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Evaluation of the Voltage Profile of Port Harcourt 33kv Power Distribution System.

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ABSTRACT:*Voltage profile is an imperative measure to evaluate the performance of a distribution system. Distribution apparatus and consumer appliances are sensitive to voltage variations. Low voltage will decrease performance of equipment and operating life of the equipment. A sample of 73 bus of Port Harcourt 33 kV Power distribution system is modelled and simulated in Electrical Transient Analyzer program (ETAP 12.6) software using Newton Raphson (N-R) load flow method for voltage profile evaluation. The results obtained showed that 35load busesare outside the statutory voltage constraint limit (0.95p.u – 1.05p.u) that is 31.35KV-34.65KV necessitating the need for voltage profile improvement. In this paper distributed generation (DG) units of 25 MW gas turbine power plantswere implemented on the test system. The optimal placement of the DGs is selected at the candidate load buses where voltage profile rises to acceptable limit through load flow repeated simulation. The result obtained after DG placementreveals acceptable voltage levels at the problem buses and the entire network.*

Keywords: *Distribution system, Voltage profile, Distributed Generation, load flow, Newton Raphson, ETAP.*

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I. INTRODUCTION

One of the major challenges in the distribution network is unbalanced voltage profiles. Voltage is the main parameters in terms of the quality of services provided by electricity distribution companies. Consumer appliances are designed to operate at rated voltage level and allowable lower and upper limits. If operated beyond these acceptable limits, performance of the appliances is affected and their operating life is decreased. Efficiency of power distribution is also decreased with reduced voltage.

The demand of electricity is increasing very rapidly in Port Harcourt City due to industrialization and oil exploration. The distribution network is radial. The main problem while using redial system as a distribution network is the voltage drop which distorts the voltage profile of whole network. The primary cause of reduction of system voltage is a huge amount of reactive power requirement of the load, because a large part of load is inductive. Around 13% of the generated power is wasted during transmission of power, so it is very necessary to improve voltage profile and to increase the efficiency of the network to prevent this loss of power. Newthon Raphson Load flow algorithm computes the voltage magnitudes and phase angles at each bus of the network under steady state operating conditions. These programs also compute real and reactive power in each of the line and power losses for all equipment, including transformers and distribution lines; thus overloaded transformers and distribution lines are identified and remedial measures can be implemented.The recent literatures relating to voltage profile evaluation in distribution system are:

Okereafor et al.(2017)carried out a load flow analysis of 33/11KV RSU Injection Substation using ETAP 7.0 software for improved performance usingDistributed Generation (DG) Units to cushion the drawback related to power losses and low voltage profile.The analysis ensured that adequate placement of DG and optimum size is investigated and adopted, however,injection substation transformers' are also upgraded for adequate power flow without overloading thetransformers.

Nagireddy et al.(2016) presents a Particle Swarm Optimization algorithm, to calculate the optimum DGs size and location in radial utility distribution system to voltage profile improvement and to reduce losses. The integration of multiple DGs to distribution system with active and reactive power generation with optimal location and size reduces the system real losses and improves voltage profiles. As DGs can generate and supply a partial reactive and real power to the local loads, hence the voltage profiles throughout distribution system feeders are improved.

Sahito et al.(2016) carried out simulation analysis of 11 kV radial distribution feeder for DG impacts on voltage profile using PSS SINCAL software . Node voltages of existing network were observed below acceptable lower limit of -5% of rated voltage. Three DG units, each of 1 MW, are proposed to meet demands locally. Simulation results of the proposed network show considerable improvement in node voltages of both H.T and L.T networks. Node voltages are improved to lie within acceptable limit.

Idoniboyeobu et al. (2017) conducted a load flow study for Port Harcourt Town(Z4) 10 bus/9 feeder 33kv power distribution network using Newton Raphson Fast decoupled Technique. From the simulation results, more power is required from the grid to the injection substations via Port Harcourt Town (Z4) control transmission substation. In the absence of adequate power supply from the grid network to the transmission substation down to the distribution injection substations, load shedding becomes the only option.

Amesi et al.(2017) examined the power flow status of Port Harcourt town (Zone 4) distribution networks using Gauss – Seidel method. The research was aimed at network reconfiguration for improved performance.

Uhunmwangho et al. (2017) carried out a study of hourly voltage log taken over a period of six months from Rumuola Distribution network Port Harcourt, Rivers State. The research indicated that power quality problems prevalent in the Network are under voltage/voltage sags and over voltage/voltage swells.

Kumar et al. (2016) implemented the PSO approach to improve the voltage profileby optimizing the location of capacitor and to find its size. This test has been performed on the IEEE 33-bus and 66-busradial distribution system which is designed with the use of MATLAB Software. The maximum number of capacitor unitsappropriate for the improvement for voltage profile was considered.

II. DESCRIPTION OF THE SAMPLED 73 BUS PORT HARCOURT POWER DISTRIBUTION SYSTEM

Port Harcourt is the capital city of Rivers State located in the south-south geopolitical zone of Nigeria. The city plays host to so many public and private organizations, including multinational oil companies. Port Harcourt receives power supply from Afam transmission station via a 132kV double circuit transmission line duly linked to the national grid at Alaoji-Afam transmission station.

Port Harcourt consists of four main transmission stations namely; Port Harcourt Main (Zone 2), Port Harcourt Town (Zone 3), Elelewo and Rumuosi

Data For The Work

The data and diagrams collected include:

- Acquisition of line data, bus data, hourly load readings of the distribution feeders.
- Installed capacity of transmission substations, injection substations, power rating of distribution transformers connected to the injection substations and their ratings.
- Port Harcourt Power Distribution network diagram.
- Software’s (MATLAB, ETAP)

The data for this work is obtained from the log books and up to date records of the Port Harcourt Electricity distribution company (PHEDC), Transmission Company of Nigeria, Rumuobiakani, Afam Power plants, and also from the independent power producers (IPP’S) operating Omoku and Trans Amadi gas turbine power plants.

Verbal interaction and oral consultationwas also carried out with the most senior and principal Engineers of both the staff of Afam Power plant, Omoku gas turbine, Trans Amadi gas turbine and PHEDC. This interview gave an in-depth knowledge on the current state of the Port Harcourt Power distribution network and the distributed generation. These data are shown below.

