electrical Distribution Network in Tai Local Government (**Base Case**)

Fig.1 shows the network layout of Tai Local Government Distribution Feeder modelled on ETAP, **Base Case without Distribution Generation Unites**). The network is one of the six feeders receiving 33KV electricity supply from the 2×60MVA Elelewo transmission station in Port Harcourt Rivers State of Nigeria, with a total length of 137.75KM and 77 branches as detailed in table 4.1 the base case simulation general information.

3.1 Line Configuration

The conductors are kept overhead and horizontally arranged. The spacing between conductors is 0.88m i.e. (AB = 0.88m, BC = 0.88m, and CA = 1.76m).

Conductor cross sectional area, A = 182mm^2 Aluminium conductor steel reinforced with galvanized (ACSR/Gz). Using phase π–model/representation of a three phase line

Where;

GMD is the geometric mean distance of conductor in m.

R. is the radius of the conductor in meters (m)

D is the distance between the adjacent conductor (D=0.88m).

G_o is the conductor of the line in Siemens

B_o is the suceptance of the line in Siemens

Radius of conductor, R = $\sqrt{\frac{A}{\prod}}m$ …. (3.1)

$$R = \sqrt{\frac{182 \times 10^{-6}}{\prod}} = 0.00761\, m \quad \text{….} \quad (3.2)$$

$$GMD = \sqrt{D_{Rr} \times D_{rB} \times D_{RB}} = 1.26 \quad \text{….} \quad (3.3)$$

$$G_{GMB} = 1.26D$$

= 1.26 x 0.88 = 1.1088m or 1.109

3.2 Resistivity of aluminium

P = 2.826 x 10^{-8} Ωm at 20°c

3.3 Per-kilometer Resistance, (R_o)

Line data for Tai feeder, 33kv distribution network

A = 182mm^2 = 182 x 10^6 $_m{}^2$

$$Ro = \frac{1000\,P}{A(10^2)} \quad \Omega/Km$$

$$= \frac{1000 \times 2.826 \times 10^{-8}\,\Omega m}{182 \times 10^{-6}\, m^2} = 0.2\frac{\Omega}{Km}$$

Considering the distance between Elelewo and Sime Bus 5 = 29km.

Thus, $r(Elelewo - Sime\, Bus5) = 0.2\frac{\Omega}{km} \times 29km = 5.8\Omega = 58\%\ resis\tan ce$

3.4 Per-kilometer reactance, (X_o)

$$X_o = 0.1445 \log_{10}\left(\frac{DGMD}{R}\right) + 0.0157\frac{\Omega}{km}$$

$$X_o = 0.1445 \log_{10}\left(\frac{1.109}{0.00761}\right) + 0.0157\frac{\Omega}{km} = 0.328\frac{\Omega}{km}$$

For 5.8km

$$X(Elelewo - SimuBuis6) = 0.328\frac{\Omega}{km} \times 29km = 9.512\Omega = 95\%\ reac\tan ce$$

$$Z(Elelewo - SimeBuis5) = 5.8 + j9.512\,\Omega = 11.14 < 58.61\% \quad impedance$$

3.5 per kilometer capacitive susceptance, (bo)

$$bo = \frac{7.58}{\log_{10}\left(\frac{DGMD}{R}\right)^{\times 10-6}} \quad 1/(\Omega km)$$

$$bo = \frac{7.58}{\log_{10}\left(\frac{1.109}{0.60761}\right)} \times 10 - 6 = 3.504 \times 10^{-6} \ {}^{1}\!\!/\!_{(\Omega km)}$$

The capacitive suceptance, b value for ElelewoBus-simeBus5(for 29km).

$= 3.504 \times 10^{-6} \times 29km = 101.616 \times 10^{-6} \ {}^{1}\!\!/\!_{(\Omega km)}$

Branch suceptance;

$$\frac{b}{2}(bus4 - Bus5) = 0.5 \times 101.6 \times 10^{-6} = j50.8 \times 10^{-6} \ {}^{1}\!\!/\!_{(\Omega km)}$$

Qc (bus 4-5) = $0.5 \times 33^2 \times 101.10^{-6}$ 55329 $\times 10^{-6}$ mvar

3.6 Per Unit Values of the line Parameters

Assume: 100MVA as Base Mva, (S_{Base})Î

33kv as Base voltage

Base Impedance $Z_b = \left(\frac{KV^2_{base}}{MVA_{base}}\right)$ (3.4)

