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Improvement of Bulk Power Supply to Ada-George Axis of Port Harcourt: A Case Study of Port-Harcourt Town/Rumuosi 132/33kV Sub-Transmission Station 33KV Feeders Feeding the Axis.

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ABSTRACT: *Power Supply to Ada-George axis of Port Harcourt has been unreliable and posing danger to the populace within the axis. Some area of the Ada- George axis is fed from the 132/33kV Port-Harcourt Town (Zone 4), mainly on Rumuolumeni feeder and UST feeder; and the 132/33kV Rumuosi sub-transmission substation in Obio-Akpor Local Government area of River State. This research is targeted to proffer solution to the area under consideration by providing bulk power supply. The application of network reconfiguration, reactive power compensation (Capacitor Bank) at strategic locations were able to enhanced the voltage profile. The networks were modeled using ETAP software from base-case to improved-case. Due to the system networks and fast convergence requirement Newton-Raphson load flow technique was used in the simulation. The various data collected are presented within. The base- case simulation results for Rumuolumeni feeder, UST feeder, and Rumuosi33kV feeders showed that they all experienced under voltages, inadequate power supply and some overloaded transformers. The voltage profile for Rumuolumeni, UST and Rumuosi 33KV feeders were obtained from the simulation of the(base-case) with ETAP software. The obtained results for Rumuolumeni (93.2%), UST (92.84%) and Rumuosi (89.7%) of the nominal bus voltage of 33kV falls short of the acceptable limit of (33kV ± 5%). Net power received (supplied load) by the three feeders in the base-case shows that only 72%-75% of the connected loads received power. After rigorous reconfiguration and applying network optimization techniques, the Rumuolumeni and UST feeders were integrated into 132/33kV Rumuosi sub-transmission substation to relieve the 132/33kV Port-Harcourt Town sub-transmission substation (Zone4) from excessive loads connected. The Ada-George axis of western Port-Harcourt is fully revamped having upgraded the Rumuosi TS to 3x 60 MVA, 132/33kV transformers; The result for the simulation of the improved- cases showed that the voltage profile for New Rumuolumeni, New UST and Rumuosi 33kV feeders improved to 99.15%, 98.82% and 98.02%of the nominal voltage respectively. These results fall within the acceptable limit of 95%-105% of the nominal voltage. The net power received by the New Rumuolumeni, New UST and Rumuosi 33kV feeders have been improved to 98.24%, 94.78% and 97.96% of the connected loads in MVA respectively. Three numbers of 30-36MVar capacitor banks were added into the feeders' networks to compensate for reactive power loss. A new 132/33kV Rumuolumeni sub-transmission substation is proposed, taking a tee-off from the Omoku TS lines at Emohua for future expansion to the neighboring communities.*

KEYWORDS: *Bulk Power Supply, ETAP Software, Newton Raphson Power Flow Method, Network Reconfiguration, Sub-Transmission Station and Feeders.*

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I. INTRODUCTION

The electricity supply situation in Ada-George axis of Port Harcourt has been very erratic as the people could stay weeks without power supply to the area. As seen in [1], the situation of the area was echoed in the online Nigeria tribune; many landlords in some parts of the Elioparanwo axis, off Rufus Ada-George have lose their tenants in multitudes due to constant power blackouts, occasioned by the near zero power supply to the area by the Port Harcourt Electricity Distribution Company [1]. The 33KV feeders to this area are too lengthy and overloaded. The area is characterized by load shedding hence the use of generators for commercial activities and attendant huge loss of returns on businesses.

The Port Harcourt Electricity Distribution Company of Nigeria (PHEDC) is yet to find a lasting solution to the problem, hence the need for this study and to proffer a considerable pathway to the Utility Company and the general populace.

1.1 Aim of the Study

The aim of this study is to analyse and improve the bulk power supply to Ada-George axis of Port Harcourt.

1.2 Objectives of the Study

In order to achieve the aim of this study the following objectives were carried out:

i) To examine the adequacy of new 33kV injection substations for bulk power supply to Ada-George axis of Port Harcourt from Rumuosi sub-transmission station.
ii) To Reconfigure the existing 33kV Rumuolumeni and UST feeder at Port-Harcourt Town (Zone 4) to Rumuosi sub-transmission station for reliable bulk power supply to the Ada-George axis of Port Harcourt
iii) To Restructure and model a new feeder/ network for the areas under consideration through Rumuosi sub-transmission station.
iv) To model a new 132kV double circuit transmission line to supply bulk power to Rumuolumeni area.
v) To run simulation to determine the load flow capability of the networks/feeders for results analysis and improvement.

1.3 Scope of the Study

The scope of this research work includes the following:

i) The status of the 33kV feeders feeding the Ada-George axis considering the power supply adequacy.
ii) Expansion of the 132/33kV Rumuosi sub-transmission station for adequate bulk power supply.
iii) Show total numbers of transformers and load connected to all the injection substations in the axis.
iv) Show adequacy of the capacities of injection substations in the axis with respect to the total number of transformers connected to them.
v) Predict for future expansion by way of additional sub-transmission substation or injection substations, etc.

II. LITERATURE REVIEW

2.1 Impact of Electric Power Supply and Outages

In order to achieve the aim of this study and have a remarkable solution one need to abreast himself in the areas of related studies. This review will look upon the sources of electric power supply, utilization features and the effects of inadequate power supply to load centres. As seen in [2], comparative studies of the position of electricity supply in other countries were analysed. Asian countries also show that inadequate power supply is a familiar problem in most developing countries and that power supply has become the next vital constituent for living after air and water. The power sector in Nigeria is marked by its erratic nature, inadequate power supply, recurrent interruption and total blackout some times. Most residential area and household utilization of this power suffer so much; domestic activities such as lighting, cooking, refrigerating, water pumping, etc., involve the use of electricity and despite its importance the solution has never been met due to technological challenges, poor maintenance culture of old installed infrastructures, inadequate protective system, fire incidents, poor funding, , power loss due to long distance of transmission of power to the distribution point, etc.,[2].

Again, according to [3], Nigerian firm suffers enormous costs as a result of frequent outages or failure in electricity supply. The paper presented assessed the impact of outages in selected electricity intensive industries in Nigeria for the year 2014. A statistical package for the social sciences (SPSS) version 16.0 was used for the analysis. The study further states that “Nigeria’s industries suffer low capacity utilization, significant reduction in productivity, low marginal profit and lack of competitiveness in the international market due to perennial shortages in energy supply resulting from high distribution losses”.

Also, in [4], the almost challenging factor for development of Nigeria is the insufficient supply of electricity in Nigeria as against the ever-increasing demand. As reported by World Bank and some foreign organizations that Nigeria is one of the worst countries with electricity shortage. Out of the nation’s population of 160 million people, 82.4 million lack accesses to electricity the report said.

[5] in his research said that it is more economical to use public power supply than private generating sets in running five cold rooms which was a case study. In the view of [6] constant and available power can thrive for industrialization of a nation but with persistent outages businesses cannot operate.

Bulk power is the transfer of available power through a transmission link on large-scale to a substation for further distribution to close load centres. The transfer is carried out from generation- transmission tie through transmission lines on high voltage, power transformers to bulk load centres. Bulk electric power supply requires huge cost in infrastructure and apparatus to transmission of the power to the load centre. When transmitted to the load centre distribution infrastructures will be tasked to distributes the available power to consumers' areas.

2.2 Power Systems Networks Improvement Methods

2.2.1 Network Reconfiguration Techniques

According to [7] network reconfiguration is one of the methods used for loss minimization in distribution systems. It can also be used for load balancing and improve distribution system automation.

[8] in their research reiterated that distribution network reconfiguration is an important aspect of operation geared towards reducing common distribution feeder losses and go on further to enhance improve system security and reliability to obtain optimum operation of distribution systems.

