Nigerian Research Journal of Engineering and Environmental Sciences 4(1) 2019 pp. 268-281

Nigerian Research Journal of Engineering and Environmental Sciences
Journal homepage: www.rjees.com

**Original Research Article**

# Comparative Load Flow Analysis of UNILAG Power Distribution Network using Newton Raphson and Gauss Seidel Methods

**Akinbulire, T.O., *Oluseyi, P.O., Udoakam, G.A. and Babatunde, O.M.**
Department of Electrical/Electronics Engineering, University of Lagos, Lagos, Nigeria.
*poluseyi@unilag.edu.ng

**ARTICLE INFORMATION**

*Article history*:
Received 09 April, 2019
Revised 15 May, 2019
Accepted 16 May, 2019
Available online 30 June, 2019

*Keywords*:
Comparative load analysis
Newton-Raphson
Gauss-Seidel
Distribution network
Sub-Stations
Active and reactive power
System losses

**ABSTRACT**

*The evaluation of power flow in the distribution network has many techniques but there has been a very much interest in the traditionally known methods. These methods have enjoyed very wide acceptability and applicability. However, a comparative study of these techniques for the investigation of the load flow analysis for any of the Nigeria's distribution systems is not adequately and proficiently documented. Thus, this inspired the adaptation of these techniques for the solution of a structured distribution network in the University of Lagos (UNILAG) Campus. The opportunity presented by this research is the deployment of these methods for the analysis and testing of a real-life power distribution network. The results obtained were validated with the IEEE-9 bus and IEEE-30 bus systems. The results obtained for the Campus distribution network were not only highly revealing but it also provided comparatively information (in respect of GS versus NR) as follows: number of iterations (i.e. 3 versus 177) , convergence time (i.e. 0.2457 versus 0.3276), power mismatch (0.017 MVAr versus 0.00 MVAr), system losses (i.e. 0.854 MW versus 0.855 MW), iteration tolerance (0.00001 versus 0.00) From this, the compared results indicated that the NR method converges faster with a least number of iterations irrespective of the number of the system buses while in the GS method, the number of iterations increases proportionally as the number of buses increases. Thus, it is evidently established that the NR method is very adequate for the analysis of large distribution networks.*



## 1. INTRODUCTION

The distribution systems hold a very significant position in the power system since it is the main point of link between bulk power and consumers (Borzacchiel *et al.,* 2016; Afandi *et al.,* 2017). Effective planning of distribution networks is required to meet the present growing domestic, industrial and commercial loads.

In order to have a properly designed and operated distribution network, the system should support energy supply at minimum operation and maintenance cost (Sedghi and Aliakbar, 2012). More so, the network capacity should satisfy the continuously changing national load demand for the active and reactive power flow.

According to Chatterjee and Mandal, (2017) and Afolabi *et al.* (2015) the common approach to power system operation is the performance of the load flow analysis in which loads connectivity and flow of the current/power is a crucial step. It is carried out to determine the steady state operating characteristics of the system including losses across the system as well as the iterative techniques for load flow study (Adejumobi *et al.*, 2013). The most important information obtained from the load flow analysis is the voltage profile and quantification of the power flow of the system (Gomez-Exposito and Abur, 2004; Borzacchiello *et al.,* (2016). If voltage varies greatly over the matrix of the power system, thus large reactive flows will result which may lead to increased real power losses. Whereby, in extreme cases, this may result in a likelihood of voltage collapse (Ali and Antonio, 2004). Furthermore, the study has the potential to determine the extent of equipment overload such as transformers and cables.

