American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-8, Issue-3, pp-229-238
www.ajer.org
Research Paper Open Access

Analysis of Electrical Power Supply to Eagle Island,Portharcourt for Improved Distribution

Inaania,Temple G.[1],Idoniboyeobu D.C[2] And Braise,S.L[3]
[123]*Department of Electrical Engineering, Rivers state University,Port Harcourt,Nigeria.*
Corresponding Author: INAANIA,Temple Gobari

ABSTRACT: *This dissertation considered the analysis of load flow, voltage drop, active and reactive power flow from Rivers state University substation injection substation to Eagle Island. Evidently the investigation shows that some of the feeders are currently overloaded and as such is characterized by low voltage profile and poor power factor. However, the existing data collection from Port Harcourt Electricity Distribution Company (PHED) was used for the study case in a bid to investigate and ascertain the level of voltage drop via electrical analyzer tool (E-Tap12.60) version so as to know the buses that are marginally or critically loaded in order to compensate the affected feeder for the purpose of improving network stability performance. The result of the existing network shows that the cables at buses 3 and 4 are marginally loaded while the feeders at buses 15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,and 31 are also marginally loaded. In the same vein the feeders on buses 32,33, and 34 are critically loaded and as such needs urgent attention. To address the problems, capacitor bank of 1200KVAR was introduced at buses 28 and 31 respectively so as to compensate the network in a view to improve the voltage profile and stability. This means that the application of capacitor bank, additional transformers to the existing network will seriously enhance effective performance .The simulation of the existing case and the compensated network shows that the improved voltage profile, active and reactive power are within the statutory limit of +5% or 0.95-1.05pu of the declared voltage as recommended by IEEE regulation.*

KEYWORDS: *Capacitor bank, voltage profile, voltage drop, voltage regulation technique, voltage stability, distribution network, transmission, bus-bar.*

Date of Submission: 25-02-2019 Date of acceptance: 18-03-2019

I. INTRODUCTION

An Electric Power System consist of the Generating station, Transmission station and Distribution stations respectively. Electrical power is transmitted by high voltage transmission lines from sending end station to receiving end substation. At the receiving end substation, the voltage is been stepped down to a lower value (say 11KV or even 33KV) as the case may be.Distribution substations connect to the transmission system and lower the transmission voltage to medium voltage with the use of transformers. The primary distribution line carries this medium voltage power to the distribution transformers located near the customers' premises. Distribution transformers again lowers the voltage to the level suitable for household utilities and hence feed several customers through the secondary distribution lines (distributors) at the same voltage.

Residential and commercial customers are connected to the secondary distribution lines through the service drops. Although electrical power customers in need of higher amount of power may be connected directly to the primary distribution line or the sub transmission level.However, in Nigeria the limiting factors to efficient and reliable power supply apart from low power generation may include: poor or inefficient voltage control system, poor transmission networks, highly overloaded transmission feeders due to lack of planning, faulty distribution system on the part ofthe electrical supplier (PHED), voltage drop along the line and from the distribution system due to the flow of current and load variation on the consumer end, damage to substation, transmission and distribution network, short circuit or over loading of electrical mains and tripping of power system. These factors has resulted to unreliable voltage variations and frequent power outages[15]. In this study, voltage drop/ voltage regulation technique and load flow analysis method was used to analyze the existing electrical power supply to Eagle Island Port Harcourt for the purpose of improvement.

Eagle Island is a small community located near Nigeria Agip Oil Company in Port Harcourt Rivers State, Nigeria. Electricity is being supplied to Eagle Island from the 11KV UST feeder located in the premises of RSU Port Harcourt. However, challenges emerge as the city expands and low voltages are experienced in some areas which led to the installation of transformers without planning, resulting to overloading of the feeder and also drop in voltage due to the distance covered by the transmission line which serves the area. Despite these challenges, there is the insufficient supply of power from the transmission station to the study case.

II. REVIEW OF PAST WORKS

Load Flow Analysis Using ETAP Software for Network Simulation

[18]In their work on load flow analysis to investigate the performance of electrical system during normal and abnormal operating conditions, provided information needed to: minimize MW and MVAR losses; optimize circuit usage; develop practical voltage profiles; develop equipment specification guidelines and identifies transformer tap settings.