Table 3.1 Line Data For Port Harcourt Power Distribution Network

FROM	TO	FROM BUS	TO BUS	LENGTH (KM)	CIRCUIT TYPE	R(P.U)	X(P.U)	B (P.U)
AFAM	PH MAIN (PHZ2)	1	2	36.80	DC	0.0394	0.014	0.167
AFAM	PH TOWN (PHZ4)	1	3	42.0	DC	0.0394	0.014	0.167
AFAM	ELELEWO (EL)	1	4	20.0	DC	0.0394	0.014	0.167
PHZ2	RUMUOSI (RU)	2	5	25.7	DC	0.0394	0.014	0.167
PHZ2	TIA (Z2)	2	6	0.42	DC	0.0394	0.0017	0.206
PHZ2	T2A (Z2)	2	7	0.42	DC	0.0394	0.0017	0.206
PHZ2	T3A (Z2)	2	8	0.42	DC	0.0394	0.0017	0.206
PHZ4	T1A (Z4)	3	9	0.30	DC	0.0394	0.0017	0.206
PHZ4	T2A (Z4)	3	10	0.30	DC	0.0394	0.0017	0.206
PHZ4	T2B (Z4)	3	11	0.30	DC	0.0394	0.0017	0.206
EL	T1(EL)	4	12	0.30	DC	0.0394	0.0017	0.206
EL	T2 (EL)	4	13	0.30	DC	0.0394	0.0017	0.206
RU	T1(RU)	5	14	0.30	DC	0.0394	0.0017	0.206
RU	T2(RU)	5	15	0.30	DC	0.0394	0.0017	0.206
TIA (Z2)	OYIGBO	6	16	11.71	DC	0.0394	0.0017	0.206
TIA (Z2)	RUMUODUMAYA	6	17	49.25	DC	0.0394	0.0017	0.206
TIA (Z2)	ABULOMA	6	18	11.40	DC	0.0394	0.0017	0.206
T1A (Z2)	WOJI	6	19	4.65	DC	0.0394	0.0017	0.206
T2A (Z2)	TRANS AMADI (RSPUB)	7	20	8.19	DC	0.0394	0.0017	0.206
T2A (Z2)	RAINBOW	7	21	5.8	DC	0.0394	0.0017	0.206
T3A (Z2)	GOLDEN LILY(RUMUOLA)	8	22	35.32	DC	0.0394	0.0017	0.206
T3A (Z2)	AKANI	8	23	0.22	DC	0.0394	0.0017	0.206
T3A (Z2)	OLD AIRPORT	8	24	187.98	DC	0.0394	0.0017	0.206
TIA (Z4)	SILVERBIRD	9	25	3.50	DC	0.0394	0.0017	0.206
TIA (Z4)	UTC	9	26	3.00	DC	0.0394	0.0017	0.206
T1A (Z4)	BOLOKIRI	9	27	11.04	DC	0.0394	0.0017	0.206
TIA (Z4)	RUMUOLUMENI	9	28	12.3	DC	0.0394	0.0017	0.206
T2A (Z4)	UST	10	29	15.15	DC	0.0394	0.0017	0.206
T2B (Z4)	SECRETARIAT	11	30	151.24	DC	0.0394	0.0017	0.206
T1(EL)	ELEME	12	31	65.4	DC	0.0394	0.0017	0.206
TI(EL)	IGBO ETCHE	12	32	9.0	DC	0.0394	0.0017	0.206
T1(EL)	IRIEBE	12	33	70.0	DC	0.0394	0.0017	0.206
T2 (EL)	BORI	13	34	60	DC	0.0394	0.0017	0.206
T2 (EL)	RSTV(ELELEWO)	13	35	50.0	DC	0.0394	0.0017	0.206
T2 (EL)	BRISTLE	13	36	20	DC	0.0394	0.0017	0.206
T1(RU)	NEW AIRPORT	14	37	38	DC	0.0394	0.0017	0.206
T1 (RU)	RUKPOKWU	14	38	15	DC	0.0394	0.0017	0.206
T2 (RU)	NTA	15	39	5	DC	0.0394	0.0017	0.206
T2 (RU)	UPTH	15	40	4.0	DC	0.0394	0.0017	0.206
OYIGBO FDR	AWETO GUEST HOUSE	16	41	7.19	DC	0.0394	0.0017	0.206
OYIGBO FDR	SHELL RES	16	42	8.5	DC	0.0394	0.0017	0.206
RUMUODUMAYA FDR	AGIP/ OKPORO	17	43	35.6	DC	0.0394	0.0017	0.206
RUMUODUMAYA FDR	UNIPORT	17	44	55.6	DC	0.0394	0.0017	0.206
RUMUODUMAYA FDR	CHOBA	17	45	55.6	DC	0.0394	0.0017	0.206
ABULOMA FDR	STALLION PHASE 2	18	46	2.0	DC	0.0394	0.0017	0.206
ABULOMA FDR	GULF ESTATE	18	47	5.0	DC	0.0394	0.0017	0.206
TRANS AMADI (RSPUB) FDR	FIRST ALLUMINIUM	20	48	2.46	DC	0.0394	0.0017	0.206
TRANS AMADI (RSPUB) FDR	ELF NIG	20	49	4.1	DC	0.0394	0.0017	0.206
TRANS	BEKEMS PROPERTY	20	50	5.8	DC	0.0394	0.0017	0.206

