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Modern Trend of Load Flow Analysis in Power System

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ABSTRACT: *Power flow is the main reason the system is connected with load. It is customary to keep bus voltages under control and at acceptable values if the loads are to be optimally serviced. Rumuola 10-bus power system in Rivers State, Nigeria was found useful in the required load flow analysis. Load flow analysis using Newton Raphson's load flow method in Electrical Transient Analyzer Program (ETAP) software showed the voltages and active power at the respective buses in the network which are pertinent and sufficient in power system planning for enhanced services. In the analysis, 95.57% was the voltage magnitude on each of buses 3, 4, 7, and 8 while 96.38% was the voltage magnitude on each of buses 5, 6, 9, and 10. Load buses 7, 8, 9 and 10 recorded loads of 9.31MW, 9.31MW, 9.21MW and 5.58MW which aggregated to 33.41MW as against 33.42MW recorded on the main buses. The analysis indicated an insignificant difference of 0.01MW which is an indication of a near lossless and ideal network and a good approach used justifying the power flow as being efficient.*

KEY WORDS: *Power flow, Bus voltage, Load flow analysis, 11kV network, Feeder, Active power.*

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I. INTRODUCTION

Load flow analysis generally provides a systematic mathematical approach to determine various bus voltages, phase angles, active power flow and reactive power flow through the various branches, generators and loads under steady state conditions [1]. Load flow analysis is coordinated and performed to get abreast with the behaviour of any inter-connected power system under short circuit conditions. A typical power system comprises of buses which are interconnected through transmission lines with impedances, admittances, and other line parameters.

While some transmission lines are charged up to the limit load, others may be overloaded, which generally affect the values of voltage and reduces system stability and security. High voltage transmission lines are the most effective means of transferring the power from the generation station (generation) to the load (distribution) through the interconnected power system (transmission). Power quality problems and the best means of transfer possible have always been a serious challenge in power transmission and distribution networks [2].

Rumuola is town in Port Harcourt the capital of Rivers State in the Niger Delta region of Nigeria. Power distribution network in Rumuola town is something that calls for concern as so much load demand is placed by industrial, commercial and residential activities respectively within and around the vicinity. The importance attached to the customers requires a deliberate approach to provide appropriate bus voltages as required as well as an unimpeded load flow or power flow.

II. RELATED WORKS

Electric power system is basically set up to supply quality electricity with little or no interruptions to its end users or customers. The factor that determines its network analysis is the quality of electricity delivered. The ability of a power system to continuously deliver quality electricity is an indication that the customers are satisfied and the electricity providers are having good returns on their investment as they continue their business of providing seamless power supply.

As electric power utilization has become an essential component that influences the drive and urge required for technology to advance and to facilitate the development of modern society, it is very pertinent therefore to take seriously the issue of power flow analysis of the power system. Generation, transmission and distribution are the three basic sections that make up the power system. At the generation station, electricity is generated and transmitted through the high voltage transmission lines to the distribution substations. The power distribution system in this case comprises of the electrical system between the substation fed by the sub transmission system and the supply line to the consumers' meters [3]. The distribution substations are always sited or located relatively near the customers for effective power delivery, monitoring and maintenance of the substation. The customer side of the distribution substation is generally referred as secondary distribution substation system [3].

Voltages generated in the power stations are of the pure sine wave form, hence the current flowing through the lines are also of the form of sine wave usually referred as "Alternating Current". Alternating currents could be "Symmetrical" or "Asymmetrical" in nature. When the wave form of the current is symmetrical about the zero-axis, it is known as "Symmetrical Current" and when the wave form of the current is not symmetrical about the zero-axis then it becomes "Assymetrical current" [4]. It is possible to assess the performance characteristics of a power distribution substation using field data [5]. The reliability performance of 11kV electricity distribution feeders can be analyzed seamlessly using the daily outage records of the affected feeders for a period of time [6]. In the same vein, a more encompassing and an efficient evaluation of the reliability of 11kV distribution network protection scheme can be achieved with less hitches using fault tree analysis [7].

Series faults can occur along the power lines due to an unbalanced series impedance condition of the lines especially in the case of one or two broken lines. This is generally observed when all three phases are not open, a case where one or two phases still becomes connected in the circuit in the event of fault [8]. Short circuit analysis is very important to investigate the level and types of faults since each provides different impacts in the power system which may affect the smooth flow of power [9]. The unplanned expansion of the networks and installation of various kinds of loads in the present-day civilization, power distribution and transmission system face serious power quality issues [10]. The power quality issues in transmission and distribution systems entails harmonics, excessive reactive power burden, load unbalancing, voltage instability etc [10]. These power quality issues affect efficient load flow in several ways.