Base Impedance $Z_b = \frac{33^2}{100} = 10.89\,\Omega$

Per unit impedance between bus 4-5

$$Z(Bus4-5)_{pu}) = \frac{0.07 + j0114\Omega}{10.89} = 10.071 + j8.51$$

Per-unit capacitive suceptance value for Bus4-5, $B_{pu(Bus4-5)}$

$$B_{Pu} = \left(\frac{Bshun + M\,\text{var}}{S_{Base}}\right)Pu \qquad (3.5)$$

$$B_{Pu} = (Bus4-5)\left(\frac{Bshun + M\,\text{var}}{S_{Base}}\right) = \frac{55329 \times 10^{-6}}{100} = 5.533 \times 10^{-3}$$

Between Base5-Base6 (paramount Ruler Sime.line) is 3.5km

$$r(Bus5-6) = 0.2\Omega\!/\!_{km} \times 3.5km = 0.7\Omega = 7\%\ resis\tan ce$$

$$Z(Bus5-6) = 0.7 + j1.148\Omega = 01.345\Omega = 13.45\%\ resis\tan ce$$

Considering the size of the network and volume of space required for calculation in this research work, the resistance and reactance on the individual branch line conductor, the attached branch losses summary report and branch connection report from ETAP simulation indicate the various % resistances, % reactance and the voltage magnitude.

IV. RESULTS AND DISCUSSION

The results of the base-case simulation of the 77 bus (from Bus4-Elelewo to Tua-tai junction Bus) distribution feeder (Tai Distribution Network) are presented in Fig. Table 4.1 shows the base-case simulation general information without DGs connection.

In line with achieving the optimal location of DGs we compare the respective ranked power losses of Table 4.7 showing sensitive in Rank1; of course the 22 locations found and integration of DG in each bus may not serve for economic purposes therefore, during integration voltages and power losses are again compared after the load flow simulation. Thus Two (2) optimal locations were found; Bus 10 (in bara community) and (korokoro community Bus). As observe from the Network after the placement of the two DGs, there was no need upgrading the 2×60MVA Transformer at elelewo Transmission station, because a very positive impact was made on the Network after the optimal placement of the DGs.

Table 4.1 General Information Result of the Base-case Load Flow (Without DG Connection)

Study ID	Load Flow Tai Feeder
Study Case ID	LF
Data Revision	Base
Diversity Factor	Normal Loading
Buses	77
Branches	77
Power Grids	1
Loads	35
Load-MW	63.048
Load-Mvar	65.453
Generation-MW	63.048
Generation-Mvar	65.453
Loss-MW	1.265
Loss-Mvar	19.57