Power Flow Analysis of Abule-Egba 33KV Distribution Grid System with Real Network Simulations

[1] model and doing simulation are methods used to overcome the computational problems of power flow solution using load flow iterative technique such as Newton.-Raphson and Gauss-Seidel, In their view they stated that the very low bus voltages and poor power magnitude obtained from their study without voltage compensation at Agbefa 11KV feeder emphasize the reality of the epileptic poor power supply at the Abule-Egba part of Lagos State, Nigeria

Impact of Distributed Generation on the Quality of Power Supply in Nigeria; Port Harcourt Network Case Study

[4] in their work considered the impact of distributed generation (DG) on the quality of electricity supply in Port Harcourt network. They gave account on the impact of both the present and the future load demand. In achieving this, power flow analysis and continuous power flow (CPF) optimization method was used to achieve the simulation. The simulation was done using MATLAB 7.9 Power System Analysis Toolbox (PSAT) Simulink environment to analyze the network. The result shows that the dispersion level of DG's among the buses increases, there was a very remarkable improvement in the voltage profile, real and reactive power and load ability of the network.

Load Flow Analysis of Port Harcourt Electricity Network by Fast Decoupled and Newton -Raphson techniques

[15] in their work on Load Flow Analysis of Port Harcourt Electricity Network by using Fast Decoupled and Newton-Raphson methods showed that the power dispatched from the national grid network to the transmission substations were inadequate, and as such each injection substation had high percentage of loading of the power available.

MATERIALS

The power supply network of 33/11KV from Rivers State University of Science and Technology (Now Rivers State University) shall be collected from Port Harcourt Electricity Distribution Company (PHEDC) including the single-line diagram, line parameters etc for the purpose of Analysis and investigation of the existing system performance.

METHODS

Voltage-drop/voltage-regulation technique will be used in the analysis and verification of the voltage profile power losses and mismatches for Eagle Island distribution feeder. Primary data were collected which serves as the input source to the activity of the distribution feeders, which are also analyzed on Electrical Transient Analysis program tools (ETAP V. 12.60) environment. The existing input data are used on the analysis of distribution network, in order to obtain predicted result. The method also considered the application of capacitor bank where applicable in order to improve the voltage profile of the network.

III. DESIGN CALCULATION OF CAPACITOR BANK

The calculation and the analysis of the size of capacitor bank to used is a major tool for power improvement, therefore power electronic device (capacitor bank) will help to control, regulate and compensate for power loss, reactive power losses and voltage profile inadequacy.

Presentation of collected data from RSU substation:
The following data were collected
i. System capacity = 2 x 15 MVA
ii. Total Apparent power (S) =5450KVA
iii. Present power factor $(Pf)_1$ = 0.8
iv. Desired Power factor $(Pf)_2$ = 0.9
v. Received line voltage = 33KV
vi. Sending end line voltage (Vs) = 11KV
vii. System frequency (f) = 50Hz

IV. ANALYTICAL FORMULATION AND DATA PROCESSING

The analytical formulations are presented as follows:
Recall that $S \times Pf = 5450 \times 0.8 = 4360KW = 4.4MW$

But Total $S_1 = 5450\ KVA = 5.5MVA$

Recall that Power factor (Pf) $= \frac{\text{Actual power (P)}}{\text{Apparent Power (S)}}$

Rearranging the Equation above we have

$$S = \frac{P}{Pf}$$

But

Present demand (S) = $\frac{\text{Present Load (P)}}{\text{Present power factor (Pf)}} = (M_{VA})_1$

Determination of Present S_1 demand

Present, S (demand) = $\frac{4.4MW}{0.8} = 5.5$

$\therefore \quad S_1 = 5.5$

i. Determination of desired MVA demand $(MVA)_2$ Desired or proposed power factor when raised to 90% using the equation above we have

Desired MVA demand = $\frac{\text{Present (P)}}{\text{Desired power factor } (Pf)_2} = (S)_2$

$$S_2 = S_2 = \frac{4.4MW}{0.9} = 4.89$$

ii. Determination of Reactive Power (Q) size required for compensation as a result of voltage drop is given as:
Q = Size of Reactive power required

Hence,
Using the first principle of power triangle, Pythagoras's principle

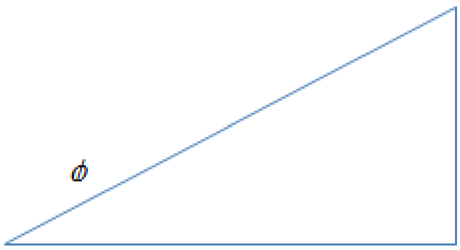

Fig 3.1 Power triangle

$$S^2 = P^2 + Q^2$$

$$Q^2 = S^2 - P^2$$

Q = $\sqrt{S_1^2 - P_1^2}$ (for 80% Power factor)