III. MATERIALS AND METHOD

3.1 Power Balance in Power System

The current entering bus i from the generator or power grid can be expressed as:

$$I_i = Y_{i1}V_1 + Y_{i2}V_2 + \dots + Y_{ik}V_K = \sum_{i,k=1}^{n} Y_{ik} V_k \quad (3.1)$$

If magnitude and phase angle are considered, then voltage and admittance can be expressed as:

$$V_k = V_K \angle \delta_k \quad \text{(voltage at the bus k)} \quad (3.2)$$

and

$$Y_{ik} = Y_{ik} \angle \theta_{ik} \text{ (admittance between bus i and bus k)} \quad (3.3)$$

Substituting equations (3.2) and (3.3) into equation (3.1) gives:

$$I_i = \sum_{i,k=1}^{n} Y_{ik} \angle \theta_{ik} V_k \angle \delta_k \quad (3.4)$$

where

δ_i, δ_k *are phase angles of* bus i and k, while θ_{ik} is the angular difference between bus i and k.

The conjugate of injected current at bus i is given as:

$$I_i^* = \sum_{i,k=1}^{n} Y_{ik} \angle -\theta_{ik} V_k \angle -\delta_k \quad (3.5)$$

Apparent power at bus i is given as:

$$S_i = V_i I_i^* = P_i + jQ_i \quad (3.6)$$

If the magnitude and angle of V_i are considered, then substituting equation (3.5) into (3.6) will result to:

$$P_i + jQ_i = V_i \angle \delta_i \sum_{i,k=1}^{n} Y_{ik} \angle -\theta_{ik} V_k \angle -\delta_k \quad (3.7)$$

If equation (3.7) is rearranged, then:

$$P_i + jQ_i = \sum_{i,k=1}^{n} Y_{ik} V_i V_k \angle (-\theta_{ik} + \delta_i - \delta_k) \quad (3.8)$$

It is generally known that:

$$\delta_{ik} = \delta_i - \delta_k \quad (3.9)$$

$$-\theta_{ik} = \theta_{ki} \quad (3.10)$$

If the relations in equations (3.9) and (3.10) are substituted into equation (3.8), then:

$$P_i + jQ_i = \sum_{i,k=1}^{n} Y_{ik} V_i V_k \angle (\theta_{ki} + \delta_{ik}) \quad (3.11)$$

From equation (3.11), the real power and imaginary power can be expressed independently as:

$$P_i = \sum_{i,k=1}^{n} Y_{ik} V_i V_k \cos(\theta_{ki} + \delta_{ik}) \quad (3.12)$$

$$Q_i = \sum_{i,k=1}^{n} Y_{ik} V_i V_k \sin(\theta_{ki} + \delta_{ik}) \quad (3.13)$$

The line flows can further be shown as changes in the computed real or generator powers with respect to pre-specified real or generator values and is generally expressed as:

$$\Delta P_i = \left| P_i^{sp} - P_i^{cal} \right| \quad (3.14)$$

where,

P_i^{sp}= the specified real bus powers at power exchange sequence i

P_i^{cal}= the computed real bus powers at power exchange sequence i using equation (3.12)

In the same vein, the reactive power changes may be given as:

$$\Delta Q_i = \left| Q_i^{sp} - Q_i^{cal} \right| \quad (3.15)$$

where,

Q_i^{sp}= the specified reactive bus powers at power exchange sequence i

Q_i^{sp}= the computed reactive bus powers at power exchange sequence i using equation (3.13)

The net power balance is expressed as:

$$\Delta P_{net} = \sum_i^n \Delta P_i^2 \quad (3.16)$$

and

$$\Delta Q_{net} = \sum_i^n \Delta Q_i^2 \quad (3.17)$$

Since admittances, line power demand, generations, and bus voltages and angles are known, Electrical Transient Analyzer Program was used to implement an optimal load flow accordingly.