To maintain the quality of service offered by the University community to the Nigerian economy, a reliable electric power supply to the University community is paramount for teaching, research and development (Akinbulire *et al.,* 2010). This can only be achieved by planning the power network such a way that the incessant occurrence of blackout is averted. In Nigeria, most institutions are supplied with a utility distribution networks which with a supply voltage of 11 kV. For instance, the UNILAG Campus is supplied by the Eko Electricity Distribution Company and is then distributed within the 50-bus system that supply the campus. Thus, the University of Lagos Akoka campus is mainly supplied by ring-main distribution system arranged in four-ring topology (Dada *et al.*, 2016). As a means of ensuring stable power supply, four captive Diesel generators are installed at the University's power sub-station which is integrated with the utility's distribution grid. Hence, the robust engineering analysis of the ensuing network is thus essential for adequate provision of technical information on the traditional energy flow in the network. This thus suggests the possibilities for mitigating the energy losses in the network (Akinbulire *et al.,* 2010).

Previous investigations on the effect of line losses with the computation of the number of iterations of Newton Raphson and Gauss Seidel as it relates to the buses of the power system showed that the solutions of Gauss Seidel method depends on the number of buses while Newton Raphson is independent of the system size (Jagpreet and Rajni, 2016). However, a method of analyzing a radial 3-phase distribution network without solving the conventional load flow equation was presented by Golkar and Turk, (2007) but didn't overcome the challenges of computational efficiency. According to the work of Archita *et al.* (2016) it is possible to evaluate the variance in NR and GS methods for a network (Hadi, S., 2010). However, the work failed to address the convenience and memory optimization challenges. In Deepinder and Supreet, (2016); various techniques of load flow study under different operating conditions using conventional methods such as Y-matrix iterative method, Z-matrix method, Newton Raphson method and other forms of iterative methods were reviewed but not validated with real life data. Also, the operational comparison between Gauss-Seidel and Newton Raphson power flow methods using a 4-bus power system was presented by Chatterjee and Mandal, (2017) but lacks details of other technicalities of load flow methodologies. In other words, a comparative study of Gauss-Seidel and Newton Raphson load flow methods in terms of computational time, number of iterations, tolerance value and convergence time was tested and carried out using IEEE-9 bus, IEEE-30 bus and IEEE-57 buses but it failed to address the losses and efficient management of load flow in detail (Afolabi *et al.,* 2015; Borzacchiello *et al.,* 2016; Vijayvargia *et al.*, 2016).

Thus, the aim of this work is to evaluate Newton Raphson and Gauss Seidel load flow methods as efficient technique for evaluating the load flow analysis of a typical stand-alone distribution network with special consideration for the energy efficiency and losses in the network.

T.O. Akinbulire et al. / Nigerian Research Journal of Engineering and Environmental Sciences
4(1) 2019 pp. 268-281

## 2. MATERIALS AND METHODS

### 2.1. Materials

The materials used for this analysis are AR6 energy analyzer, voltage and current clamps, electrical transient and analysis program (ETAP) power flow software and MATLAB.

### 2.2. Methods

Comparative load flow method was applied in this study (Montoya *et al.,* 2018). Newton-Raphson method is an iterative method which approximates the set of non-linear equations using Taylor's series expansion and the terms are restricted to the first order approximation. This method is one of the most popular procedures for solving these power flow equations.

$$P_i = \sum_{k=1}^{n} \left| V_i . V_k . Y_{ik} \right| \cos(\theta_i - \theta_k - \delta_{ik}) \tag{1}$$

$$Q_i = \sum_{k=1}^{n} \left| V_i . V_k . Y_{ik} \right| \sin(\delta_i - \delta_k - \theta_{ik}) \tag{2}$$

i =1, 2…,n

Where:

n =total number of buses in the system
Pi and Qi =specified active and reactive demand at load bus i
Yik= element of line conductance
Vi = bus voltage at bus i
Vj = bus voltage at bus j
θi, θj = bus voltage angle
δij= load angle

The power flow equations (Equations (1) and (2)) are nonlinear and it is required to solve 2 (n-1) such equations involving $|V_i|$, $\delta_i$, $P_i$, and $Q_i$ at each bus for the load flow solution (Glover and Sarma, 2002).