2.2.2 Upgrades of Power Systems Network Components and Load flow

In the research carried out by [9], they used Newton-Raphson techniques to evaluate the static load flow problems and obtained the real and reactive power flow, the various bus voltages and power losses in the networks. Their research was centred on the performance characteristics of the 132kV sub-transmission lines in the Nigeria power network with a case study of Port Harcourt sub-region of Rivers State. It is also seen that some power transformers were upgraded to adequately draw power from the grid to the load centres. Electrical Transient Analyzer Program (ETAP 12.6) was used also to model the network and to perform simulation. Table 2.1 was the power transmission network of Port-Harcourt sub-region with substations as seen in [9].

In [10] a load flow analysis was used to investigate the performance of the electrical power system during normal and abnormal operating conditions. ETAP software was used in their simulation for planning and coordination of the relays in the distribution system. Their investigation provided the necessary information to maximize MW and MVar, Voltage profile improvement, etc. ETAP is computer-based software that simulates real time steady-state power system operation, enabling the computation of system bus voltage profiles, real and reactive power flow and line losses, etc. [10].

[11], affirmed that the distribution system is frequently faced with an ever-increasing load demand. He however suggested that to meet the increasing load demand an effective distribution system upgrade is performed which can be achieved by executing a power flow study on the distribution system.

In his view, [12] buttressed on the fact that the information obtained from power flow study is of utmost importance for the effective monitoring of the present condition in a typical power system. He further noted that an alternative plan for future system expansion is provided from the result obtained in order to satisfy the increasing loads on the distribution system.

2.2.3 Distributed Generation for Improving Power Systems Networks

[7] pointed out that DG allocation techniques are used in an interconnected system where distributed sources are available. According to [13] in their work pointed out that distributed generation provides an immediate solution to the growing energy demand due to its short construction time line and its low installation lost. In addition, they noted that the presence of DG in distribution system helps in relieving transmission and distribution capacity; improve system efficiency reliability, safety and quality of service.

2.2.4 Feeder Bifurcation

Feeder bifurcation involves the construction of new express feeders parallel whose load is to be balanced or shared by the feeder [14].

2.2.5 Capacitor Placement

In [15], they stated that static capacitor bank in distribution system helps in improving the power factors, reduce power loss and improve the voltage profile. However, they noted that to derive the maximum benefit, the capacitor bank must be placed nearer to the load centres.

According to [16] 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 (Legha et al., 2013).

DESCRIPTION OF NETWORK UNDER ANALYSIS

Two power distribution networks are under analysis for bulk power supply to Ada George axis namely; Port Harcourt Town (Zone 4) sub-transmission station through Rumuolumeni and UST outgoing 33KV feeders and Rumuosi sub-transmission station on 132kV (incomer) through NTA(Nigeria Television Authority) and UPTH (University of Port Harcourt Teaching Hospital) 33kV outgoing feeders.

III. MATERIALS AND METHOD

3.1 Materials Required for the Power System Network

The following materials are required in the reconfiguration, development and modelling of Ada-George Axis of Port Harcourt for rapid restoration of power supply. The data collected from all the service centres under consideration are presented here in the various Tables below which constitutes part of the materials required for simulation. Also, data from Table 3.1 will be useful in our analysis with other materials such as:

i. Overhead transmission line cross-section area per conductor (ACSR of 182mm^2) - (Aluminum conductor steel reinforced). The transmission lines are on single circuit carried overhead using line support (steel tower and strain insulators, etc.)
ii. Transformers voltage rating under consideration are 132/33kVand 33/11kV
iii. Power transformers range (30MVA – 100MVA)
iv. Distribution transformer for secondary bulk power range (2.5MVA – 30MVA)
v. Source of power supply from the grid via Omoku and Trans-Amadi sub-transmission lines on 132kV.
vi. Capacitor bank for reactive power compensation
vii. Electrical Transient Analyzer Program (ETAP 12.6) software for network modeling and simulation.

3.2 Techniques for Improving Power System Networks

To improve the power system networks whether transmission or distribution network the following techniques enumerated here are useful:

i. Upgrading of Power system facilities. (such as upgrading of transformer rating, tap setting)
ii. Network feeder reconfiguration
iii. Supplementary power penetration from distributed generation.
iv. Capacitor placement for reactive power compensation
v. Feeder Bifurcation (i.e. splitting of a feeder that is too long)
vi. Conductor grading (resizing), etc.
vii. High voltage distribution system.

3.2.1 The Techniques Used for Analysis.

The four feeders that require urgent attentions are (NTA and UPTH) and (Rumuolumeni and UST).To improve power supply to the axis, we shall use, network reconfiguration techniques, feeder bifurcation, with upgrade of Rumuosi sub-transmission station facilities**.**

The network under consideration (as seen in appendix) is a large system hence, the method of simulation and results coordination will be a **Load Flow-Based Method using Newton-Raphson Load Flow techniques for the simulation** in Electrical Transient Analyzer program (ETAP) environment .ETAP is computer-based software that simulates real time steady-state power system operation, which enables the computation of the system bus voltage profiles, real and reactive power flow and line losses, optimal capacitor placement, transient analysis, etc. The system load flow as mentioned above will be simulated, therefore writing computational programme is not necessary.

The need for **Bulk power supply** to Ada-George axis of Port Harcourt is further strengthened by looking at table 3.1, which shows the current state of each of the transmission station in Port Harcourt. It is clear from that figure that the power transformer in PH Town, zone 4 (T1A:60MVA) serving Rumuolumeni and (T2A:30MVA) serving UST 33kV feeder sand Power transformer (T1:40MVA) at Rumuosi are fully loaded and under stress.

Table 3.1: Sub-Transmission Stations, Capacity and their Power Transformer Loading in Rivers State. (Incoming Power from 132kV Grid)

Name of State	State Capacity	Station	Total MVA	Transformer Capacity	Present Max. Load (MVA)	Max. Power (MW) at 0.8 Pf	Present Max. Power loading (MW)	% Loading
Rivers	550MVA	PH Mains (Zone 2)	180 MVA	T1: 60MVA	69.25	48	55.4	**115**
				T2: 60MVA	69.25	48	55.4	**115**
				T3: 60MVA	69.25	48	55.4	**115**
		PH Town (Zone 4)	165 MVA	T1A:60MVA	60	48	48	**100**
				T1B:30MVA	24.88	24	19.9	**83**
				T2A:30MVA	35.63	24	28.5	**119**
				T2B: 45MVA	33.75	36	27	**75**
		Afam	45MVA	T: 45MVA	42.88	36	34.3	**95**
		Elelenwo	120MVA	T1:60MVA	40.38	48	32.3	**67**

		T2:60MVA	57.13	48	45.7	**95**
Rumuosi	40MVA	T1:40MVA	41.5	32	33.2	**104**
		T2: **60MVA**	Not Com	Not Com	Not Com	**Not Com**

Not Com: Not Commission yet

Table 3.2: Injections Substations in the Ada-George Axis of Port Harcourt under Consideration 33/11kV

Injections Substations with Transformer Capacity

S/No.	**Injection Substations**	**No. of Transformers**	**Total Capacity**
1	U.O.E	1x 2.5MVA, 1x 7.5MVA	10MVA
2	Agip Housing Estate	1x7.5MVA	7.5 MVA
3	NAOC Agip Base	2x3MVA (3x2.5MVA)	13.5MVA
4	NTA	2x15MVA	30MVA
5	School of Nursing	2 x15MVA	30MVA
6	RSU	2 x15MVA	30MVA
7	RSU Estate	1 x7.5MVA	7.5MVA
8	Eagle Island (Uncommission)	2 x 15MVA	30MVA
	Total installed Capacity	**15 No.**	**166MVA**

3.3 Newton-Raphson (NR) Method

This is an iterative method which uses Taylor's series expansion to approximate a set of non-linear simultaneous equations to a set of linear simultaneous equations. For power flow study, it is the most used iterative method due to its convergence features that are faster compared to other methods [17]. Newton-Raphson (NR) method is very suitable for load flow studies on large systems. The advantages of using Newton-Raphson method are as follows:

(i) More accuracy and surety of convergence
(ii) The number of iterations for convergence of a power problem is less than as compared to Gauss-Seidel method
(iii) The number of iterations is independent of the system's size.
(iv) This method is insensitive to factors like slack bus selection, regulating transformer, etc.