Where

$S_1 = 5.5$; $P_1 = 4.4$

Q = $\sqrt{(5.5)^2 - (4.4)^2}$ = $\sqrt{30.25 - 19.36}$

∴ $Q_1 = 3.3$

Q_2 = $\sqrt{S_2^2 - P_2^2}$

Where

$Q_2 = 4.89$; P = 4.4

From collected data

$P_1 = P_2 = 4.4$

Thus:

Q_2 = $\sqrt{(4.89)^2 - (4.4)^2} = \sqrt{23.9121 - 19.36}$

∴ $Q_2 = 2.133$

Hence, Reactive power rating becomes: Q = $Q_2 - Q_1$

Q = 2.133−3.3

Q = - 1.167MVAR = 1200KVAR

It is important to note that the negative sign represents lagging power factor.

iv Determination of capacitive reactance per phase of the capacitor bank.

Collected value from RSU substation

Line voltage (V_L) = 11KV

Capacitor current capacitor bank is L_{LC}

I_{LC} = $\frac{Q}{\sqrt{3}V_L} = \frac{1200}{\sqrt{3 \times 11 \times 10^3}}$ = 0.0629A

Phase current capacitor bank I_{ph}

I_{ph} = $\frac{I_{Lc}}{\sqrt{3}} = \frac{0.0629}{\sqrt{3}} = 0.036\,A$

The capacitive reactance is X_C and X_C = $\frac{V_L}{I_{ph}}$

Where X_C is capacitive reactance

V_L is the line voltage

I_{ph} is the phase current to the capacitor bank

Thus X_C = $\frac{V_L}{I_{ph}} = \frac{1200}{0.036}$ =33333.3 Ω /phase

(v) Determination of the capacitance per phase of the capacitor bank:

From X_C = $\frac{1}{2\pi fc}$ we have

Capacitance C = $\frac{1}{2\pi f X_C}$

Where f = Frequency

C = Capacitance

π = 3.142

Thus, Capacitance, C $\frac{1}{2\pi f X_C}$

C = $\frac{1}{2\pi \times 50 \times 33333.3}$

= $9.54\text{x}10^{-6}$F = 10 μF

Therefore, the value of capacitor bank per phase is 10 μF

(vi) Determination of correction factor that will correct or improve the existing power factor to a desired level (according to appendix A). The corresponding multiplying factor that covers the range of existing power factor and the desired power factor ie 80% to 90% is given as 27

Multiplication factor given as: $\frac{\text{value from the table}}{100} = \frac{27}{100} = 0.27$

Multiplication factor (mf) = (0.27)

The capacitor bank reactive power rating becomes MVAR = Multiplying factor (mf) x Load power demand (MW)

= 0.27 x4.4= 1.188MVAR = 1200 KVAR.

From the analysis it is clear that the correction factor corresponds to the previously calculated capacitor bank sizing.

Thus, the recommended capacitor bank reactive power rating needed to improve the power required to match 4.4MW is 1200KVAR on buses (28, and 31) respectively so as to enhance voltage upgrade and improved performance

V. RESULTS AND DISCUSSION

Fig 3.2 shows the schematic line diagram of the network when modeled using an E-Tap 12.60 version.

Fig 3.3 shows the schematic line diagram of power supply network when simulated via ETAP. From the simulation it showed that the cable at buses 3, and 4 showed a pink colour which simply means that the cables are marginally loaded. Similarly buses 15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30 and 31 also flagged a pink colour which signifies that the feeders on that buses are marginally overloaded and as such requires attention so as to avoid a total collapse in the future. But however buses 32,33,and 34 indicated a red colour which simply means that the buses are in critical condition and needs urgent attention so as to avert loss of losses both to service providers and consumers.Evidently, the study had shown that the network is marginally loaded which is indeed is tolerable to a certain extent but needed urgent measures to be taken so as to avert breakdown.