AMADI (RSPUB) FDR								
TRANS AMADI (RSPUB) FDR	TRANS AMADI GARDENS	20	51	8.19	DC	0.0394	0.0017	0.206
TRANS AMADI (RSPUB) FDR	GALBA	20	52	60	DC	0.0394	0.0017	0.206
TRANS AMADI (RSPUB) FDR	RIVOC	20	53	5.8	DC	0.0394	0.0017	0.206
TRANS AMADI (RSPUB) FDR	AIR LIQUID	20	54	8.19	DC	0.0394	0.0017	0.206
TRANS AMADI (RSPUB) FDR	STALLION 1	20	55	6.2	DC	0.0394	0.0017	0.206
TRANS AMADI (RSPUB) FDR	OIL INDUSTRY	20	56	7.0	DC	0.0394	0.0017	0.206
TRANS AMADI (RSPUB) FDR	ONWARD FISHERY	20	57	9.70	DC	0.0394	0.0017	0.206
RAINBOW FDR	ELEKAHIA	21	58	7.0	DC	0.0394	0.0017	0.206
RUMUOLA FDR	SHELL. INDUSTRIAL	22	59	5.2	DC	0.0394	0.0017	0.206
RUMUOLA FDR	PRESIDENTIAL HOTEL	22	60	21.0	DC	0.0394	0.0017	0.206
OLD AIRPORT FDR	ENEKA	24	61	30.0	DC	0.0394	0.0017	0.206
OLD AIRPORT FDR	BIG TREAT	24	62	35.0	DC	0.0394	0.0017	0.206
SILVERBIRD	SHELL KIDNEY ISLAND	25	63	0.3	DC	0.0394	0.0017	0.206
UTC FDR	WATER WORKS	26	64	6.0	DC	0.0394	0.0017	0.206
BOLOKIRI FDR	EASTERN BYPASS	27	65	9.0	DC	0.0394	0.0017	0.206
RUMUOLUMENI FDR	SCHOOL OF NURSING	28	66	29.5	DC	0.0394	0.0017	0.206
RUMUOLUMENI FDR	U.O.E	28	67	20.5	DC	0.0394	0.0017	0.206
RUMUOLUMENI FDR	NAVAL BASE	28	68	32.8	DC	0.0394	0.0017	0.206
RUMUOLUMENI FDR	MASTER ENERGY	28	69	4.3	DC	0.0394	0.0017	0.206
UST	AGIP HOUSING ESTATE	29	70	5.0	DC	0.0394	0.0017	0.206
UST	NAOC AGIP BASE	29	71	3.2	DC	0.0394	0.0017	0.206
SECRETARIAT	JUANUTA	30	72	35.6	DC	0.0394	0.0017	0.206
SECRETARIAT	MARINE BASE	30	73	7.0	DC	0.0394	0.0017	0.206

Source: Port Harcourt electricity distribution company (PHEDC)

TABLE 3.2 BUS DATA FOR PORT HARCOURT POWER DISTRIBUTIONNETWORK (73 BUS NETWORK)

BUS NO	BUS NAME	BUS TYPE	V(P.U)	PHASE (DEQ)	P(MW)	Q(MVAR)
1	AFAM	1	1.00	0.00	150.0	0.00
2	PH MAINS (PHZ2)	2	1.00	0.00	70.0	0.00
3	PH TOWN (PHZ4)	2	1.00	0.00	75.0	0.00
4	ELELEWO (EL)	2	1.00	0.00	45.0	0.00
5	RUMUOSI (RU)	2	1.00	0.00	30.0	0.00
6	TIA(Z2)	3	0.00	0.00	30.5	18.3
7	T2A(Z2)	3	0.00	0.00	39.8	23.9
8	T3A(Z2)	3	0.00	0.00	46.6	28.0
9	TIA(Z4)	3	0.00	0.00	34.5	20.7
10	T2AZ4)	3	0.00	0.00	21.2	12.7
11	T2B(Z4)	3	0.00	0.00	28.9	17.3
12	TI(EL)	3	0.00	0.00	31.6	19.0
13	T2(EL)	3	0.00	0.00	32.0	19.2
14	T1(RU)	3	0.00	0.00	30.0	18.0
15	T2(RU)	3	0.00	0.00	31.2	18.7
16	OYIGBO	3	0.00	0.00	12.2	7.6
17	RUMUODUMAYA	3	0.00	0.00	24.0	14.9
18	ABULOMA	3	0.00	0.00	9.7	6.0
19	WOJI	3	0.00	0.00	10.8	6.7
20	TRANS AMADI	3	0.00	0.00	29.5	18.3
21	RAINBOW	3	0.00	0.00	17.3	10.7
22	GOLDEN LILY(RUMUOLA)	3	0.00	0.00	18.2	11.3
23	AKANI	3	0.00	0.00	14.9	9.2
24	OLD AIRPORT	3	0.00	0.00	21.8	13.5
25	SILVERBIRD	3	0.00	0.00	16.0	9.9
26	UTC	3	0.00	0.00	10.8	6.7
27	BOLOKIRI	3	0.00	0.00	9.8	6.1
28	RUMUOLUMENI	3	0.00	0.00	13.8	8.6
29	UST	3	0.00	0.00	22.8	7.9
30	SECRETARIAT	3	0.00	0.00	16.2	10.04
31	ELEME	3	0.00	0.00	20.3	12.6
32	IGBO ETCHE	3	0.00	0.00	26.6	16.5
33	IRIEBE	3	0.00	0.00	8.9	5.5
34	BORI	3	0.00	0.00	11.4	7.1
35	RSTV (ELELEWO)	3	0.00	0.00	18.5	11.5
36	BRISTLE	3	0.00	0.00	10.8	6.7
37	NEW AIRPORT	3	0.00	0.00	20.9	13.0
38	RUKPOKWU	3	0.00	0.00	12.1	7.5
39	NTA	3	0.00	0.00	18.0	11.2
40	UPTH	3	0.00	0.00	13.6	8.4
41	AWETOGUEST HOUSE	3	0.00	0.00	10.1	6.3
42	SHELL RES	3	0.00	0.00	12.4	7.7
43	AGPIP/ OKPORO	3	0.00	0.00	11.2	6.9
44	UNIPORT	3	0.00	0.00	10.0	6.2
45	CHOBA	3	0.00	0.00	6.5	4.0
46	STALLION PHASE 2	3	0.00	0.00	8.9	5.5
47	GULF ESTATE	3	0.00	0.00	7.4	4.6
48	FIRST ALLUMINIUM	3	0.00	0.00	10.6	6.6
49	ELF NIG	3	0.00	0.00	12.0	7.4
50	BEKEMS PROPERTY	3	0.00	0.00	10.5	6.5
51	TRANS AMADI GARDENS	3	0.00	0.00	11.4	7.1
52	GALBA	3	0.00	0.00	10.9	6.8
53	RIVOC	3	0.00	0.00	12.3	7.6
54	AIR LIQUID	3	0.00	0.00	10.5	6.5
55	STALLION 1	3	0.00	0.00	13.4	8.3
56	OIL INDUSTRY	3	0.00	0.00	12.2	7.6
57	ONWARD FISHERY	3	0.00	0.00	13.8	8.6
58	ELEKAHIA	3	0.00	0.00	14.8	9.2
59	SHELL. INDUSTRIAL	3	0.00	0.00	13.8	8.6
60	PRESIDENTIAL HOTEL	3	0.00	0.00	10.7	6.6
61	ENEKA	3	0.00	0.00	7.9	4.9
62	BIG TREAT	3	0.00	0.00	8.7	5.4
63	SHELL KIDNEY ISLAND	3	0.00	0.00	5.2	3.3
64	WATER WORKS	3	0.00	0.00	3.8	2.4
65	EASTERN BYPASS	3	0.00	0.00	11.6	7.2
66	SCHOOL OF NURSING	3	0.00	0.00	3.7	2.3

