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OPTIMIZATION OF EGI-CLAN 33KV POWER DISTRIBUTION SYSTEM FOR IMPROVED PERFORMANCE

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Abstract

Power flow algorithms and Newton Raphson load flow solutions were used to examine the sensitivity of buses/feeders existing status with the consideration with variations of power loading conditions, conductor length, the total capacity distribution transformers. This is used to ensure that electrical power transfer from generator to consumers through the grid system is considered. The flow of reactive power to the consumer components system is seriously an important consideration for efficient, an acceptable quality of services to the consumer satisfaction. Numerical data of the study case were implemented to the existing formulated equations for purpose of improving system overload condition under investigation, buses 10 and 12 shows significant overstressed transformer overloads results into regular outages in the study area. The existing system were actually modeled with electrical transient analyzer tool with version 12.6, the identified overloads buses of 10 and 20 were actually compensated by the penetration of 700MVAR reactive power compensation. Essentially, about 12% significant improvement of the power quality and voltage profile were determined which strongly enhanced effective power supply characteristics to the study case under study. This paper has demonstrated existing and improved scenario to ensure reliable power supply to the consumer satisfaction.

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

1.0 Introduction

Availability of stable and reliable power supply is the prerequisite or key indicator for determining the socio-economic and technological development of any country (Gupta, 2006). In Nigeria, the supply of electricity is not commensurate to the demand. Consequently, this has steered the management of power utility company in resulting to load-shedding as an alternative means to mitigate this challenge. According to many studies, the distribution system is the most visible part of power system infrastructure and exposed to critical observation by its users has suffered electricity deficit which has led to the collapse of so many small scale businesses and loss of revenue by the government. About 13% of the generated power is consumed as losses at the distribution level. Consequently, many households and commercials uses generators to meet their daily electricity demand (Amesi, 2016).

The growing rate of energy demand and electric power supply particularly in Egi-Clan Distribution network in (ONELGA) Rivers State has necessitated the consideration of many variables due to micro economic activities in the area.

- 1. Overloaded the existing distribution transformers
- 2. Caused black-out due to consistent tripping of line parameters congestion

1.1 Objective of Assessment

The objectives of this work are:

- 1. Formulate load flow equations to represents the activities of the network under study.
- 2. Collect of numerical data to implement into formulated equations.
- 3. Model the existing network under study for purposes of investigation
- 4. Simulate existing model distribution network and identify violated buses, transformers, feeders, line etc.
- 5. Optimally size and determine power electric controller capacity (either static var, capacitor bank etc) for purpose of providing for improvement of power quality to the affected zone and component under investigations.

2.0 Literature Review

Adeba, (2016) focused on the study of distributed generation in enhancing the power system reliability. From the research carried out in Addis center substation, it was noted that the substation suffers consistent power outage due to earth fault in the substation. It was further review that the average interruption duration falls below statutory condition. However, in other to enhance the reliability of the distribution network, a distributed generation of 3.5MW was incorporated to the power as a back-up when interruption occurs.

Adegboye (2010) in his research, analyzed the number, type, and duration of the outages that occurred on five (5) 11kV distribution feeder. From the daily outage data collected for a period of about twelve (12) months (April 2003 to April 2004) on the 11kv feeder and 33KV feeders were compared and optimization was proposed to improve electricity availability on the feeders.

According to Behailu (2014) in his study on distribution substation improvement at Beshoftu city. It was noted that the substation is faced with a lot of challenges ranging from energy mis management, poor maintenance service and very low reliability level. However, a new substation consisting of automatic switches, communication and earthling systems were proposed to reduce interruption durations.

Philip (2016) noted that one of the foremost impact of distributed generation system in feeder loss minimization. He added that DG placement in loss minimization is similar to capacitor bank placement. The dissimilarity between them is that DG supply both active and reactive power while capacitor bank supply only reactive power.