Gauss Seidel is another method of solving a non-linear equation. The principle of this method is rather simple. It is used for solving the equation of the form:

$$F(x) = 0 \tag{3}$$

Where:
F(x) = non-linear function of a variable.

For a typical power system equation of the form:

$$S_i = P_i + jQ_i = V_i I_i^* \tag{4}$$

Where:

$$I_i = Y_{ik} V_k \tag{5}$$

Therefore:

$$P_i - jQ_i = V_i^* \sum_{\substack{k=1 \\ k\neq i}}^{n} Y_{ik}.V_k \tag{6}$$

Hence, from Equation (5), for an n-bus power system:

$$I_i = \frac{P_i - jQ_i}{V_i^*} = Y_{ii}.V_i + \sum_{\substack{k=1 \\ k\neq i}}^{n} y_{ik}.V_k \tag{7}$$

From Equation (7):

$$V_i = \frac{1}{Y_{ii}}\left[\frac{P_i - jQ_i}{V_i^*} - \sum_{\substack{k=1 \\ k\neq i}}^{n} Y_{ik}.V_k\right] \tag{8}$$

Another important step in this analysis are the flow charts shown in Figures 1 and 2. These charts were developed to explain the algorithms for the analysis of the load flow study using both Newton-Raphson and Gauss-Seidel techniques respectively (Keyhani *et al*., 1989). These flow charts are essentially implemented while deploying the MATLAB codes.

These were provided for easy understanding of the procedure for achieving the load flow analysis. Thus, the active and reactive powers mismatched are obtained as shown in Equations (9) and (10).

$$\Delta P_i = P_{i,inj} - P_{i,calc} = P_{di} - P_{i,calc} \tag{9}$$

$$\Delta Q_i = Q_{i,inj} - Q_{i,calc} = Q_{di} - Q_{i,calc} \tag{10}$$

T.O. Akinbulire et al. / Nigerian Research Journal of Engineering and Environmental Sciences
4(1) 2019 pp. 268-281