The disadvantages of this method are:

1) The solution technique is difficult.
2) There are more calculations in each iteration and therefore computer time per iteration is large.

The computer memory requirement is large. But fortunately, this drawback has been overcome by a compact storage scheme.

3.4 Determination of Overloaded Transformer

1) The percentage loading of the transformers in the network was determined using the apparent power performance index. The loading for distribution transformers (DT) shall be 70% of the design rating whereas power transformers (PT) shall be loaded 60% for normal operation. Any (DT) with loadings in excess of 70% and (PT) 60% respectively is considered as overloaded for continuous operation. With reference to Amesi et al., (2017), the percentage loading of each distribution and power transformers will be calculated using equation (3.14).

$$\%\ loading = \sum_{i=1}^{N_T} \left(\frac{S_{MVA}}{S_{MAX}}\right) x\ 100 \quad (3.14)$$

Where:

S_{MAX} is the MVA rating of the transformer; S_{MVA} is the operating MVA found in the power flow computation and N_T is the number of transformers. For example, T1A in Table 3.1, rated 60MVA and operates at 60MVA. The transformer is considered overloaded.

$$\%\ loading\ of\ T1A = \frac{60MVA}{60MVA} x\ 100 = 100\%$$

3.5 Determination of Bus Operating Voltage

To determine the percentage bus operating voltage the bus voltage performance index was used. Bus voltages less than 95% are considered under voltage, whereas those above 105% are considered over voltage [18].

IV. RESULTS AND DISCUSSIONS

4.1 Results of Simulated Feeders/Networks

The affected feeders/networks under Port-Harcourt Town (Zone 4) were Rumuolumeni 33KV feeder and UST 33KV feeder, and all Rumuosi 132/33KV sub-transmission station's feeders of Port-Harcourt Electricity Distribution Company (PHEDC). The networks were simulated and analysed using ETAP Software on the various base-cases. However, due to inadequate power received or supplied (base-case) which do not match the connected loads, there were tendency of under voltages in the networks below marginal level. The simulation results of both base-case and improved case scenarios showing voltage profile at the various buses and the load or power flow in all the branches of the feeders are presented below.

4.1.1 Base-Case Networks Load Flow Results (Rumuolumeni & UST Feeder)

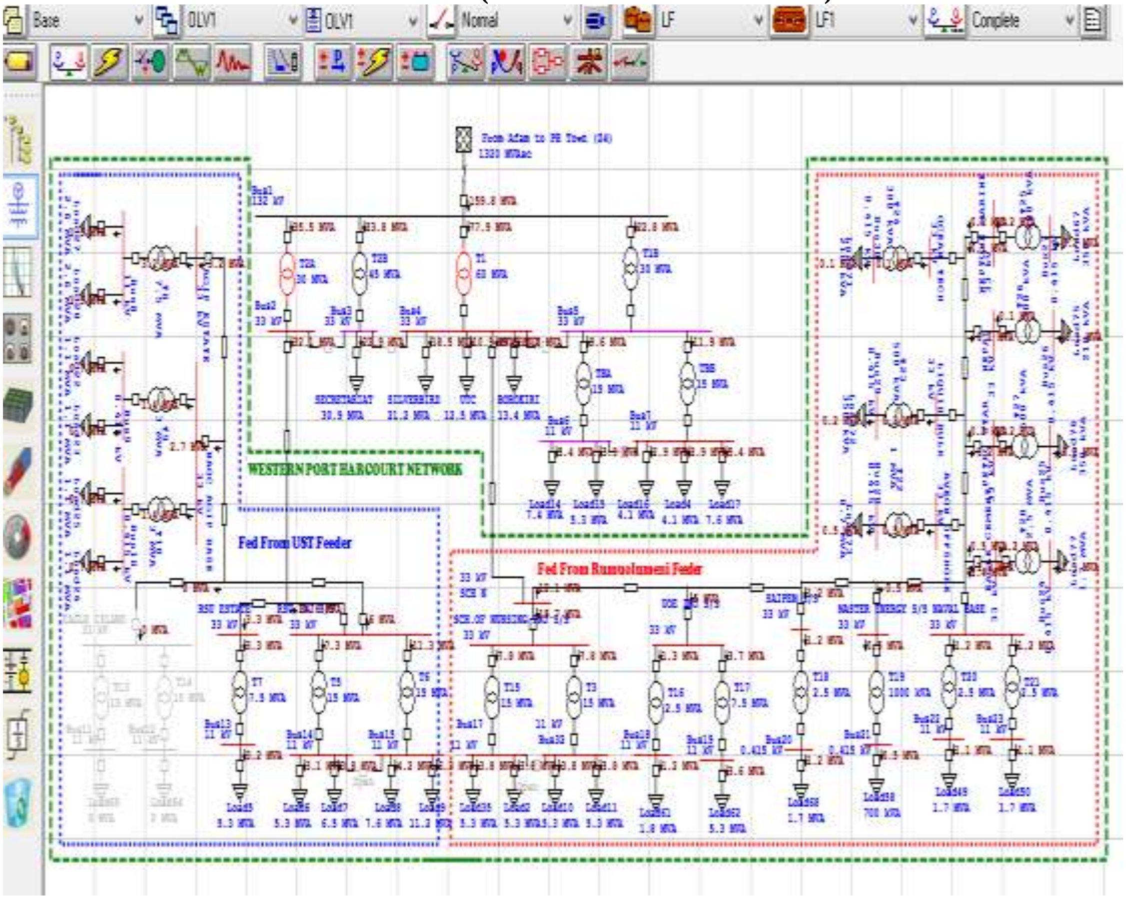

Figure 4.1: Load Flow Simulation Output for Port-Harcourt (Zone 4) (Base-case)

Figure 4.1 is the load flow simulation output for Port-Harcourt (Zone 4) (Base-case) indicating the power flow into each bus. On general indication, buses on red colour indicate (bus critical condition), purple colour indicates (bus marginal condition) and black colour indicates (bus acceptable condition). On this figure presented, transformers tagged with T2A (=30MVA) and T1 (=60MVA) were overloaded.

Table 4.1: Load Flow Results for Rumuolumeni 33kV Feeder/Networks (Base-case)

RumuolumeniInj S/S	**Connected Lump Load**	**power factor**	**Received Net Power**	**power factor**	**% Received Net Power**
	MVA	%PF	MVA	%PF	
Sch. of Nursing Inj S/S	**21.2**	85	**15.657**	81.9	73
UOE Inj S/S	**7.1**	85	**4.992**	82.7	70.3
Saipem Inj S/S	**1.7**	85	**1.194**	83.3	70.23
Master Energy Inj S/S	**0.7**	85	**0.490**	83.8	70
Naval Base S/S	**3.4**	85	**2.364**	83.3	69.53
Eagle Cement S/S	**1.7**	85	**1.182**	83.3	69.53

Petro Star S/S	**0.35**	85	**0.244**	84.4	69.71
NEPAS S/S	**0.21**	85	**0.146**	84.4	69.52
Neptune Marine S/S	**0.35**	85	**0.244**	84.4	69.71
Aveon Offshore S/S	**0.7**	85	**0.488**	83.8	69.71
Liquid Bulk S/S	**0.35**	85	**0.244**	84.4	69.71
Ocean Tech S/S	**0.21**	85	**0.146**	84.4	69.52
Total	**37.97**	85	**27.391**	83.68	72.14

Table 4.1 shows the load flow results for Rumuolumeni 33KV feeder/Networks (Base-case). The total connected lump load is 37.97MVA and the received net power was 27.39MVA, which means that only 72.14% of the net power was receive.