Fig 3.4 shows the improved state of the network with the introduction of capacitor bank compensator of 1200KVAR at bus 28 and 31 respectively. The introduction of thecapacitor bank cleared the numerous violations at the various parts of the network and as a result improved the power quality, voltage profile and power factor of the network

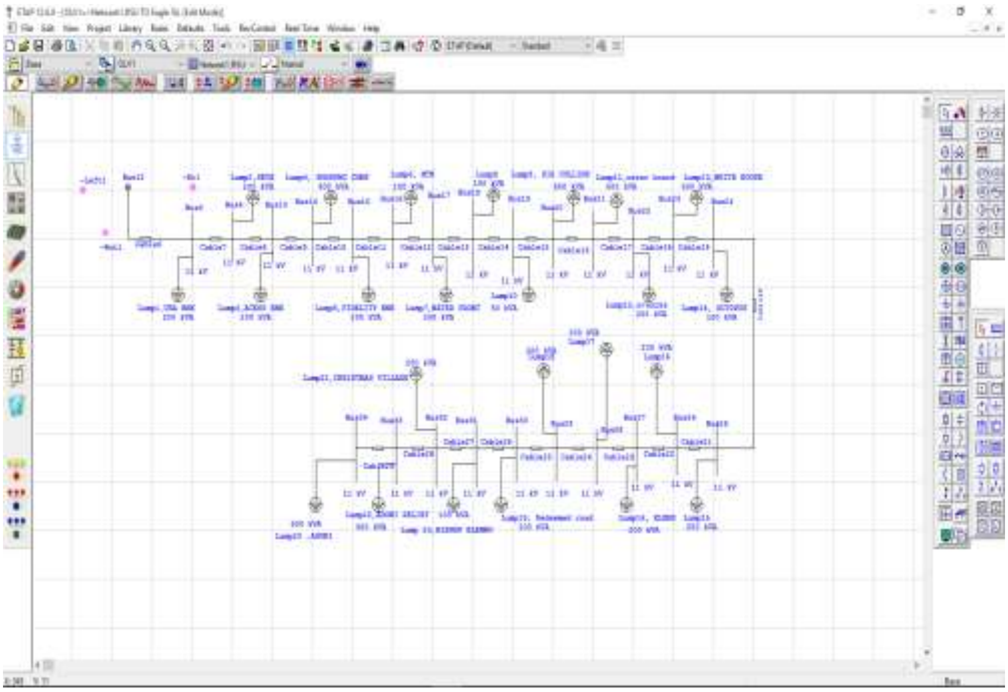

Figure 3.2 Schematic Line Diagram of Power Supply Network of Eagle Island (Not Simulated)

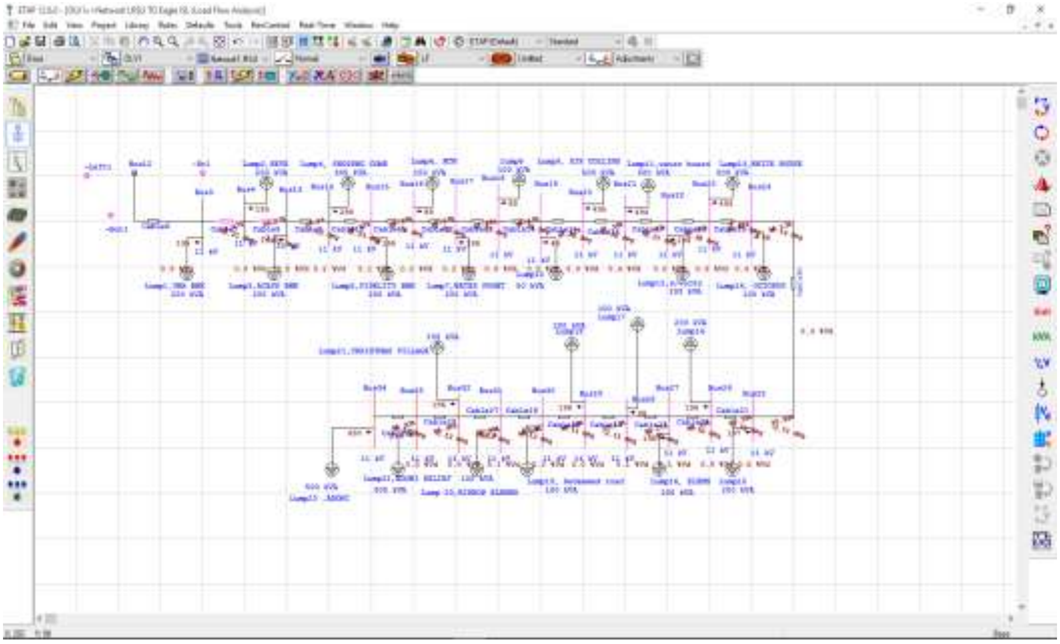

Figure 3.3 Schematic Line Diagram of Power Supply Network of Eagle Island (Simulated)