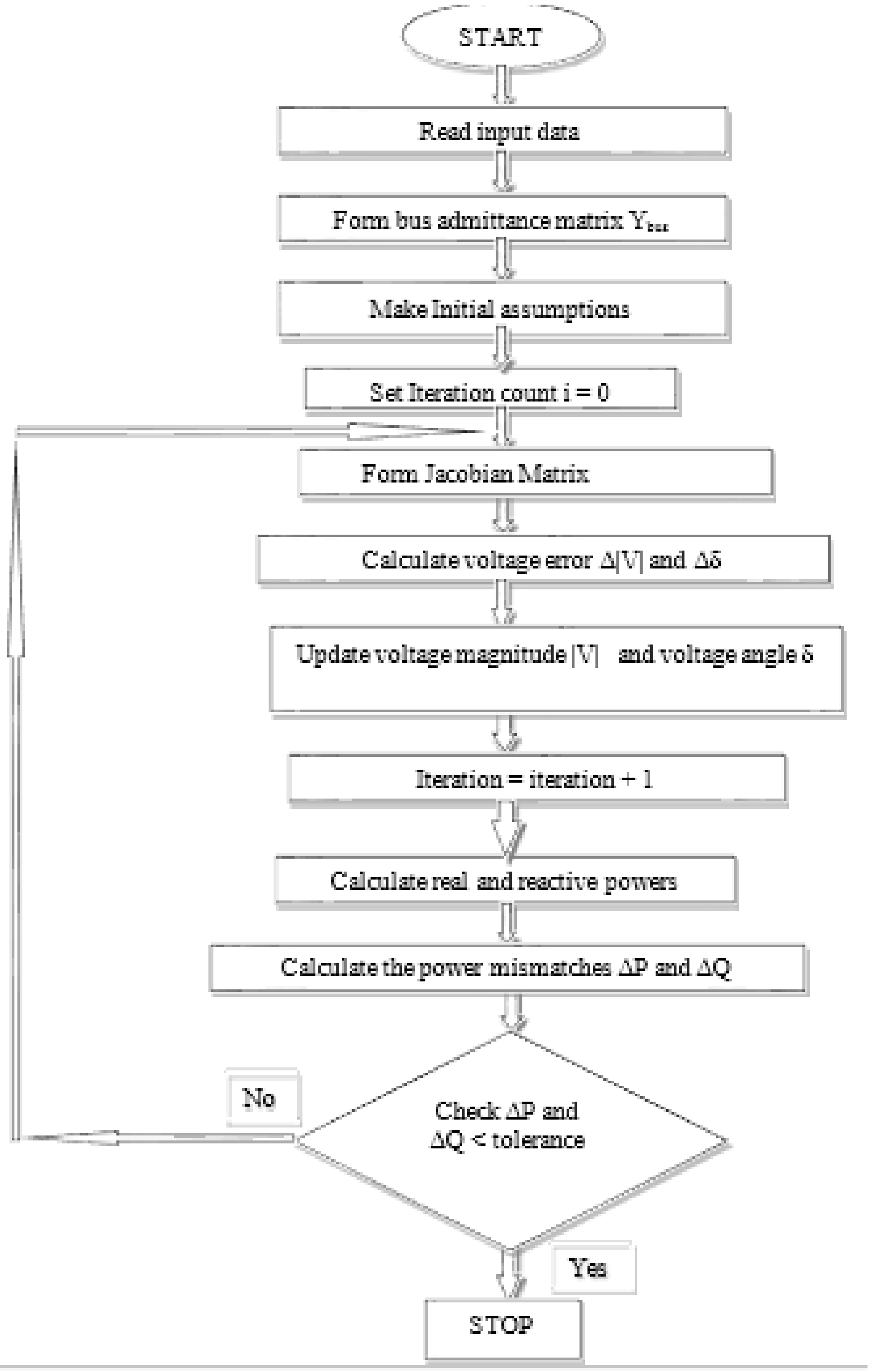


Figure 1: Flow chart for load flow solution using Newton-Raphson method (Hadi, 2010)

T.O. Akinbulire et al. / Nigerian Research Journal of Engineering and Environmental Sciences
4(1) 2019 pp. 268-281