Figure 4.2 is the graphical representation of load/power flow results for Rumuolumeni 33kV feeder/networks (Base-case) with 73 % power received at School of Nursing injection substation whereas NEPAS S/S and Ocean Tech S/S received 69.52% of the expected load power. On the graph both lines almost fit-in at the Petrol Star S/S to Ocean Tech S/S.

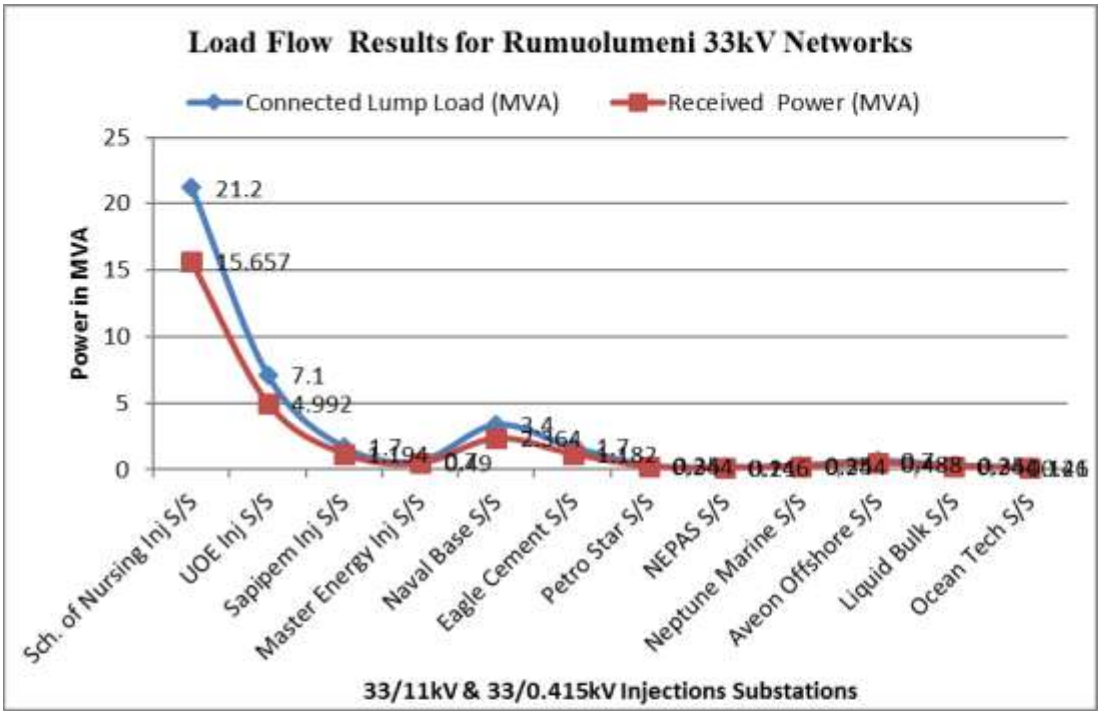

Figure 4.2: Load Flow Results for Rumuolumeni 33kV Feeder/Networks (Base-case)

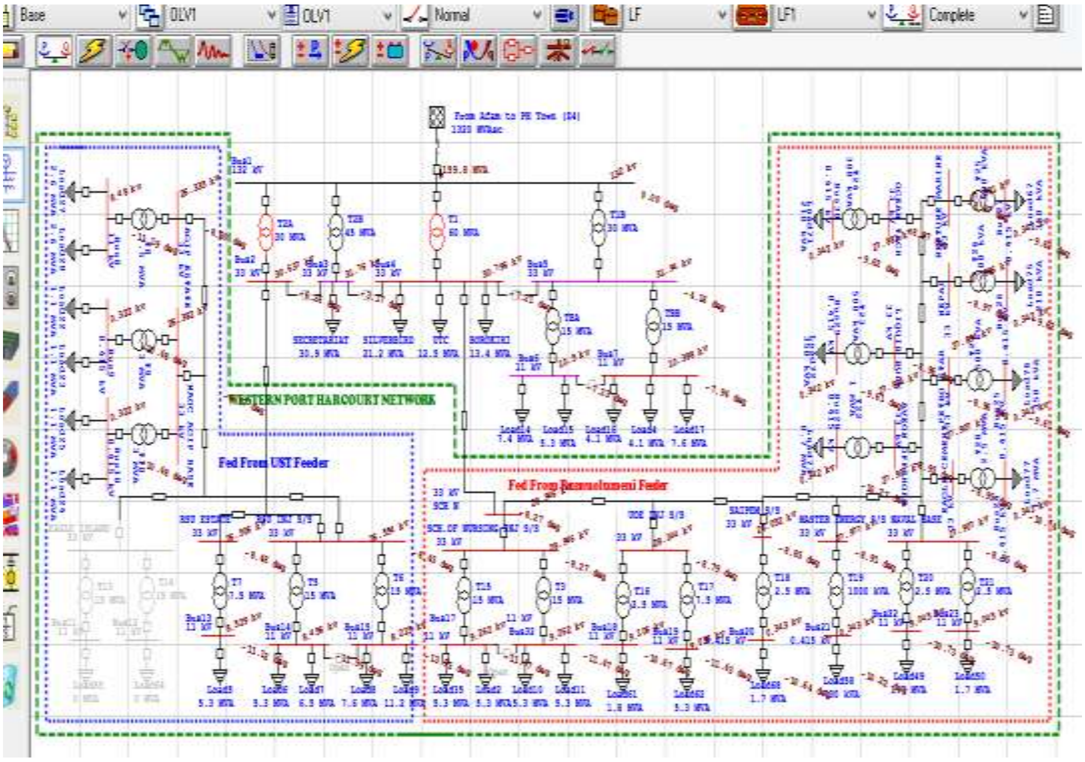
Base
OLV1
OLV1
Normal
LF
LF1
Complete
WESTERN PORT HARCOURT NETWORK
Fed From UST Feeder

Figure 4.3: Voltage Profile Simulation Output for Port-Harcourt Town (Zone 4) (Base-case)

Table 4.3: Voltage Profile Results for Rumuolumeni 33kV Feeder /Networks (Base-case)

Base-case Voltage Profile at each Bus for Rumuolumeni 33kV Feeder

Bus ID.	Rated Voltage	Operating Voltage		Bus ID.	Rated Voltage	Operating Voltage	
	kV	%	kV		kV	%	kV
Bus 4 (Zone4)	33	93.32	**30.79**	Sch of Nursing Inj S/S	33	87.72	**28.95**
UOE Inj S/S	33	85.29	**28.15**	Saipem S/S	33	85.00	**28.05**
Master Energy S/S	33	84.78	**27.97**	Naval Base S/S	33	84.57	**27.91**
Eagle Cement S/S	33	84.57	**27.90**	Petro Star S/S	33	84.53	**27.89**
NEPAS S/S	33	84.50	**27.88**	Neptune Marine S/S	33	84.49	**27.88**
Ocean Tech S/S	33	84.49	**27.88**	Liquid Bulk S/S	33	84.53	**27.89**
AVEON Offshore S/S	33	84.57	**27.91**				

Voltage levels: **Under Voltage (i.e less than 95%)**

Table 4.3 shows that all the bus operating voltages are under voltage (i.e. less than 95% of the rated voltage of 33KV).

Figure 4.5 shows the graphical representation of the voltage profile for Rumuolumeni 33kV Feeder/Networks (Base-case) with highest voltage recorded is 93.32% (i.e. 30.79kV) and lowest voltage was 84.5% (i.e. 27.88kV), these voltages falls short of the acceptable limit of (33kV ± 5%); hence the networks needs to be improved. Table 4.3 provided for Figure 4.5 as shown here.