Maheswari and Vijayalakshmi (2012) In their work, stated that distribution generation is very effective in improving power transfer capability and voltage stability of the distribution system. In addition, it helps to meet increasing electricity demand, efficiency, and reliability.

According to Reza et al (2012), a capacitor bank consists of collection of capacitors connected together and arrangement of the capacitors may be in series or parallel and when installed in distribution network, improves the voltage profile of the feeder, minimizes power loss and increases the maximum transmitted electric power in cables and transformer. They buttressed in their paper that appropriate installation and value of the capacitor bank is essential to ensure that network power loss and total capacitor costs are less.

3.0 Methods Adopted for this Work

3.1 Description of Existing Network

Egi is a clan in Onelga Rivers State which play host to several multi-national oil and gas companies operating in Rivers State Nigeria. The distribution network received its supply from Ahoda 132/33kV substation double circuit transmission duly linked to the national grid at Owerri and Total E&P Nigeria 2×10 MW gas turbine plant. The actual distribution of electricity in the clan is through the respective 33KV feeders (primary distribution lines) scattered within the network.



Figure1: Pre-upgrade single line diagram of Egi-clan 33/0.415kv distribution network

3.2 Data Collection

The acquisition of data for this research work is from the Port Harcourt Electricity Distribution Company (PHED). Also, site visitation and verbal interaction were also carried out with engineers of Port Harcourt Electricity Distribution Company. This gave an in-depth knowledge on the current state of the distribution network.

3.3 Mathematical Model

The average load current
$$(I_L)$$
 is giving by
 $I_L = \frac{I_R + I_V + I_B + I_N}{3}$ (1)
The calculated load in KVA is giving by
 $KVA_{Load} = \sqrt{3} * I_L * V_S$ (2)
Where
 I_R is current in the red phase
 I_V is current in the red phase
 I_R is current in the blue phase
 I_R is current in neutral
 I_L is average load current
Vs is the secondary voltage of the transformer
3.3.2 Newton Raphson Load Flow Method
Complex power at the *ith* node on the distribution line is given by
 $S_i = V_i I_i^* = P_i + jQ_i$ (3)
 $I_i = \left(\frac{S_i}{V_i}\right)^* = \frac{P_i - jQ_i}{V_i^*}$ (4)
 $I_i = \frac{P_i - jQ_i}{V_i^*} = \sum_{k=1}^n Y_{ik} V_k$ (5)
 $P_i - jQ_i = V_i^* (\sum_{k=1}^n Y_{ik} V_k)$ (6)
Let $V_i^* = V_i (\sum_{k=1}^n Y_{ik} V_k \angle \delta_k$ and $Y_{ik} = Y_{ik} \angle \theta_{ik}$
 $P_i - jQ_i = V_i^* (\sum_{k=1}^n Y_{ik} V_k \angle \delta_k + \theta_{ik} - \delta_i)$ (7)

$$P_i - jQ_i = \sum_{k=1}^n |Y_{ik}| |V_i| |V_k| \left[\cos(\delta_k + \theta_{ik} - \delta_i) + j\sin(\delta_k + \theta_{ik} - \delta_i) \right]$$
(8)

Separating (3.8) into real and imaginary parts we have,

$$P_i = \sum_{k=1}^n |Y_{ik}| |V_k| \cos(\delta_k + \theta_{ik} - \delta_i)$$
(9)

$$Q_{i} = -\sum_{k=1}^{n} |Y_{ik}| |V_{i}| |V_{k}| \sin(\delta_{k} + \theta_{ik} - \delta_{i})$$
(10)