67	U.O.E	3	0.00	0.00	13.2	8.2
68	NAVAL BASE	3	0.00	0.00	10.1	6.3
69	MASTER ENERGY	3	0.00	0.00	7.9	4.9
70	AGIP HOUSING ESTATE	3	0.00	0.00	8.8	5.5
71	NAOC AGIP BASE	3	0.00	0.00	9.8	6.1
72	JUANUTA	3	0.00	0.00	11.0	6.8
73	MARINE BASE	3	0.00	0.00	8.7	5.4

Source: Port Harcourt Electricity Distribution Company (PHEDC)
Key: 1 (Slack bus)
2 (PV bus)
3 (PQ bus)

III. METHODOLOGY

The methodology adopted in this paper involves are :

i. Modelling of 73 bus network of 33kV Port-Harcourt power Distribution Network using Electrical Transient Analyzer Program (ETAP 12.6) software for load flow analysis.
ii. Steady state assessment of the network through load flow Analysis using Newton-Raphson (N-R) method.

Newton Raphson load flow will be simulated in ETAP software. This will be used to come up with the candidate buses for DG placement.

4.1 Newton Raphson(N-R) Methodfor Load Flow Studies In Port Harcourt Power Distribution System

Newton Raphson (NR) method is an iterative technique for solving a set of simultaneous non-linear equations in an equal number of unknowns and can be generally formulated in either the rectangular form or the polar form. The polar co-ordinate form is widely used in practice because it results in a smaller number of equations than the total number of equations involved in rectangular form. The N- R method needs less number of iterations to reach convergence, takes less computer time hence computational cost is less and the convergence is certain. It is more accurate, and insensitive to factors like slack bus selection, regulating transformers etc. The number of iterations required in this method is independent of the power system network size.

Newton Raphson Load flow programs compute the voltage magnitudes and phase angles at each bus of the network under steady state operating conditions. These programs also compute real and reactive power in each of the line and power losses for all equipment, including transformers and distribution lines; thus overloaded transformers and distribution lines are identified and remedial measures can be implemented.

4.2 Etap Software

The software used for the analysis is ETAP 12.6 is a fully graphical Electrical Transient Analyzer Program that provides a very high level of reliability, protection and security of critical applications. The software can be used to run analysis such as load flow, short circuit, harmonic transient stability, motor starting, cable capacity, optimal power flow, generator start-up, etc. Its modular functionality can be customized to fit the needs of any company, from small to large power systems. Among ETAP's most powerful features are the composite network and motor element. Composite elements allow you to graphically nest network elements within themselves to an arbitrary depth. For example, a composite network can contain other composite networks, providing the capability to construct complex electrical networks while still maintaining a clean, uncluttered diagram that you want to emphasize. ETAP provides five levels of error checking. The active error viewer appears when you attempt to run a study with missing or inappropriate data.

The input data for the power flow analysis includes Grid MVAsc, line parameters, bus parameters, transformer ratings, feeder loadings, etc. In ETAP 12.6, the user is allowed to choose from four different a.c load flow iteration schemes, which include: Adaptive Newton Raphson, Newton Raphson, Fast -Decoupled and Accelerated Gauss-Seidel. In this research, the Newton Raphson iteration scheme was used.

IV. RESULT AND DISCUSSION

5.1 NEWTON RAPHSON LOAD FLOW SIMULATION DIAGRAM IN ETAP ENVIRONMENT (BASE CASE)

Figure 1 to 5 shows the simulated composite diagram of the 73 bus of the Port Harcourt 33kv power distributed system without the placement of distributed generation.

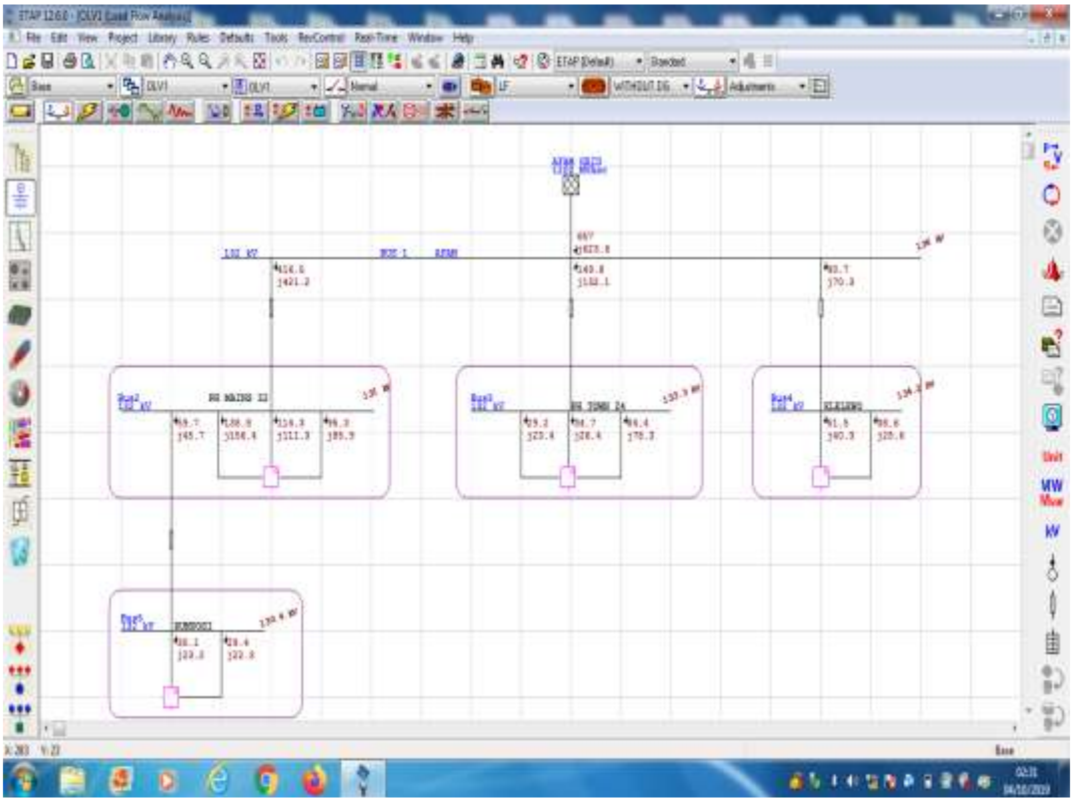

Figure 1 composite simulated main diagram of the 73 bus Port Harcourt 33kv power distribution system without DG