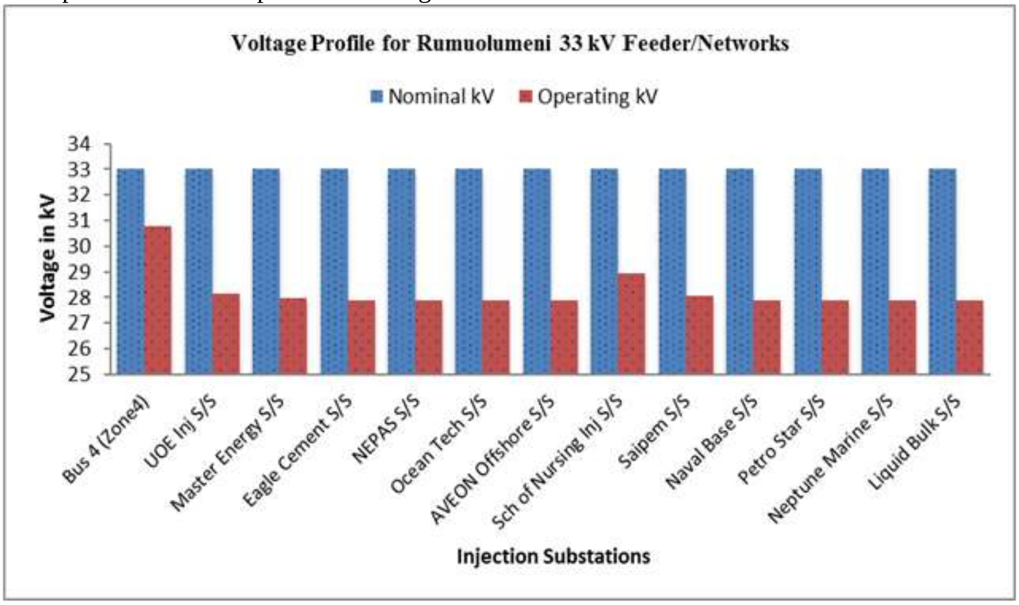

Figure 4.5: Voltage Profile for Rumuolumeni 33kV Feeder/Networks (Base-case)

4.1.3 Base-case Networks Load Flow Results (Rumuosi Sub-TS)

Figure 4.6 shows the load or power flow simulation output for the Rumuosi Sub-Transmission Station (base-case) indicating the power flowing into each bus respectively. The only in-service transformer available indicates red colour indicator meaning the transformer is overloaded and the buses are in red colour which indicates critical conditions.

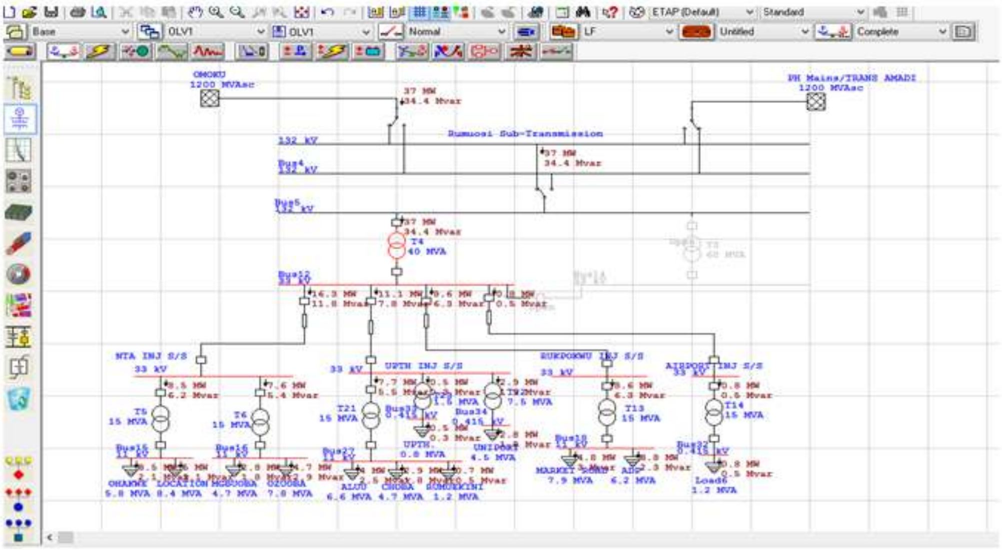

Figure 4.6: Load Flow Simulation Output for Rumuosi Sub-TS (Base-case)

Table 4.4 Load Flow Results for Rumuosi-TS 33kV Feeder/Networks (Base-case)

Base-case Load Flow for Rumuosi-TS 33kV Networks					
RumuosiInj S/S	**Connected Lump Load** MVA	**power factor** %PF	**Received Net Power** MVA		**% Received Net Power** %
NTA Inj S/S	**26.7**	85	**19.84**	81.1	74.31
UPTH Inj S/S	**17.8**	85	**13.51**	81.9	75.90
RukpokwuInj S/S	**14.1**	85	**10.66**	80.9	75.60
Airport Inj S/S	**1.2**	85	**0.960**	84.7	80.0
Total	**59.8**	85	**44.97**	82.15	75.20

%PF: Percentage Power Factor

Table 4.4 shows the load flow for Rumuosi TS 33KV feeder/Networks (Base-case) respectively. Total connected lump load is 59.8MVA against the received net power of 44.97MVA, which means that only 75.2% of the net power was received.

Figure 4.7 is the graphical representation of Table 4.4 which shows the load flow results for Rumuosi-TS 33kV Feeder/Networks (Base-case). Here, the Airport injection substation received 80% net power while NTA injection substation received 74.31% net power.

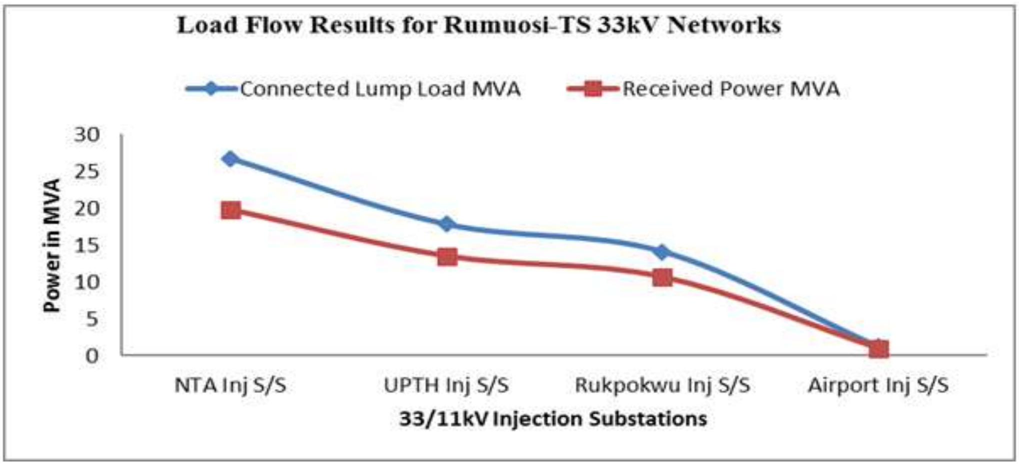

Figure 4.7: Load Flow Results for Rumuosi-TS 33kV Feeder/Networks (Base-case)

4.1.4 Base-case Networks Voltage Profile Results (Rumuosi Sub-TS)

Figure 4.8 shows the voltage profile simulation output for Rumuosi Sub-Transmission Station (base-case) indicating the various bus voltage magnitude and angles at each of the buses respectively. Buses indicating red colour shows that the buses are in critical condition, meaning under voltage experienced.