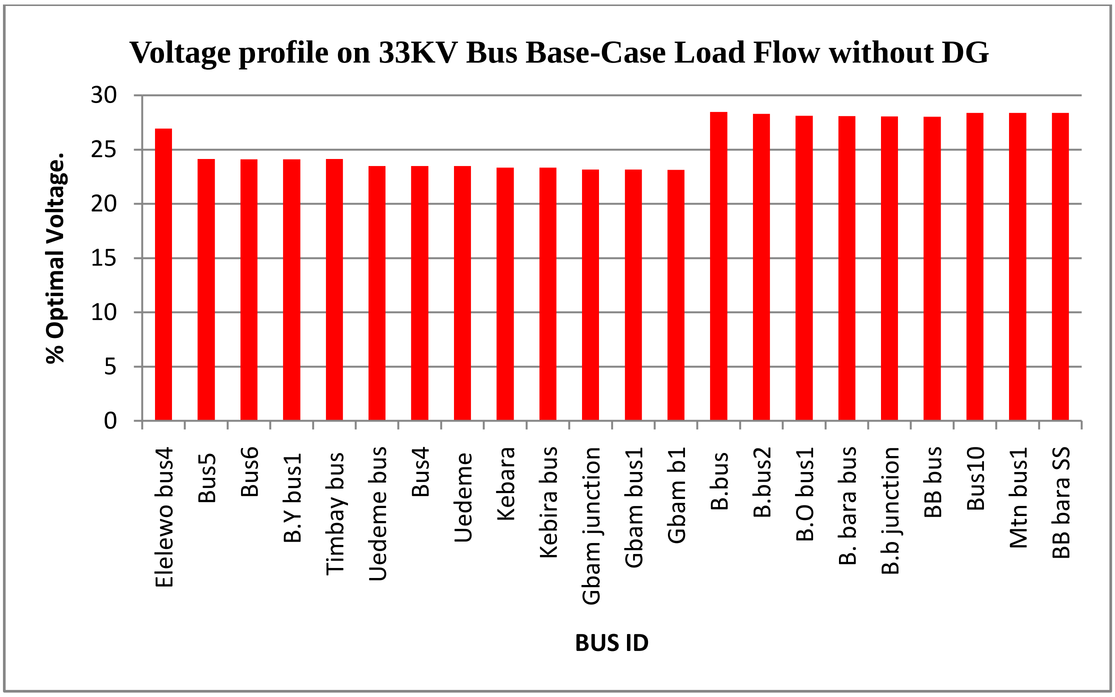


Fig 4.1 above shows the voltage profile on 33KV bus base case load flow without the placement of distributed generation, from Elelewo bus4 – BB bara SS. As seen from the fig. The busses are accompanied with

low voltage compared with the applied voltage of the system. The voltages received ranges from 23.14KV Gbam B1 – 28.38KV Kira JB of 33KV. The detail of the model network is shown in Fig 4.3. The network is accompanied with low voltage and power losses the red bar as seen from the modelled network indicate low voltage on the buses with arrows showing the direction of power flow.

The desirable DG placement is decided by many factors as shown below according to Availability of feeder section

I. Vulnerability of weather conditions
II. Space availability
III. Public willingness and interest
IV. Critical loads.

As listed above on the factors that determine the placement of distributed generation, the factor most considered here is the critical load; this factor improves the value of the location of DG as the critical load pick up is the main aim. It is decided by putting in consideration loads surrounded by the proposed DG location as seen from the ranked table above.

The ranking is done by ranging from the least of minimum power losses first as Rank1, followed by least Rank2 and vice versa. The most sensitive buses indicated by the integration of Distribution Generation (DG) at each bus falls within Rank1 and Rank2.

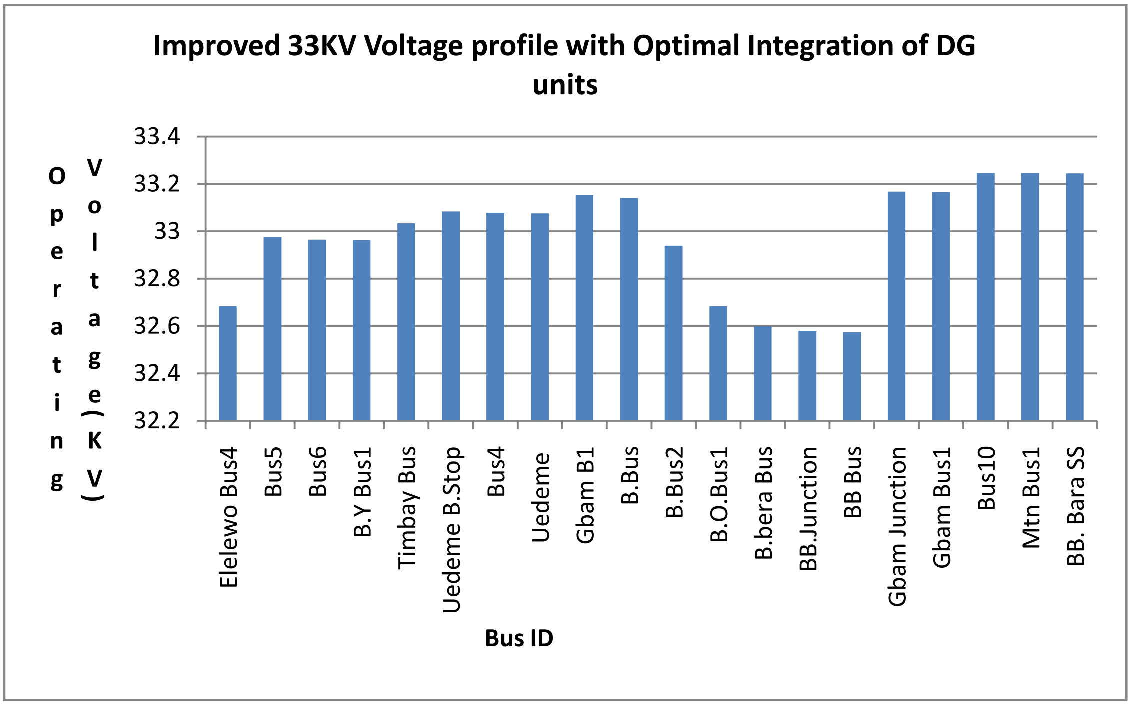
4.1.2 Optimal sizing of DG:

Considering the base case simulation result in Fig. 4.3 all the buses with indication red implies **critical** load (low voltage) at that point due to the increase in electrical demand in this area. A careful choice was made in the selection of **Photovoltaic Array** (PV Array) to suit the network and upcoming electric energy demand in the area.

Table 4.2: Improved General Information Load Flow Result (With DGs Connection)

Study ID	**Load Flow Tai Feeder**
Study Case ID	LF
Diversity Factor	Normal Loading
Buses	80
Branches	80
Power Grids	1
Loads	32
Load-MW	21.97
Load-Mvar	17.215
Generation-MW	21.97
Generation-Mvar	17.215
Loss-MW	0.456
Loss-Mvar	1.095

The table 4.2 above shows the general load flow information **With Distribution Generation Placement** on the network. In line with achieving the optimal location of DGs we compare the respective ranked power losses which shows sensitive in Rank1; of course the 22 locations was found and integration of DGs on each of these buses may not serve for economic purposes. Therefore, during integration voltages and power losses are again compared after the load flow simulation. Thus Two (2) optimal locations were found; Bus 10 in Bara community, and Korokoro community Bus. As observe from the Network table 4.2, after the placement of the two DGs, there was no need upgrading the 2×60MVA Transformer at Elelewo Transmission station to improve Tai network, because a very positive impact was made on the network after the placement of the DGs unit.



`Fig.4.2 shows the voltage profile improvement on 33KV, from Elelewo Bus4-BB.Bara SS. respectively, representing the voltage profile with optimal placement of the distributed generation units. The chart shows the bus identities with their respective improved voltage, as seen from the chart a very good improvement was achieved from the 23.14KV Gbam B1 least voltage of 33KV base case (table 4.2) to 33.14KV on B.Bus located at Bunu Tai community.

Fig 4.4 shows the improved network diagram of Tai LGA of Rivers State with optimal placement of distributed generation after simulation with Electric transient analyser program. (ETAP) 12.6.0 software, ETAP is full analytical engineering software; specialize in the analysis simulation, monitoring, control, optimization, and automation of electrical power system.

V. CONCLUSION AND RECOMMENDATIONS

Considering various approaches utilised to perfectively impact a change for improvement of electric power distribution network or system, takes stringent methods in achieving the objective of this research work the method and materials used here are technically direct, applying a load flow approach with its simulation tool to investigate the various scenarios/sections of the methodological algorithms in relation with the objective of the research work. The Tai feeder in general is among the longest and was not effective in its operational capacity due to low voltage associated at the tail end of the feeder.

Analytically with the finding, the improvement Generation was integrated to Bus10 located at Bunu community off Gbam junction and Kpite, There was a drastic improvement on the voltage profile from 27.31KV least voltage recorded (Base case Without DG placement) to 33.47KV of the nominal voltage (with the placement of DG) on the 33KV Bus. Also on the branch power losses there was a reduction and increase the net power received at the consumer's terminal. The impact of optimal placement of DG into Tai LGA Network reduces the branch power losses from (1265KW, 19570KVar) without DG to (456KW, 1095KVar). With placement of DG units

APPENDX

APPENDIX1: ANALYSIS TABLES

Fig 4.3.Electrical Distribution modelled Network for Tai Local Government Base Case **(Without DG.)** simulation result on