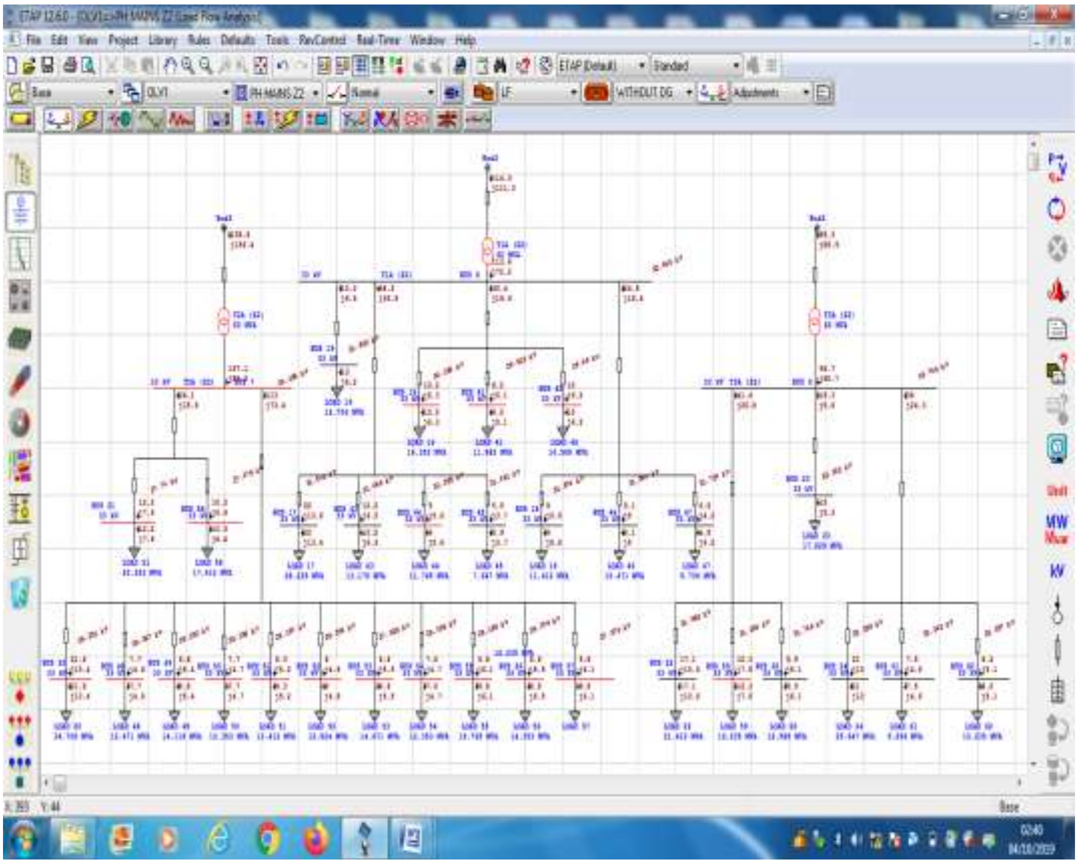

Figure 2 composite simulated diagram of (PHZ2) Port Harcourt 33kv power distribution system

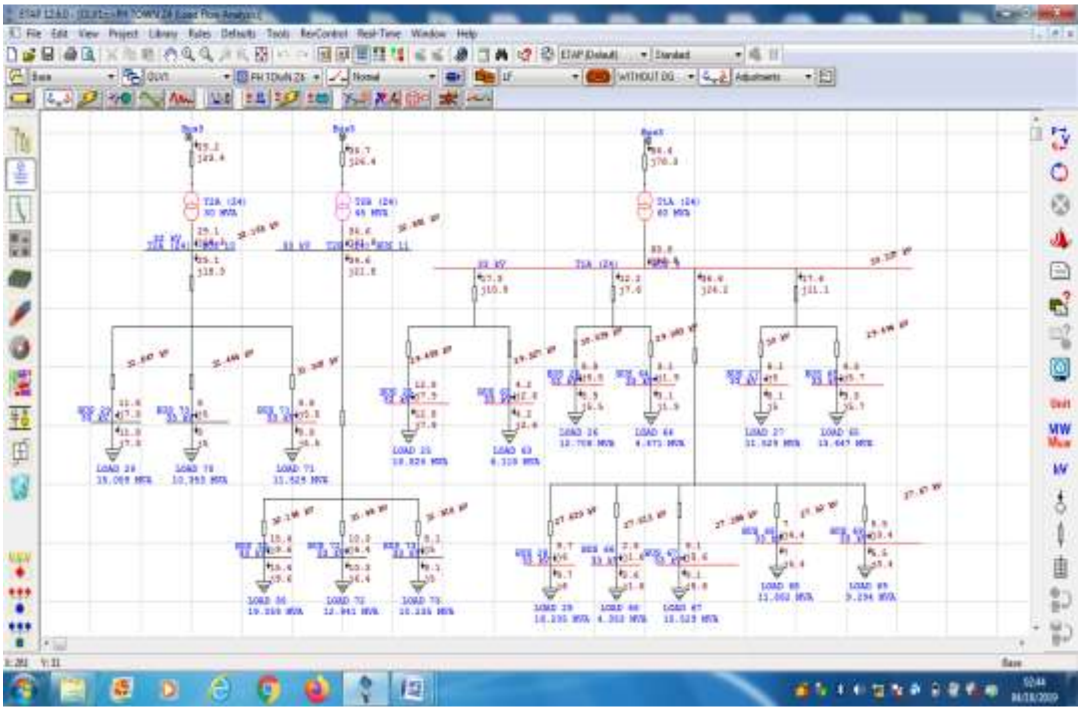

Figure 3 composite simulated diagram of (PHZ4) Port Harcourt 33kv power distribution system