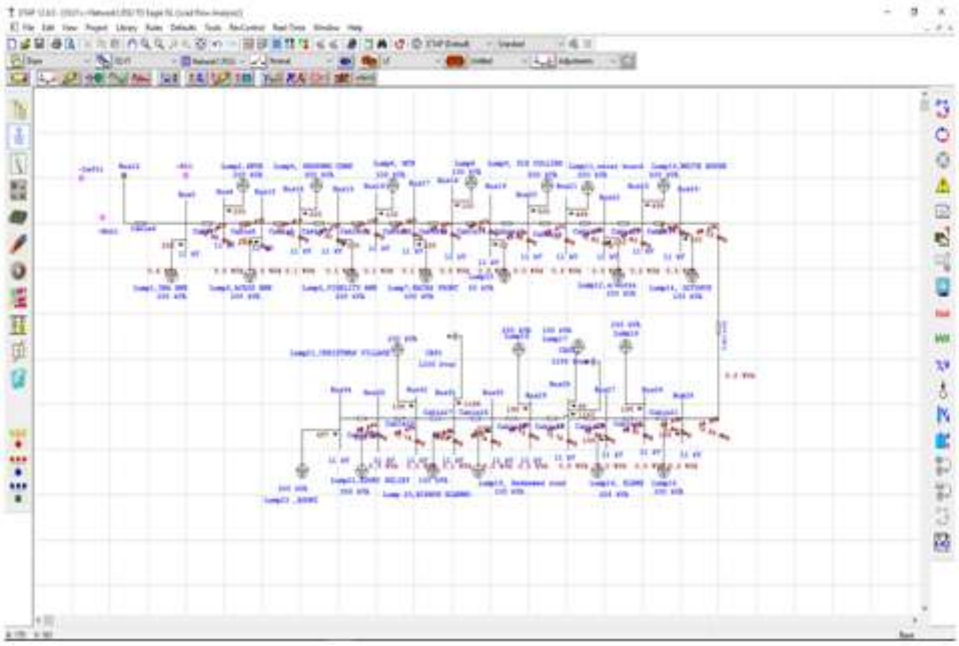

Figure 3.4: Schematic Line Diagram of the Study Case (Eagle Island): Improved Network with Compensation of Capacitor Bank. (FACTS Controller)

Table 4.2: Bus Voltage Percentage against Bus Voltage Number

Bus- voltage Number	Bus voltage Percentage
Bus-21	95.68
Bus-22	96.05
Bus-23	96.89
Bus-24	97.86
Bus-25	97.76
Bus-26	98.02
Bus-27	97.62
Bus-28	94.66

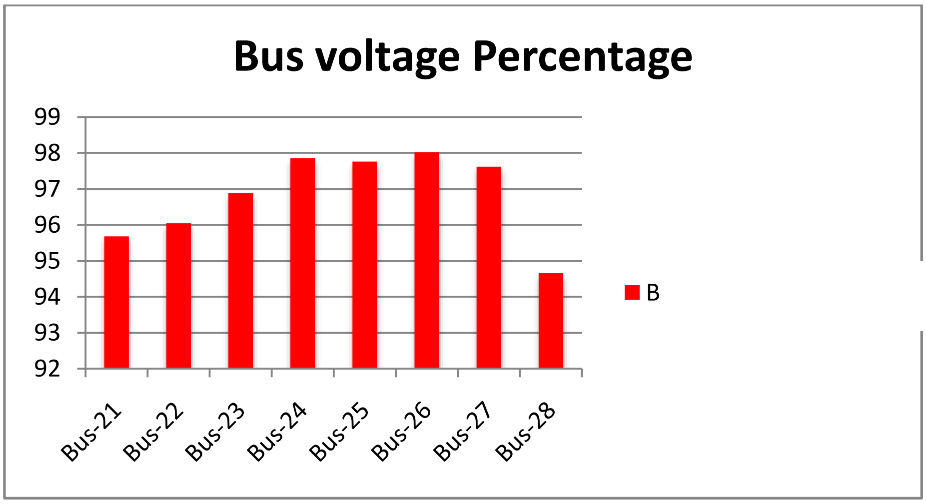

Figure 4.2:Plot of Bus Bar Voltage Percentage Vs Bus Voltage Number

This graph representation depicts the percentage loading profile of bus 21- bus28 of the existing network before compensation. From the above result bus bar 26 which is 98.02% seems to be the only normally loaded bus bar while bus bar 21, 22, 23, 24, 25, 27 and 28 are all marginally loaded.