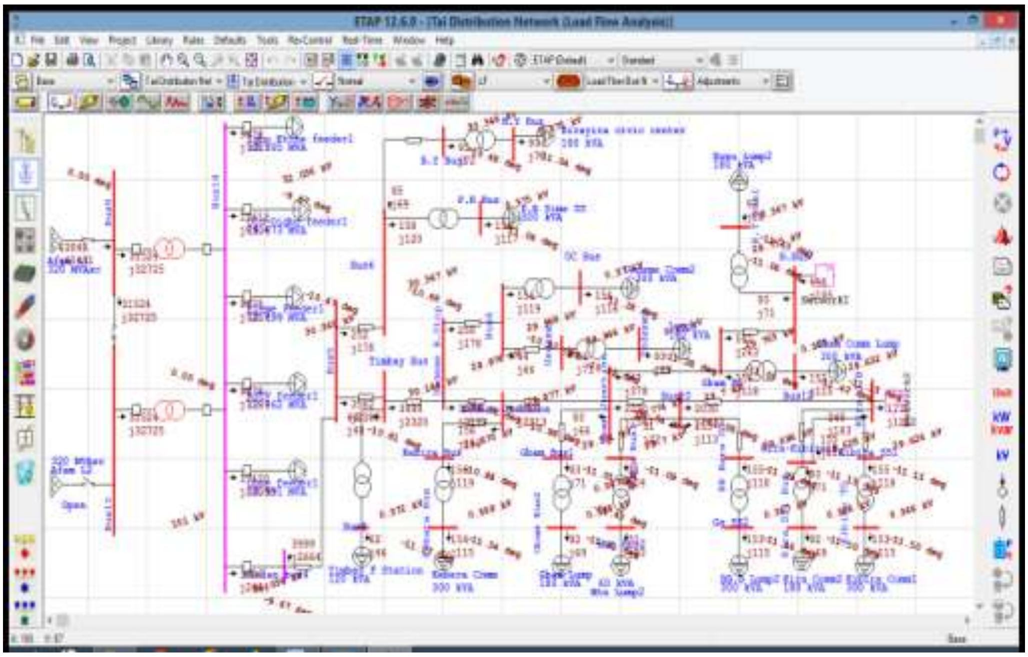


Table 4.3 Base Case Load Flow Result showing the available voltage from Elelewo Bus4 – BB Bara SS, 33KV buses.

Bus ID	Voltage kV	Deg
Elelewo Bus4	26.92	-11.47
Bus5	24.13	-13.11
Bus6	24.11	-13.13
B.Y Bus1	24.11	-13.13
Timbay Bus	24.13	-13.11
Uedeme Bus	23.49	-13.54
Bus4	23.48	-13.54
Uedeme	23.48	-13.54
Kebara	23.33	-13.65
Kebira Bus	23.33	-13.65
Gbam Junction	23.16	-13.77
Gbam Bus1	23.16	-13.77
Gbam B1	23.14	-13.78
B.Bus	28.462	-11.80
B.Bus2	28.286	-11.93
B.O Bus1	28.119	-12.08
B. Bara Bus	28.076	-12.11
B.B Junction	28.045	-12.13
BB Bus	28.037	-12.13
Bus10	28.385	-11.84
Mtn Bus1	28.384	-11.84
BB Bara SS	28.378	-11.84

Fig 4.4 Improved Electrical Distribution network diagram for Tai Local Government **(with DG)**