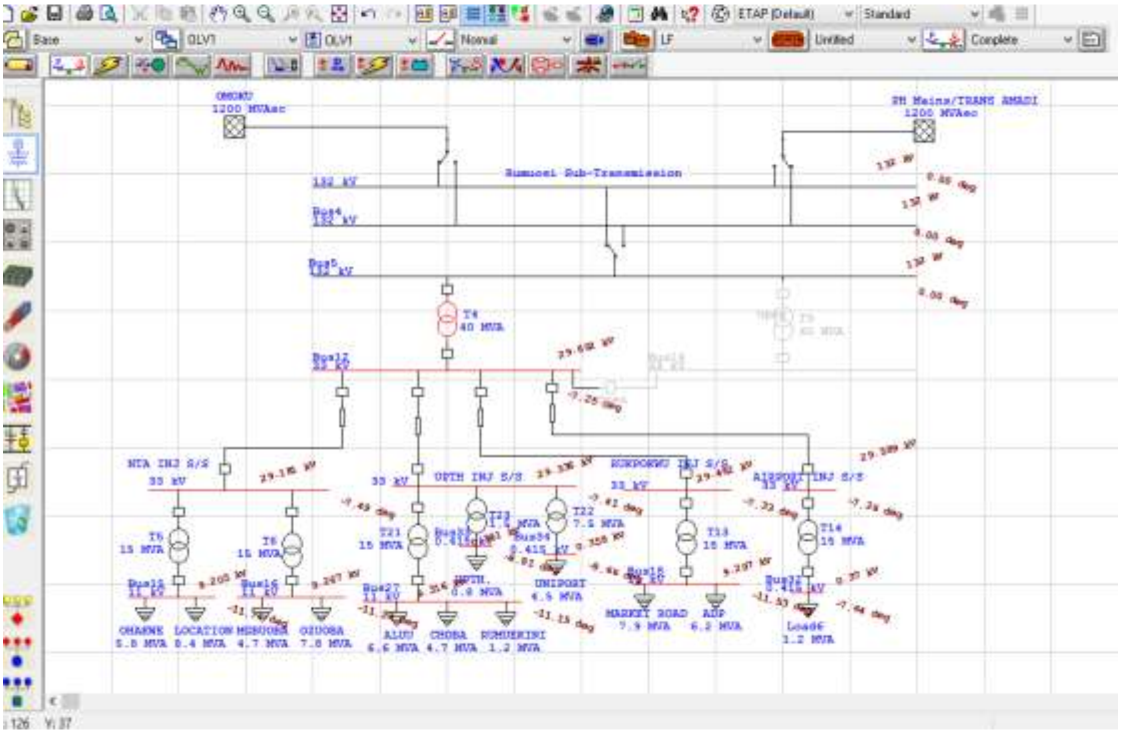

Figure 4.8: Load Flow Simulation Output for Rumuosi Sub-TS (Base-case)

Table 4.5 Voltage Profile for Rumuosi-TS 33kV Feeder/Networks (Base-case)

Base-case Load Flow Voltage Profile at each Bus for Rumuosi-TS 33kV Feeder

Bus ID.	Rated Voltage	Operating Voltage		Bus ID.	Rated Voltage	Operating Voltage	
	kV	%	kV		kV	%	kV
Main Bus 12	33	89.70	**29.60**	NTA Inj S/S	33	88.43	**29.18**
UPTH Inj S/S	33	88.89	**29.34**	Rukpokwu Inj S/S	33	89.28	**29.46**
Airport Inj S/S	33	89.67	**29.59**				

Voltage levels: Under Voltage (**i.e less than 95%**)

Table 4.5 is the voltage profile of all the bus operating voltages for Rumuosi TS 33kV networks. The bus voltages are below the specified limit of 33kV ± 5%.

Figure 4.9 shows the graphical representation of Table 4.5 which shows the voltage profile for Rumuosi-TS 33kV Feeders/Networks (Base-case) with the Main-Bus 12 operating at 89.70% (29.60kV) whereas NTA injection substation received at 88.43% (29.18kV). The characteristic of the networks is under voltage.

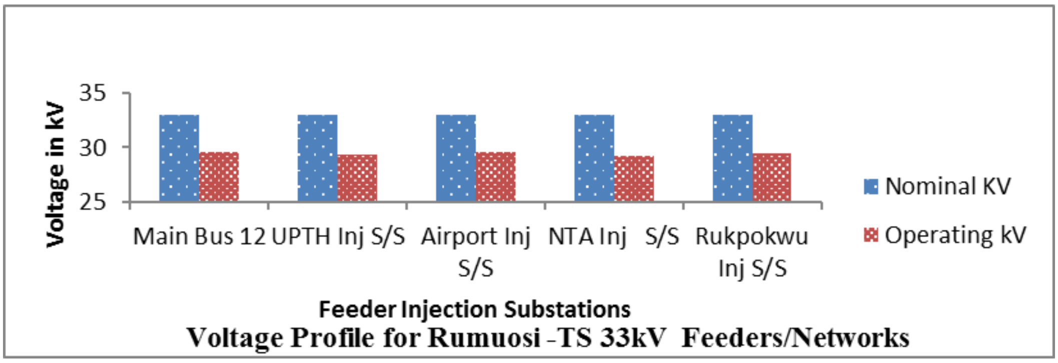

Figure 4.9: Voltage Profile for Rumuosi-TS 33kV Feeders/Networks (Base-case)

4.2 Improved Case Networks

After applying network optimization techniques on the base-case, the networks were reconfigured and upgraded; a new proposed transmission substation was also added. The existing network is provided with two power supply inputs via Omoku Sub-transmission line and Port-Harcourt Mains/Trans-Amadi. Rumuolumeni feeder and UST feeder has been reconfigured into Rumuosi TS to provide adequate and reliable bulk power supply to the Ade-George Axis of Port-Harcourt.

4.2.1 Results of Improved Case Bulk Power Supply (Rumuosi TS)

The improved networks are presented below. Figure 4.10(a) shows the upgraded and improved Rumuosi-TS 132/33kV networks (improved case). The figure showing two sources of power supply via Omoku double lines, and Port-Harcourt Mains/Trans-Amadi power supply axis.

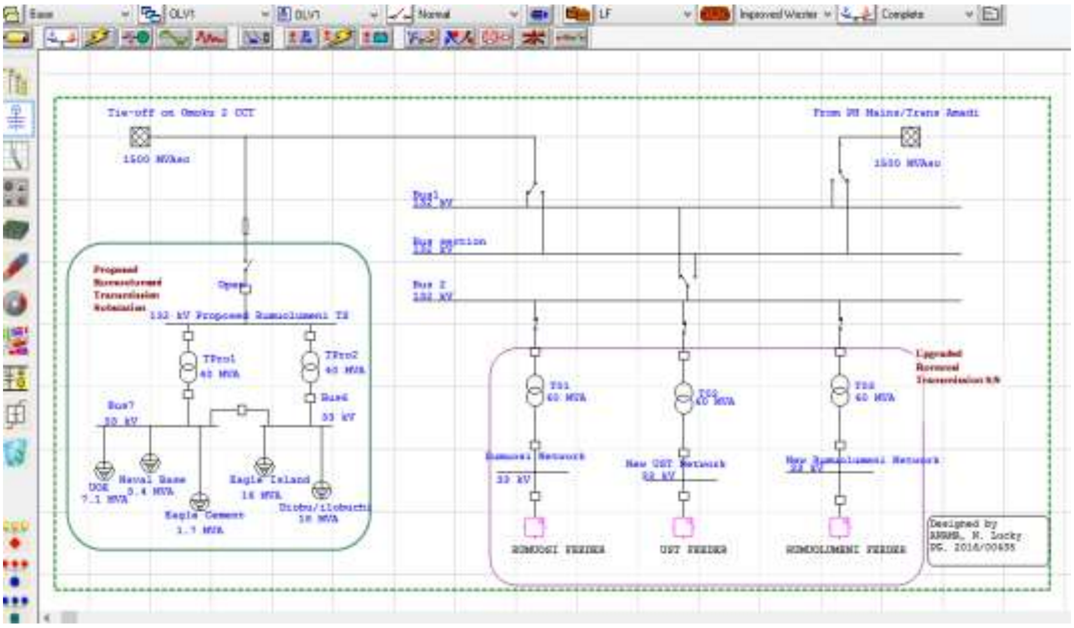

Figure 4.10(a): Upgraded and Improved Rumuosi-TS 132/33kV Networks (Improve case)

Figure 4.10(b) shows the improved case of bulk power supply to Rumuosi-TS 132/33kV distribution networks with a gross power drawn from the grid to a value of 156.1 MVA: Proposed Rumuolumeni TS in closed scenario 47.8MVA, Rumuosi network 46.3MVA, New UST network 35.8MVA and New Rumuolumeni network 36.6MVA.