Table 4.3: Bus Voltage Percentage Against Bus Voltage Number

Bus voltage Number	Bus voltage Percentage
Bus-29	96.88
Bus-30	97.63
Bus-31	97.86
Bus-32	96.54
Bus-33	97.52
Bus-34	74.6

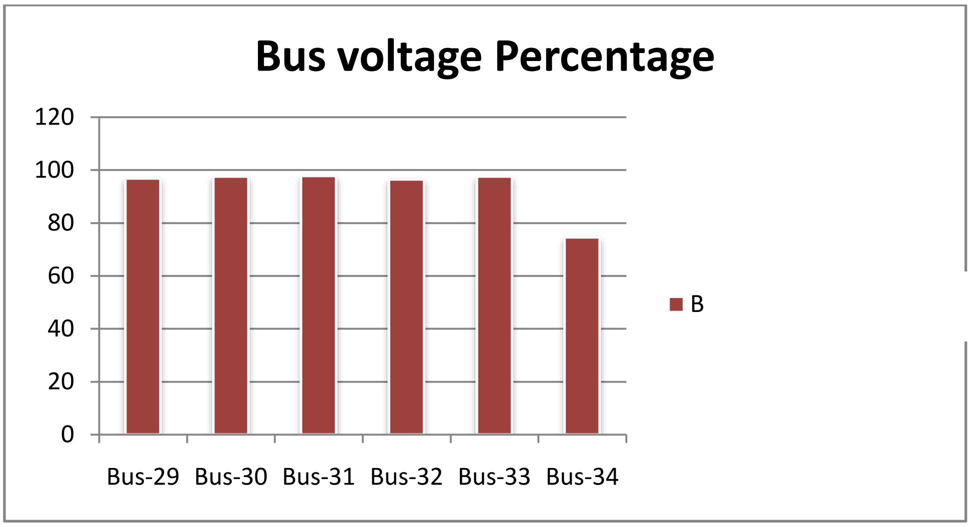

Figure 4.3: Plot of Bus Bar voltage Percentage VS bus voltage Number

This graph shows the percentage level of voltage at bus bar 29-34 before improvement from the result all the bus bar are marginally loaded because they are less 98% loading, and hence needs improvement to avoid breakdown in the future.

Table 4.5: Bus% Voltage (Existing) and Bus% Voltage(Improved) Vs Bus Voltage Number

Bus- Voltage Number	Bus Voltage Percentage (Existing)	Bus-Voltage Percentage (Improved)
Bus-21	95.68	100.36
Bus-22	96.05	99.8
Bus-23	96.89	99.78
Bus-24	97.86	99.29
Bus-25	97.76	99.13
Bus-26	98.02	98.69
Bus-27	97.62	98.68

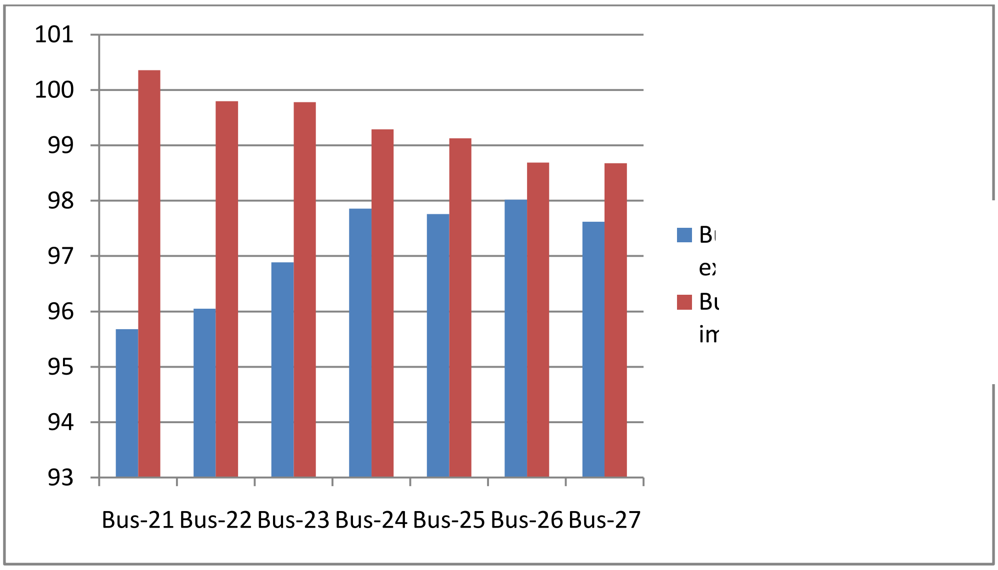

Figure 4.5: Plot of Bus Bar %Voltage (Existing) and busbar %Voltage (Improved) Vs Bus Voltage Number

This graph depicts the existing voltage percentage before improvement and after improvement. Before improvement the voltage profile at bus 21 was at 95.68% but after the introduction of the capacitor bank it increased to 100.36%.