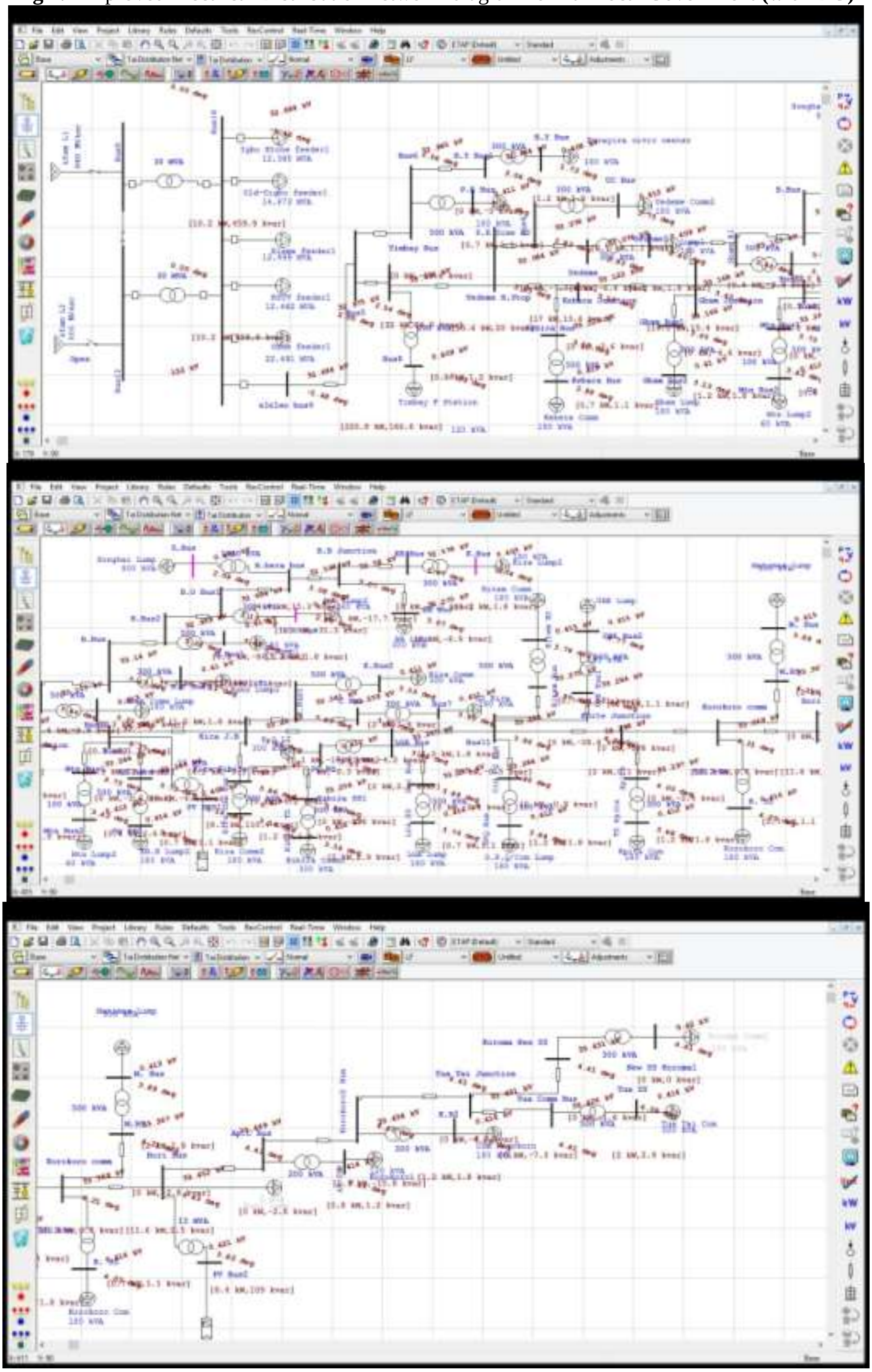


Table 4.5 Total number of transformers and sizes connected to Tai distribution network

s/no	No. of Transformer	Transformer rating
1	2	200KVA
2	12	300KVA
3	15	500KVA
4	1	100KVA
	TOTAL = 30	TOTAL = 11,600KVA

Table 4.6 Load Flow Result (**Improved** Voltage Profile with DG)

Bus ID	**Voltage KV**	**Deg**
Elelewo Bus4	32.684	-1.48
Bus5	32.975	2.05
Bus6	32.965	2.04
B.Y Bus1	32.964	2.04
Timbay Bus	33.034	2.54
Uedeme B.Stop	33.084	2.93
Bus4	33.078	2.92
Uedeme	33.076	2.92
Gbam B1	33.153	3.44
B.Bus	33.14	3.43
B.Bus2	32.939	3.28
B.O.Bus1	32.684	3.13
B.bera Bus	32.598	3.08
BB.Junction	32.58	3.07
BB Bus	32.575	3.07
Gbam Junction	33.168	3.45
Gbam Bus1	33.166	3.45
Bus10	33.246	3.73
Mtn Bus1	33.246	3.76
BB. Bara SS	33.244	3.73
Kira JB	33.26	3.86
Kira-Kibira B.	33.256	3.86
Kibira SS1	33.254	3.86
K.Bus1	33.241	3.85
C.Bus	33.239	3.85
LAG Bus	33.265	3.89
Sec Bus	33.265	3.89
Bus11	33.284	3.96
Old PQ Bus	33.284	3.96
Bitem Bus	33.275	3.95
UBE Bus1	33.284	3.96
Kpite Junction	33.298	4
Kpite	33.297	4
Korokoro Comm	33.369	4.21
M. Bs	33.367	4.21
Bori Bus	33.452	4.4
Ap.c Bus	33.449	4.42

Korokoro2 Bus	33.434	4.42
Tua tai Junction	33.431	4.41
Tua Comm Bus	33.426	4.41
Koroma New SS	33.431	4.41

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