Where

 Y_{ik} = the admittance matrix P_i = the injected real power

 Q_i = the injected reactive power δ_i = phase angle

Expanding (3.9) and (3.10) in Taylors series neglecting higher order terms we have

$$\begin{bmatrix} \Delta P_{2}^{(k)} \\ \vdots \\ \frac{\Delta P_{n}^{(k)}}{\Delta Q_{2}^{(k)}} \\ \vdots \\ \Delta Q_{n}^{(k)} \end{bmatrix} = \begin{bmatrix} \begin{vmatrix} \frac{\partial P_{2}^{(k)}}{\partial \delta_{2}} & \cdots & \frac{\partial P_{2}^{(k)}}{\partial \delta_{n}} \\ \vdots & \ddots & \vdots \\ \frac{\partial P_{n}^{(k)}}{\partial \delta_{2}} & \cdots & \frac{\partial P_{n}^{(k)}}{\partial \delta_{n}} \end{vmatrix} \begin{vmatrix} \frac{\partial P_{2}^{(k)}}{\partial |V_{2}|} & \cdots & \frac{\partial P_{2}^{(k)}}{\partial |V_{n}|} \\ \frac{\partial P_{n}^{(k)}}{\partial \delta_{2}} & \cdots & \frac{\partial P_{n}^{(k)}}{\partial \delta_{n}} \end{vmatrix} \begin{vmatrix} \frac{\partial Q_{2}^{(k)}}{\partial |V_{2}|} & \cdots & \frac{\partial P_{n}^{(k)}}{\partial |V_{n}|} \\ \frac{\partial Q_{2}^{(k)}}{\partial \delta_{2}} & \cdots & \frac{\partial Q_{2}^{(k)}}{\partial \delta_{n}} \end{vmatrix} \begin{vmatrix} \frac{\partial Q_{2}^{(k)}}{\partial |V_{2}|} & \cdots & \frac{\partial Q_{2}^{(k)}}{\partial |V_{n}|} \\ \vdots & \ddots & \vdots \\ \frac{\partial Q_{n}^{(k)}}{\partial \delta_{2}} & \cdots & \frac{\partial Q_{n}^{(k)}}{\partial \delta_{n}} \end{vmatrix} \begin{vmatrix} \frac{\partial Q_{2}^{(k)}}{\partial |V_{2}|} & \cdots & \frac{\partial Q_{n}^{(k)}}{\partial |V_{n}|} \\ \frac{\partial Q_{n}^{(k)}}{\partial |V_{2}|} & \cdots & \frac{\partial Q_{n}^{(k)}}{\partial |V_{n}|} \end{vmatrix} \end{bmatrix} \begin{bmatrix} \Delta \delta_{2}^{(k)} \\ \vdots \\ \Delta \delta_{n}^{(k)} \\ \frac{\Delta \delta_{n}^{(k)}}{\Delta |V_{n}^{(k)}|} \\ \frac{\partial Q_{n}^{(k)}}{\partial |V_{n}|} \end{vmatrix}$$

$$(11)$$

The Jacobian matrix gives the linearized relationship between mall changes in voltage angle $\Delta \delta_i^{(k)}$ and magnitude $\Delta |V_i^{(k)}|$ with small change in real $\Delta P_i^{(k)}$ and reactive power $\Delta Q_i^{(k)}$ respectively.

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 & J_3 \\ J_2 & J_4 \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \Delta |V| \end{bmatrix}$$
(12)

Where

 J_1, J_2, J_3, J_4 are the elements of the Jacobian matrix

The diagonal and the off diagonal elements of J_1 are

$$\frac{\partial P_i}{\partial \delta_i} = \sum_{k \neq k} |Y_{ik}| |V_i| |V_k| \cos(\delta_k + \theta_{ik} - \delta_i)$$
(13)

5.1

$$\frac{\partial P_i}{\partial \delta_i} = -|Y_{ik}||V_i||V_k|\sin(\delta_k + \theta_{ik} - \delta_i)$$
(14)