Table 4.6: Bus Voltage Percentage (Existing) and Bus Voltage Percentage (Improved) Against Bus Voltage Number

Bus voltage Number	Bus voltage Percentage (Existing)	Bus voltage Percentage (Improved)
Bus-28	94.66	98.66
Bus-29	96.88	98.65
Bus-30	97.63	98.63
Bus-31	97.86	98.62
Bus-32	96.54	98.54
Bus-33	98.52	98.52
Bus-34	94.6	98.52

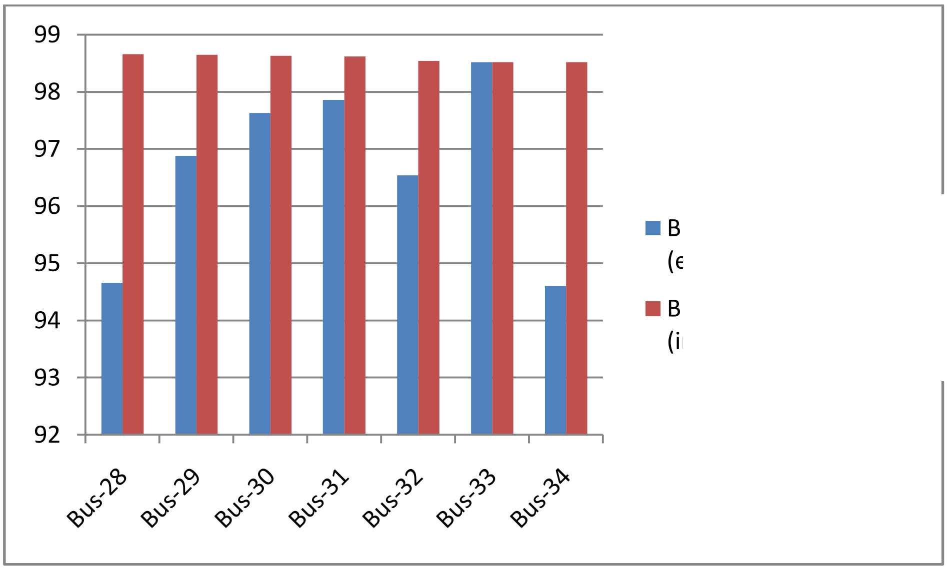

Figure 4.6: Plot of Bus Bar Voltage Percentage (Existing) and Bus Voltage Percentage (improved) Vs Bus Voltage Number

This graph shows the degree of improvement of the voltage profile of the existing network before improvement and after improvement. From the simulated result, bus 28 and 34 were not in a good condition because their voltage profile was 94.66% and 94.6% respectively but after improvement it increased to 98.66% and 98.52% respectively.

VI. CONCLUSION AND RECOMMENDATION

Conclusion

In conclusion, haven examined the existing state of the electrical power network at Eagle Island 11KV distribution network taking its power supply from Rivers State University 331/11KV Injection substation. The study engaged optimization strategy as a way of improving system overload by determining the optimal sizing of capacitor bank required to improve the specific bus overload problem on the network in a view to enhance power quality, voltage profile and power factor.

The penetration of sized capacitor bank at the affected buses improved the voltage profile and performance on the network.This is a standard practice and a requirement that the bus voltage in the distribution network shall not be deviated beyond the standard acceptable value of 0.95-1.05pu in order to satisfy statutory regulations and policy practice.

Recommendation

Based on the findings, the following recommendations are highlighted to ensure optimum performance and reliability of the 11KV distribution network.

1. Additional 500KVA transformers should be added in the network especially to the affected buses; bus 28 and 31 respectively.
2. Replacement of undersized cables in the network.
3. Integrating capacitor bank compensator where necessary in order to reduce voltage instability problems, electricity cost due to excessive losses.