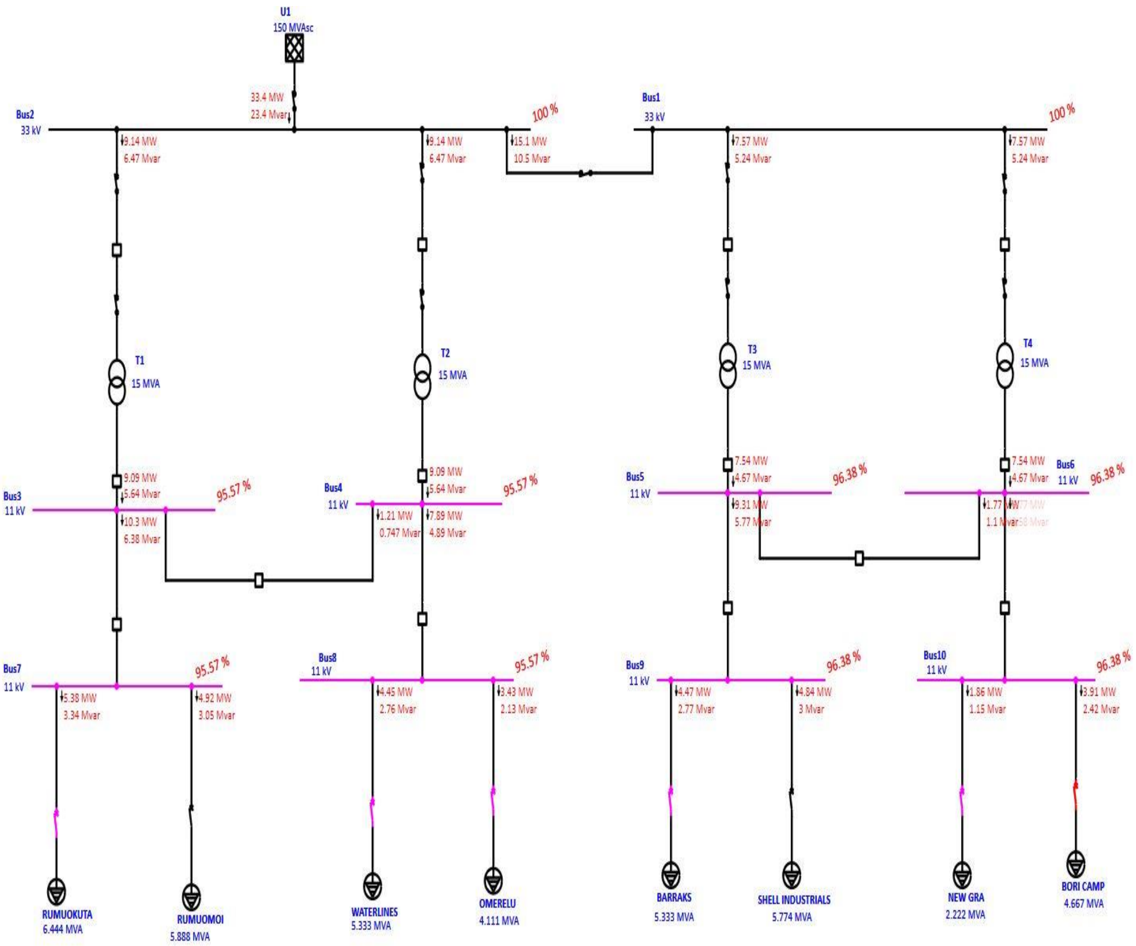

Figure 3.1: Load Flow Analysis of Rumuola 11kV Distribution Network

IV. RESULTS AND DISCUSSION

4.1 Load Flow Analysis Result Summary

Load flow results are shown for the purpose of clarity. The results obtained from the load flow analysis are shown in Tables 4.1- 4.2 and Figures 4.1 – 4.2 respectively.

Table 4.1: Voltage Magnitude

Bus	Voltage (KV)	Voltage Magnitude (%)
1	33	100
2	33	100
3	11	95.57
4	11	95.57
5	11	96.38
6	11	96.38
7	11	95.57
8	11	95.57
9	11	96.38
10	11	96.38