Similarly, the diagonal and off diagonal element of J_2, J_3, J_4 can be computed

$$\Delta P_i^{(k)} = P_i^{sch} - P_i^{(k)} \tag{15}$$

$$\Delta Q_i^{(k)} = Q_i^{sch} - Q_i^{(k)} \tag{16}$$

4.0 Result Presentation

Branch ID	Power-flow MW (before)	Power-flow MVAR (before)	Losses (before)	Power-flow MW (after)	Power-flow MVAR (after)	Losses (after)
Cable-1	-3.679	0	0	0	0	31.4
Cable-2	0	-3.679	-0.101	30.2	-3.709	0
Cable-3	0	0	0	0	0	0
Cable-4	3.679	0	0	0	0	2.1
Cable-5	2.258	3.679	0.101	2	3.709	2.4
Cable-6	0.328	2.258	0.034	2.2	2.277	0
Cable-7	0.466	0.328	0.002	0	0.33	0.2
Cable-8	0.624	0.466	0.002	0.2	0.469	0.2
transformer-1	-3.675	0.624	0.005	0.2	0.629	1.3
transformer-2	0.106	-3.675	-0.042	1.3	-3.705	0.9
transformer-3	0.131	0.106	0.001	0.8	0.107	1.3
transformer-4	0.109	0.131	0.002	1.3	0.132	0.7
transformer-5	0.101	0.097	0.001	0.7	0.098	0.9
transformer-6	0.097	0.109	0.001	0.9	0.11	0.8
transformer-7	0.102	0.101	0.001	0.8	0.102	0.7
transformer-8	0.103	0.097	0.001	0.7	0.098	0.8

 Table 1: Power flow and line loses



Figure1: graph of power flow versus system components



Figure2: graph of power flow versus system components





5.0 Discussion

The dynamic behaviour of power supply network from Egi power generating station via 132KV transmission line to 33KV injection distribution line to the study case in Ogba/Egbema/Ndoni Local Government Area of Rivers State was examined using load flow analysis to account for

losses (MW, MVAR) from the sending to receiving-end. The post upgrade simulation network diagram is shown in appendix. The power injected into the network to the zone under investigation when simulated using Etap version 12.6 software shows the system was overloaded. However, the simulated violated network was compensated with the integration of 700MVAR capacitor of a capacitor bank (power electronics controller) to improve the power quality.

Hence, the size of the capacitor bank was calculated accurately to take care of the existing problem to ensure stability and minimize the cost of power supply and utilization for effective planning and optimizations. Evidently, the installation of the 700MVAR capacitors to the 33KV distribution networks and cases strongly improved the system stability, losses are drastically reduced to a barest and accepted operating conditions. Table 1 shows the power flow results and line losses and figure 1-3 shows the graph of power flow versus the various system components respectively.

6.0 Conclusion

In this paper, the existing Egi-Clan distribution system was examined and modeled in Electrical Transient Analyzer Program (ETAP12.6) software using Newton-Raphson power flow analysis method The total electric power supply loss in the 33KV distribution network in the study case was compensated using 700Mvar capacitor bank. Based on findings, it is here by concluded that line losses and voltage drop were reduced to acceptable operating condition while voltage profile improved after optimization. This means that for the same power injected into the network more real power load can be accommodated in order to support injection substation capacity and performance.

7.0 Recommendation

The following recommendations are highlighted to ensure optimum performance and reliability of the distribution system.

- 1. Appropriate electricity power supply should be installed in the affected feeders to free up load in the network as they are being operated critically for purposes of future expansion or upgrade of the network.
- 2. Regularly, simulate buses and feeders to know all weak insulators for upgrade which will enhance a proper maintenance.
- 3. More network should be Added to the existing feeders in the system, so as to ease burden of overloaded feeders that has led to frequent outages/blackout.
- 4. Feeder should be re-conducted with large sizes and reduced lengths; reducing losses and voltage drop.
- 5. Appropriately size capacitors bank to be located at strategic locations in order to improve electricity power supply and quality.

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Appendix



Figure 2: Post- upgrade single line diagram of Egi-clan 33/0.415kv distribution network