REFERENCES

[1]. Abduikareem, A., Awosope, C. O. A., Orovwode, H.P., Adekakum, A.A (2014). Power Flow Analysis of Abule-Egba 33KVDistribution Grid System with Real Network Simulations. OSR Journal of Electrical and Electronics Engineering 2(9) 6740.

[2]. Afolabi, O.A., All, W.H., Colic, P., Fulier, J. Obiomon, P. & Kolawole, E. S (2015). Analysis of the Load Flaw Problem in Power System Planning Studies. Energy and Power Engineering, 7(10), 509-523.

[3]. Ahmed, A.S.H (2013) Simulation and Modelling of Detailed Load Flow Analysis for the 4OKVand 132KVA Iraqi Grid, .Joumal of Engineering, 19(10) 1-14.

[4]. Ajabuego, O. G. Okafor, P.C. N; lzueghunsm F., Otubiwe, M. (2017). Impact of Distributed Generation on the Quality of Power Supply in Nigeria; Port Harcourt Network Case Study.

[5]. Aroop, B., Satyajit, B. & Sanjib, H. (2014). Power Flow Analysis on IEEE 57 Bus System Using Matlab, International Journal & Engineering Research Technology. http://dx.dol.oro/10.4236/epe.2015.710048

[6]. Barboza, L, Dimuro, G. & Reiser, R. (2004). Power Flow with Load Uncertainty. Tendecias em Matemética Aplicada e computational, 5(l). doi:10.5540/tema.2004.05.01.0027.

[7]. Barboza, L. Dimuro, G. Reiser, R. (2004). Power flow with load uncertainty-Tendénicias em Materńatica Aplicada e computational, (1).

[8]. Billintton, R. & Allan, I. N., (2010). Concepts of Data for Assessing the Reliability of Transmission and Distribution Equipment, 'The Reliability of Transmission and distribution Equipment. 29-31, conference publication N0.406,IEEE, 2010,pp 1-6.

[9]. Brown, N.E (2013). Solution of large Network by Matrix Method, 2nd ed, Baghdad: JOHN WIELY & SONS, INC.

[10]. Chen, P., Chen, 7. & flak-Jensen, 8. (2008). Probalistic Load Flow: A Review 2008 Third International Conference in Electric Utility Deregreletion as restructuring and Power Technologies, doi: 10.11 09/drpt, 2008.4523658,doi:10.5540/ tema.2004.05.01.0027

[11]. Elgerd, OJZ (2012). Electric Energy System Theory. An introduction (2nd ed.) New York: Mo-Graw-Hill.

[12]. Gupta, J. B (2014). A Course in power System 15th Edition, S. K. Kararia and Sons, 4760-6123, Arisari Road Daryagani., New Delhi, India.

[13]. Hart, H. I (2018). Sustainable Electricity Generation in Nigeria: of Enthalpy, Entropy, Energy and all that, not politics. An Inaugural Lecture. Series No.53.

[14]. Hart, H.I (2012). A framework for Efficient and sustainable power Delivery in Nigeria. Mechanical Engineers distinguished lecture (MEDL), Nigeria institute of Mechanical Engineering, Port Harcourt, Nigeria.

[15]. Idoniboye Obu, D. C., Ibeni C. (2017). Analysis for electrical Load flow studies in port Harcourt Nigeria, Using Newton Raphson Fast Decoupled Techniques. American Journal of Engineering Research, e-ISSN: 23220-0847 P-ISSN: 2320-0936 Volume -6, Issue – 12, PP- 230 240 www.ajer.org.

[16]. Izucgtunam, F. L., Duruibe, S.I. & Ojukwu G.G (2011). Power Flow and Contingency Assessment Simulation on the expanding 330KV Nigeria Grid Using Power World Simulator, Journal of Emerging Trends on Engineering as Applied Science 2, 1002- 1008.

[17]. Jabr, R. A, Singh, It, & Pal, B.C (2012). Minimum Loss Network Reconfiguration (Jing Mixed-Integer Convex Programming. IEEE Transactions on Power Systems, 27(2) 1106—1115.

[18]. Jayaprakash, J; Angelin, P. M; Jothilakshmi, R. & Juanola, P. J. (2016). Planning and Coordination of Relay in Distribution System using ETAP. Pakistan Journal of Biotechnology, 13(5), 252-256.

INAANIA,Temple Gobari" Analysis of Electrical Power Supply to Eagle Island,Portharcourt for Improved Distribution" American Journal of Engineering Research (AJER), vol.8, no.03, 2019, pp.229-238