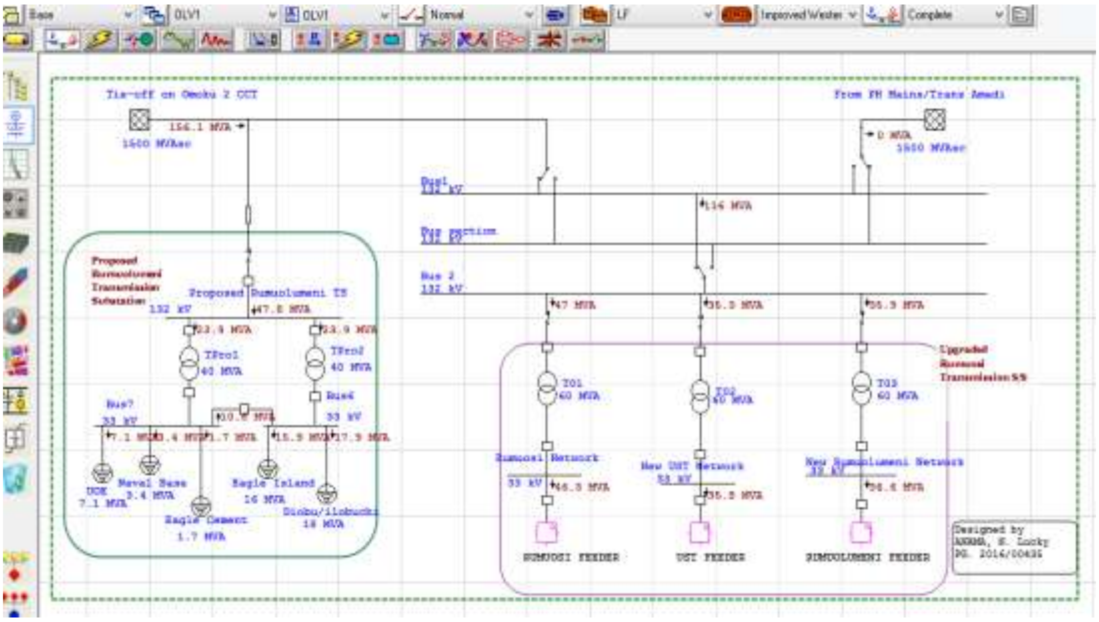

Figure 4.10(b): Bulk Power Supply to Rumuosi-TS 132/33kV Networks with Proposed Rumuolumeni TS in Closed Scenario (Improved case)

4.3 Improved Case Results of New Rumuolumeni 33kV Networks

The improved New Rumuolumeni 33kV networks are presented as follows: The branch and bus power flow and the bus voltage profile

4.3.1 Load Flow Results (New Rumuolumeni 33kV Networks) Improved Case

Figure 4.11 shows the load flow simulation output for **New Rumuolumeni 33kV networks** with a power flow of 36.6MVA; all buses alert indictors are in black colour (improved case).

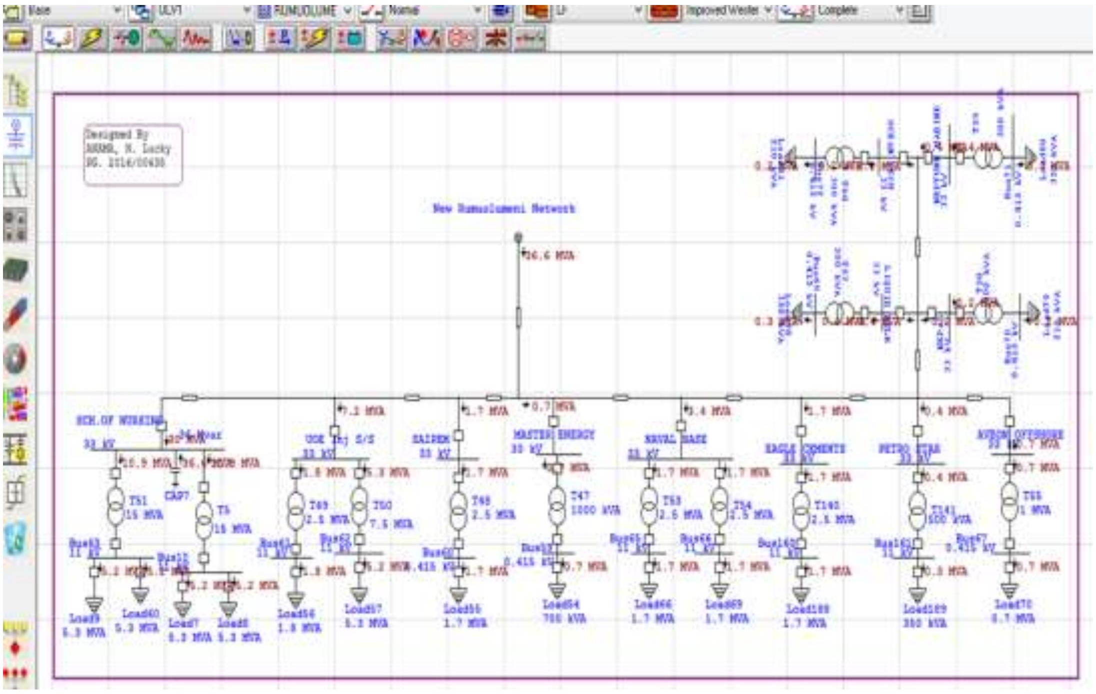

Figure 4.11: Load Flow Simulation Output for New Rumuolumeni 33kV Networks (Improved case)

Table 4.7: Load Flow Results for New Rumuolumeni 33kV Networks (Improved case)

Load Flow for Rumuolumeni 33kV Feeder/Networks (Improved-case)					
RumuolumeniInj S/S	**Connected Lump Load**		**Received NetPower**		**% Received Net Power**
	MVA	%PF	MVA	%PF	%
Sch. of Nursing Inj S/S	**21.2**	85	**20.8**	85	98.11
UOE Inj S/S	**7.1**	85	**7.0**	85	98.59
Saipem Inj S/S	**1.7**	85	**1.7**	85	100
Master Energy Inj S/S	**0.7**	85	**0.7**	85	100
Naval Base S/S	**3.4**	85	**3.4**	85	100
Eagle Cement S/S	**1.7**	85	**1.7**	85	100
Petro Star S/S	**0.35**	85	**0.3**	85	85.71
NEPAS S/S	**0.21**	85	**0.2**	85	95.24
Neptune Marine S/S	**0.35**	85	**0.3**	85	85.71
Aveon Offshore S/S	**0.7**	85	**0.7**	85	100
Liquid Bulk S/S	**0.35**	85	**0.3**	85	85.71
Ocean Tech S/S	**0.21**	85	**0.2**	85	95.24
Total	**37.97**	85	**37.3**	85	98.24
Addition of Capacitor Bank	**36Mvar**		**36Mvar**		100

%PF: Percentage Power Factor

Table 4.7 is the load flow results for New Rumuolumeni 33kV networks (improved case). The total connected lump load is 37.97MVA while the received Net Power was 37.3MVA which means that the supplied power to the connected load have improved from 72.14% to 98.24%.

4.3.2 Voltage Profile Results (New Rumuolumeni 33kV networks) Improved Case

Figures 4.12 shows the voltage profile output for New Rumuolumeni 33kV feeders/networks (improved case). A capacitor bank of 36MVar was added at School of Nursing injection substation to compensate for reactive power loss in the network.