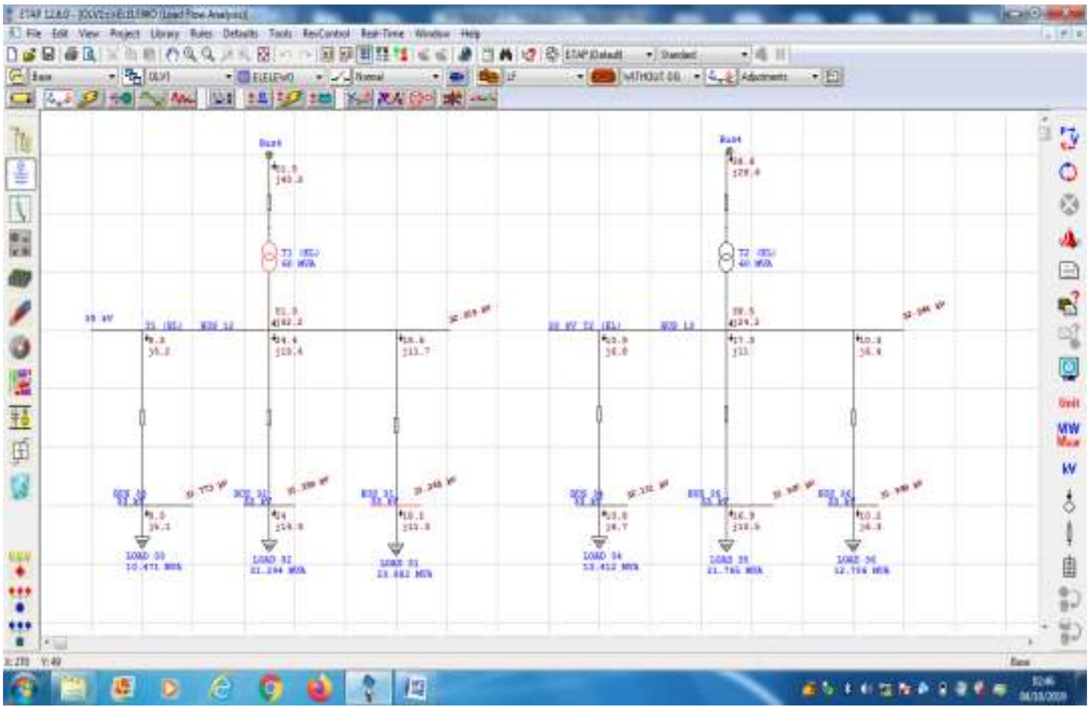

Figure 4 composite simulated diagram of ELELEWO Port Harcourt 33kv power distribution system

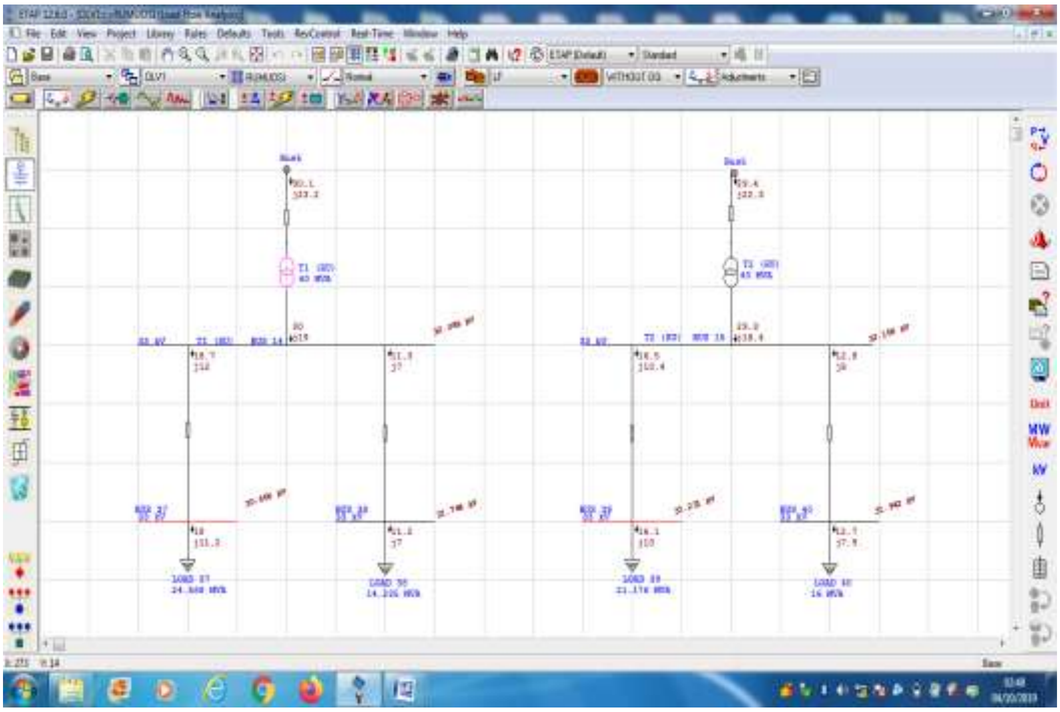

Figure 5 composite simulated diagram of (RUMUOSI) Port Harcourt 33kv power distribution system

5.2 Newton Raphson Load Flow Simulation Result In Etap Environment (Base Case)

TABLE 5.2.1 RESULT FOR BUS VOLTAGE PROFILE (BEFORE DG)

Bus ID	Nominal kV	Calculated Voltage(KV)	P.U Value	Condition
BUS 1	132	135.96	1.03	normal
BUS 2	132	131.043	0.99	normal
BUS 3	132	133.282	1.01	normal
BUS 4	132	134.176	1.02	normal
BUS 5	132	130.438	0.99	normal
BUS 6	33	32.465	0.98	normal
BUS 7	33	30.156	0.91	undervoltage
BUS 8	33	33.768	1.02	normal
BUS 9	33	30.337	0.92	undervoltage
BUS 10	33	32.165	0.97	normal
BUS 11	33	32.851	1.00	normal
BUS 12	33	32.019	0.97	normal
BUS 13	33	32.546	0.99	normal
BUS 14	33	32.089	0.97	normal
BUS 15	33	32.166	0.97	normal
BUS 16	33	30.156	0.91	undervoltage
BUS 17	33	31.601	0.96	normal
BUS 18	33	31.874	0.97	normal
BUS 19	33	31.833	0.96	normal
BUS 20	33	28.251	0.86	undervoltage
BUS 21	33	27.74	0.84	undervoltage
BUS 22	33	31.982	0.97	normal
BUS 23	33	33.162	1.00	normal
BUS 24	33	32.359	0.98	normal
BUS 25	33	29.489	0.89	undervoltage
BUS 26	33	30.039	0.91	undervoltage
BUS 27	33	30	0.91	undervoltage