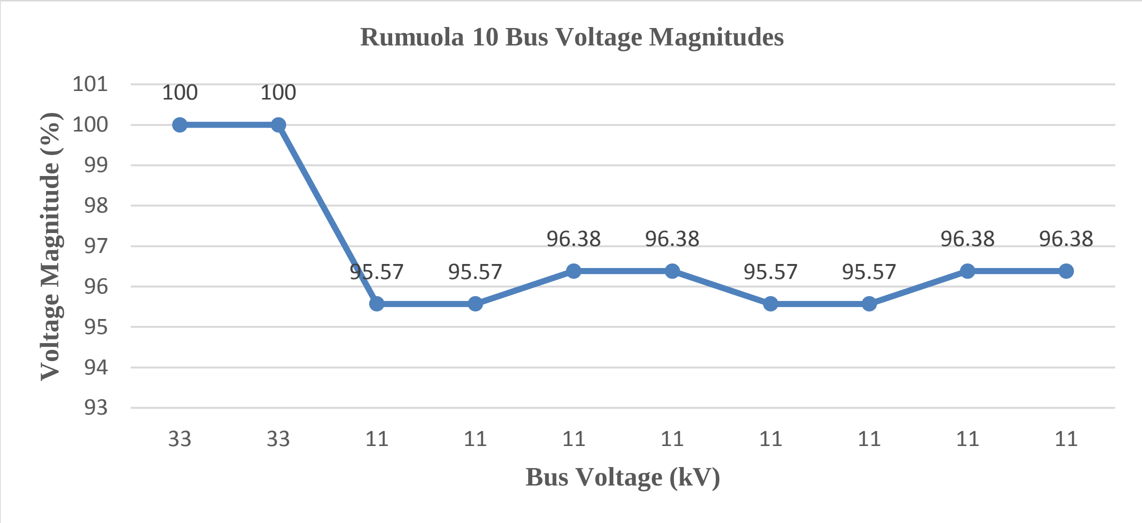

Figure 4.1: Graph Showing Rumuola 10 Bus Voltage Magnitudes

Table 4.2: Active Power Flow

Bus	Voltage (KV)	Active Power (MW)
1	33	18.28
2	33	15.14
3	11	9.09
4	11	9.09
5	11	7.54
6	11	7.54
7	11	9.31
8	11	9.31
9	11	9.21
10	11	5.58

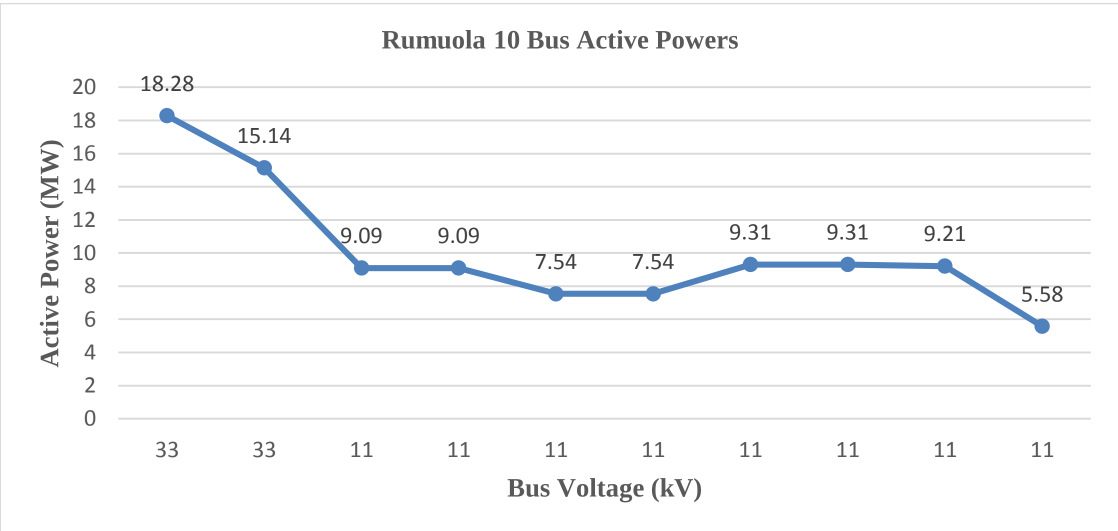

Figure 4.2: Graph Showing Rumuola 10 Bus Active Powers

V. CONCLUSION

5.1 Conclusion

The load flow analysis was conducted in a 10-bus system to determine the operating condition of components in the network as well as active power flow in the network with a negligible indication of under-voltage which was experienced by the downstream buses immediately after the transformers, thus, the buses are said to be marginally loaded which explains their colour being pink. Buses 3, 4, 7 and 8 are operating with a voltage magnitude of 95.57% while buses 5, 6, 9 and 10 are operating with a voltage magnitude of 96.38%.

The active power flows through the network are displayed in MW. The main or supply bus recorded a consumption of 33.42MW while the load buses recorded 33.41MW having an insignificant difference of 0.01MW. This minor difference was due to the slight disparity in voltage magnitude between the supply buses and load buses and it depicts a lossless electrical network.

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