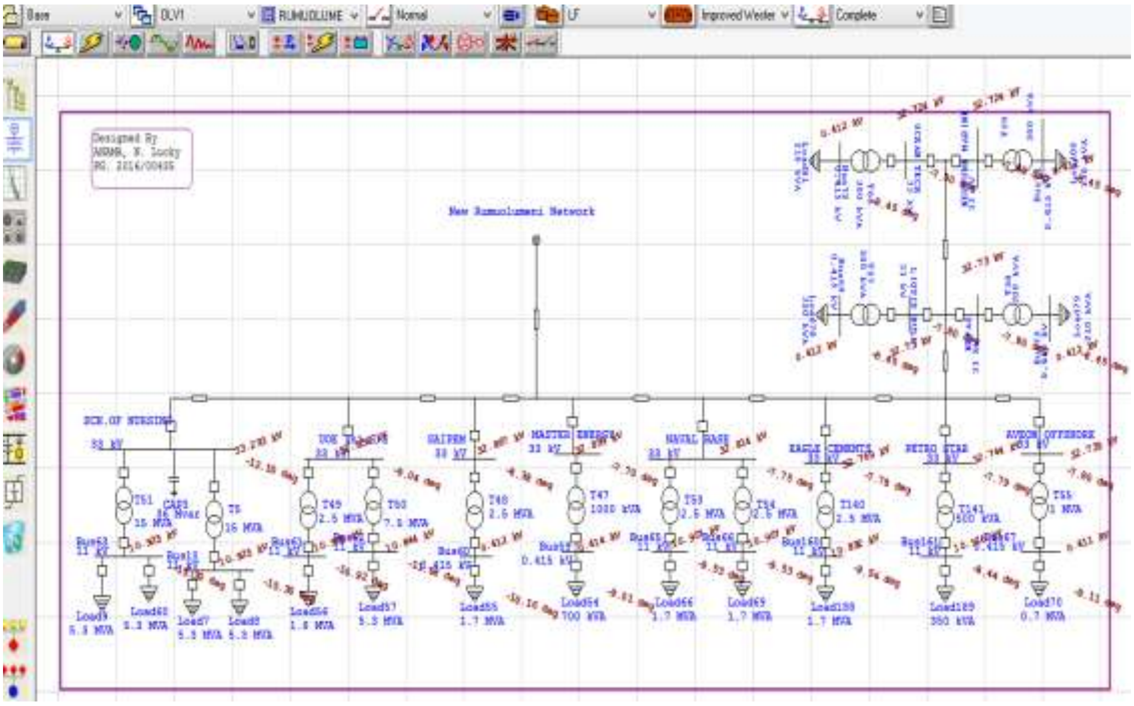

Figure 4.12: Voltage Profile Output for New Rumuolumeni 33kV Feeders/Networks (Improved case)

Table 4.8: Voltage Profile for New Rumuolumeni 33kV Feeder /Networks (Improved case)

Improved Voltage Profile at each Bus for New Rumuolumeni 33kV Networks

Bus ID.	**Rated Voltage**	**Operating Voltage**		**Bus ID.**	**Rated Voltage**	**Operating Voltage**	
	kV	%	kV		kV	%	kV
New Rumuolumeni Network Bus	33	101.3	**33.42**	Sch of Nursing Inj S/S	33	100.87	**33.29**
UOE Inj S/S	33	99.58	**32.86**	Saipem S/S	33	99.61	**32.87**
Master Energy S/S	33	99.67	**32.89**	Naval Base S/S	33	99.42	**32.81**
Eagle Cement S/S	33	99.30	**32.77**	Petro Star S/S	33	99.21	**32.74**
NEPAS S/S	33	99.18	**32.73**	Neptune Marine S/S	33	99.15	**32.72**
Ocean Tech S/S	33	99.15	**32.72**	Liquid Bulk S/S	33	99.18	**32.73**
AVEON Offshore S/S	33	99.21	**32.74**				

No. of Bus= 13; Acceptable voltage limit (33 ± 1.65) kV

Table 4.8 is the voltage profile results for New Rumuolumeni 33kV networks (improved case). All the bus operating voltages have been improved to between 99.15% to 101.3% and are within the acceptable voltage limit.

Table 4.9 Voltage Profile Compensator for 33kV Feeders/Networks

Capacitor Banks Installed

Location ID	**Rated Q- power**		**Operating Q-power**	
	MVar	**Max kV**	**MVar**	**kV**
Rumuosi Network Bus	30	34.5	29.6	33.39
RSU Inj S/S	36	34.5	35.2	32.63
Sch of Nursing Inj S/S	36	34.5	36.0	33.29

Table 4.9 presents the voltage profile compensators used for the 33kV feeders/networks with an operating Q-power of 29.6MVar (connected bus voltage 33.39kV), 35.2MVar (connected bus voltage 32.63kV) and 36.0MVar (connected bus voltage 33.29kV). This capacitor enhances the voltage profile of the respective networks. The generated reactive power at the generation end transmitted to load centres is not adequate therefore it is necessary in power systems.

Table 4.10: Summary of Bulk Power Supply to Rumuosi –TS 132/33kV Networks

Bulk Power Supply to Rumuosi –TS 132/33kV Networks (Improved case)

Bulk S/S	**Transformer Used**	**Connected Lump Load**		**Net Received Power**	
		MVA	%PF	MVA	%PF
Rumuosi S/S	**60MVA, 132/33kV**	**53.8**	85	**52.7**	85
New UST S/S	**60MVA, 132/33kV**	**40.2**	85	**38.1**	85
New Rumuolumeni S/S	**60MVA, 132/33kV**	**37.97**	85	**37.3**	85
Total	**180MVA**	**131.97**	85	**128.1**	85

Table 4.10 shows the summary of the bulk power supply for Rumuosi –TS 132/33kV networks with a total connected load of 131.97MVA and improved received power 128.1 MVA at a power factor of 0.85 (109MW). The networks experience some losses due to transformer constant and variable losses, as well as network feeders (conductors) I^2R losses.

V. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The new arrangement with upgrade of the Rumuosi sub-transmission substation provides the appropriate feeders/networks with adequate power supply; the substation is fed from either Omoku transmission lines (single circuit) or from the Port-Harcourt Mains/ Trans-Amadi lines with a required power of approximately 142MVA (120.7MW +j74.80MVar**)** with New Rumuolumeni Network 38 MVA, New UST Network 41MVA and Rumuosi Network 54MVA from the total connected loads point of view.

The various bus voltages under the base-cases were under voltage, below 95% of the nominal bus voltage and were improved above 95% (31.35kV) of the nominal bus voltage. The acceptable voltage limit is

(33kV ± 5%) at the receiving end. The 11kV networks are considered as lump load on 33kV feeders. The tee-off on the Omoku transmission lines to the proposed Rumuolumeni 132/33KV Transmission station will provide for expansion and for future growth to the neighbouring communities.

Three capacitor banks (1x 30MVar, 1x 36MVar and 1x 36MVar) were added to the respective networks to improve the reactive power loss thereby improving the bus voltage profile.

5.2 Recommendations

To provide adequate bulk power supply to Ada- George axis the following recommendations are to be carried out:

i. The Rumuolumeni and UST feeders at the 132/33kV Port-Harcourt Town (Zone 4) should be reconfigured to 132/33kV Rumuosi sub-transmission substation for better performance of the networks.
ii. The 132/33kV Rumuosi sub-transmission substation existing 40MVA transformer should be replaced with 60MVA; the uncommission 60MVA transformer should be commissioned and additional 60MVA transformer be added to the sub-transmission substation.
iii. The transformers at the sub-transmission substation should not exceed 70% maximum loading.
iv. Integration of 3 No. capacitor banks, each with a maximum rating of 36MVar, 34kV at the respective feeders/ networks. One capacitor bank per network is recommended.
v. The old and new 33kV feeders' right of way should be adjusted for smooth operation of the networks.
vi. The proposed 2 x 40MVA new Rumuolumeni sub-transmission substation should be put in place for loads transfer and future growth of the neighbouring communities.
vii. Without adequate power generation, there will be insufficient power transmitted to heavily loaded centres therefore; we recommend additional generation of power at the Omoku Power generation station.

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