BUS 28	33	27.629	0.84	undervoltage
BUS 29	33	31.647	0.96	normal
BUS 30	33	32.196	0.98	normal
BUS 31	33	31.265	0.94	undervoltage
BUS 32	33	31.359	0.95	normal
BUS 33	33	31.773	0.96	normal
BUS 34	33	32.111	0.97	normal
BUS 35	33	31.507	0.95	normal
BUS 36	33	31.999	0.97	normal
BUS 37	33	30.666	0.93	undervoltage
BUS 38	34	31.784	0.93	normal
BUS 39	35	31.231	0.89	undervoltage
BUS 40	36	31.942	0.89	normal
BUS 41	37	29.819	0.81	undervoltage
BUS 42	38	29.69	0.78	undervoltage
BUS 43	39	31.468	0.81	normal
BUS 44	40	31.295	0.78	undervoltage
BUS 45	41	31.481	0.77	normal
BUS 46	42	31.544	0.75	normal
BUS 47	43	31.724	0.74	normal
BUS 48	44	28.067	0.64	undervoltage
BUS 49	45	28.202	0.63	undervoltage
BUS 50	46	28.186	0.61	undervoltage
BUS 51	47	28.197	0.60	undervoltage
BUS 52	48	28.204	0.59	undervoltage
BUS 53	49	27.928	0.57	undervoltage
BUS 54	50	28.093	0.56	undervoltage
BUS 55	51	28.185	0.55	undervoltage
BUS 56	52	28.079	0.54	undervoltage
BUS 57	53	27.878	0.53	undervoltage
BUS 58	54	27.475	0.51	undervoltage
BUS 59	55	31.166	0.57	undervoltage
BUS 60	56	31.769	0.57	normal
BUS 61	57	32.142	0.56	normal
BUS 62	58	32.057	0.55	normal
BUS 63	59	29.527	0.50	undervoltage
BUS 64	60	29.983	0.50	undervoltage
BUS 65	61	29.494	0.48	undervoltage
BUS 66	62	27.613	0.45	undervoltage
BUS 67	63	27.388	0.43	undervoltage
BUS 68	64	27.52	0.43	undervoltage
BUS 69	65	27.57	0.42	undervoltage
BUS 70	66	31.444	0.48	normal
BUS 71	67	31.307	0.47	undervoltage
BUS 72	68	31.98	0.47	normal
BUS 73	69	31.918	0.46	normal

5.3 Newton Raphson Load Flow Simulation Result In Etap Environment (With Dg)

TABLE 5.3.1 RESULT FOR BUS VOLTAGE PROFILE AFTER DG PLACEMENT

Bus ID	Nominal kV	Calculated Voltage(KV)	P.U Value	Condition
BUS 1	132	135.96	1.03	Improved
BUS 2	132	132.131	1.00	Improved
BUS 3	132	133.952	1.01	Improved
BUS 4	132	134.538	1.02	Improved
BUS 5	132	131.667	1.00	Improved
BUS 6	33	33.83	1.03	Improved
BUS 7	33	33.856	1.03	Improved
BUS 8	33	34.34	1.04	Improved
BUS 9	33	32.829	0.99	Improved
BUS 10	33	32.327	0.98	Improved
BUS 11	33	33.016	1.00	Improved
BUS 12	33	33.014	1.00	Improved
BUS 13	33	32.633	0.99	Improved
BUS 14	33	33.292	1.01	Improved
BUS 15	33	32.469	0.98	Improved
BUS 16	33	33	1.00	Improved
BUS 17	33	32.93	1.00	Improved
BUS 18	33	33.214	1.01	Improved
BUS 19	33	33.171	1.01	Improved
BUS 20	33	32.389	0.98	Improved
BUS 21	33	32.784	0.99	Improved
BUS 22	33	33.011	1.00	Improved
BUS 23	33	33.723	1.02	Improved
BUS 24	33	32.907	1.00	Improved
BUS 25	33	31.911	0.97	Improved
BUS 26	33	32.506	0.99	Improved
BUS 27	33	32.465	0.98	Improved
BUS 28	33	32.691	0.99	Improved
BUS 29	33	31.806	0.96	Improved
BUS 30	33	32.358	0.98	Improved
BUS 31	33	33	1.00	Improved
BUS 32	33	32.333	0.98	Improved
BUS 33	33	32.76	0.99	Improved
BUS 34	33	32.198	0.98	Improved
BUS 35	33	31.592	0.96	Improved
BUS 36	33	32.085	0.97	Improved
BUS 37	33	33	1.00	Improved
BUS 38	33	32.976	1.00	Improved
BUS 39	33	31.525	0.96	Improved
BUS 40	33	32.243	0.98	Improved
BUS 41	33	32.544	0.99	Improved
BUS 42	33	32.404	0.98	Improved
BUS 43	33	32.791	0.99	Improved
BUS 44	33	32.611	0.99	Improved
BUS 45	33	32.805	0.99	Improved
BUS 46	33	32.87	1.00	Improved
BUS 47	33	33.059	1.00	Improved
BUS 48	33	32.178	0.98	Improved

BUS 49	33	32.333	0.98	Improved
BUS 50	33	32.314	0.98	Improved
BUS 51	33	32.327	0.98	Improved
BUS 52	33	32.335	0.98	Improved
BUS 53	33	33	1.00	Improved
BUS 54	33	32.208	0.98	Improved
BUS 55	33	32.314	0.98	Improved
BUS 56	33	32.192	0.98	Improved
BUS 57	33	33	1.00	Improved
BUS 58	33	33	1.00	Improved
BUS 59	33	33	1.00	Improved
BUS 60	33	32.79	0.99	Improved
BUS 61	33	32.686	0.99	Improved
BUS 62	33	32.599	0.99	Improved
BUS 63	33	31.952	0.97	Improved
BUS 64	33	32.445	0.98	Improved
BUS 65	33	31.916	0.97	Improved
BUS 66	33	32.673	0.99	Improved
BUS 67	33	33	1.00	Improved
BUS 68	33	32.563	0.99	Improved
BUS 69	33	33	1.00	Improved
BUS 70	33	31.602	0.96	Improved
BUS 71	33	31.464	0.95	Improved
BUS 72	33	32.141	0.97	Improved
BUS 73	33	32.078	0.97	Improved

TABLE 5.3.2 COMPARISON OF VOLTAGE PROFILE BEFORE AND AFTER DG PLACEMENT

S/N	Bus No	Nominal kV	WITHOUT DG	P.U Value	WITH DG OF 25MW	P.U Value
1	BUS 7	33	30.156	0.91382	33.856	1.02594
2	BUS 9	33	30.337	0.91930	32.829	0.99482
3	BUS 16	33	30.156	0.91382	33.000	1.00000
4	BUS 20	33	28.251	0.85609	32.389	0.98148
5	BUS 21	33	27.740	0.84061	32.784	0.99345
6	BUS 25	33	29.489	0.89361	31.911	0.96700
7	BUS 26	33	30.039	0.91027	32.506	0.98503
8	BUS 27	33	30.000	0.90909	32.465	0.98379
9	BUS 28	33	27.629	0.83724	32.691	0.99064
10	BUS 31	33	31.265	0.94742	33.000	1.00000
11	BUS 37	33	30.666	0.92927	33.000	1.00000
12	BUS 39	33	31.231	0.94639	31.525	0.95530
13	BUS 41	33	29.819	0.90361	32.544	0.98618
14	BUS 42	33	29.690	0.89970	32.404	0.98194
15	BUS 44	33	31.295	0.94833	32.611	0.98821
16	BUS 48	33	28.067	0.85052	32.178	0.97509
17	BUS 49	33	28.202	0.85461	32.333	0.97979
18	BUS 50	33	28.186	0.85412	32.314	0.97921
19	BUS 51	33	28.197	0.85445	32.327	0.97961
20	BUS 52	33	28.204	0.85467	32.335	0.97985
21	BUS 53	33	27.928	0.84630	33.000	1.00000
22	BUS 54	33	28.093	0.85130	32.208	0.97600
23	BUS 55	33	28.185	0.85409	32.314	0.97921

24	BUS 56	33	28.079	0.85088	32.192	0.97552
25	BUS 57	33	27.878	0.84479	33.000	1.00000
26	BUS 58	33	27.475	0.83258	33.000	1.00000
27	BUS 59	33	31.166	0.94442	33.000	1.00000
28	BUS 63	33	29.527	0.89476	31.952	0.96824
29	BUS 64	33	29.983	0.90858	32.445	0.98318
30	BUS 65	33	29.494	0.89376	31.916	0.96715
31	BUS 66	33	27.613	0.83676	32.673	0.99009
32	BUS 67	33	27.388	0.82994	33.000	1.00000
33	BUS 68	33	27.520	0.83394	32.563	0.98676
34	BUS 69	33	27.570	0.83545	33.000	1.00000
35	BUS 71	33	31.307	0.94870	31.464	0.95345

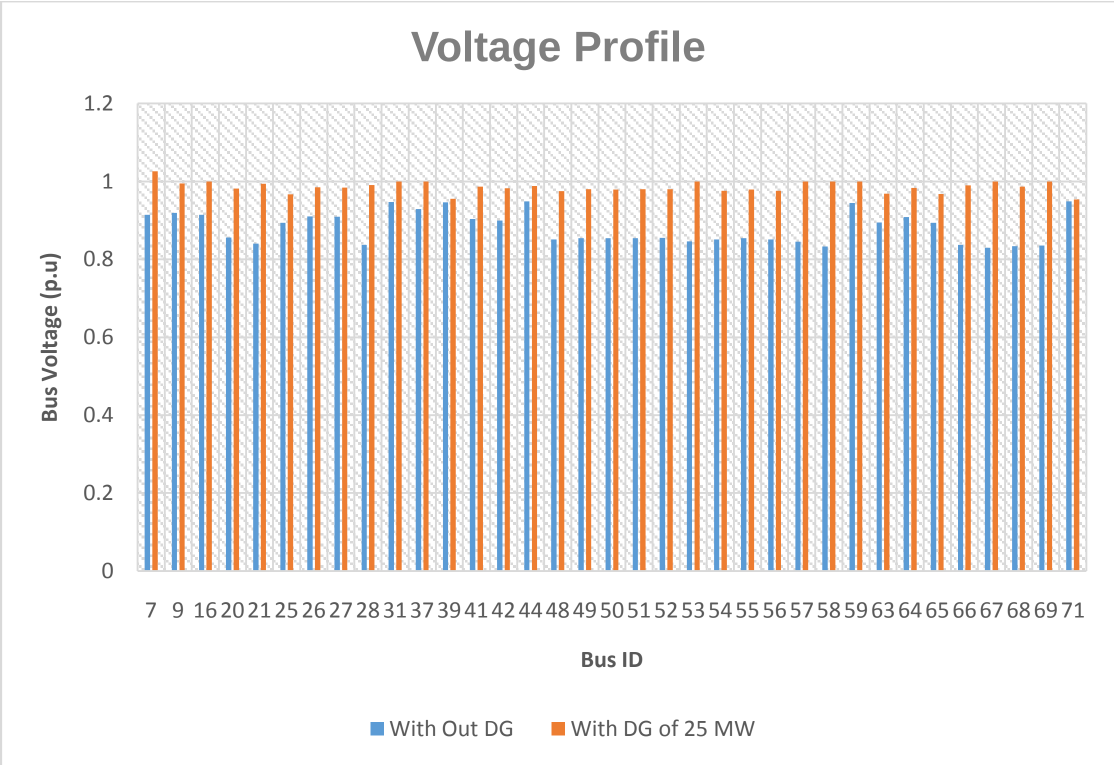

FIGURE 6: COMPARISON OF VOLTAGE PROFILE BEFORE AND AFTER DG PLACEMENT

V. DISCUSSION

After performing the load flow analysis of the 73 bus test distribution system under review using ETAP12.6 software, an alert summary report was generated which shows 35 candidate load bus are outside the statutory voltage constraint limit (0. 95p.u – 1. 05p.u)that is 31.35KV- 34.65KV. This is shown in table 5.2.1. Distributed generation units of 25MW gas turbine synchronous generator was place at the candidate bus that give rise to voltage profile improvement through repeated load flow simulation. The candidate buses identified are: BUS 16, BUS31, BUS37, BUS53, BUS57, BUS58, BUS59, BUS67, BUS69. When DG_{1-9} units are place in these respective candidate buses the voltage profile improved and fall within the statutory voltage constraint limit as shown in table 5.3.1.This is taken as the optimal placement for DG in the 73 bus Port Harcourt power distribution system for voltage profile improvement.

VI. CONCLUSION

Distribution system provides a final linkage betweenthe high voltage transmission system and the customers.The X/R ratio of distribution system is low as comparedto the transmission system. This causes the high power lossand drop in voltage magnitude. The distribution network is radial and the major drawback is that all the consumers are connected to a single distributorso there is huge fluctuation of load which cause thevariation in system voltage and distorts the voltage profile

It is important to evaluate the voltage profile of the distribution system at regular interval so that the weak bus voltages will be identified and remedial measures will be chosen to ensure good quality of power supply to load consumers.Distribution Generation is suggested to be a feasible solution to overcome the poor voltage profile inherent in Port Harcourt Power Distribution Network.

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