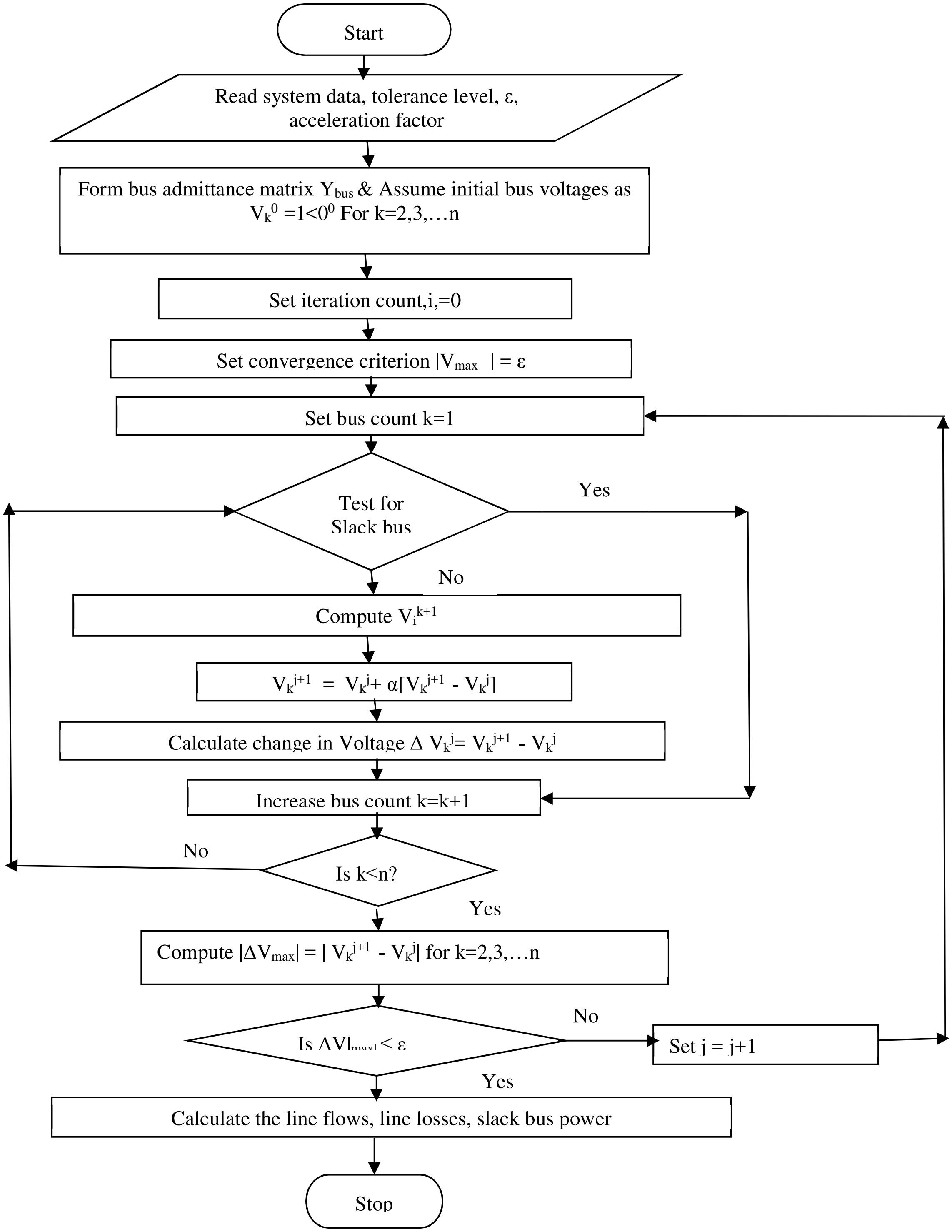

Figure 2: Flow chart for load flow solution using Gauss Seidel method (Hadi, 2010)

T.O. Akinbulire et al. / Nigerian Research Journal of Engineering and Environmental Sciences
4(1) 2019 pp. 268-281

After the iteration processes is stopped, the final voltage magnitude (|V|) and voltage angle (δ) are calculated therefore the problem of power flow system will be solved.

## 3. RESULTS AND DISCUSSION

The load flow analysis of IEEE-9 Bus, IEEE-30 Bus systems and the power distribution network of the University of Lagos campus were used as sources of data in this study. The IEEE-9 Bus and IEEE-30 Bus systems are the standard power networks that are used for validating the results obtained from the real-life power systems. The comprehensive loading capacity as well as the voltage profile of the UNILAG power distribution network was obtained using power analyzer (AR6) as shown in Table 1. It is observed that the voltage magnitude suffer variation from the nominal operating voltage value and angle for both techniques. Thus, the system was then subjected to further analysis to identify the cause of the noticeable variations. In the same vein, the analysis was extended to IEEE-9 and IEEE-30 bus systems.

In continuation of the analysis of the UNILAG power distribution network, whereby each cable was given identification tag to preserve the coordination of the individuality of the magnitude of the flow through each cable was presented. Table 2 shows the power flow results along the cables used in University of Lagos power distribution network using NR method. Table 3 displayed same operation as it was performed using the GS technique. It can be seen that the maximum losses occurred in cable 14 which is the branch connecting the power station to the Faculty of Engineering, this is as a result of the nature of loads (such as Electric motors, Electromagnets solenoids as well as heating equipment) connected to the Engineering Bus. The ETAP software is used to further explained the scenario described above. It is thus as presented in Figure 3.

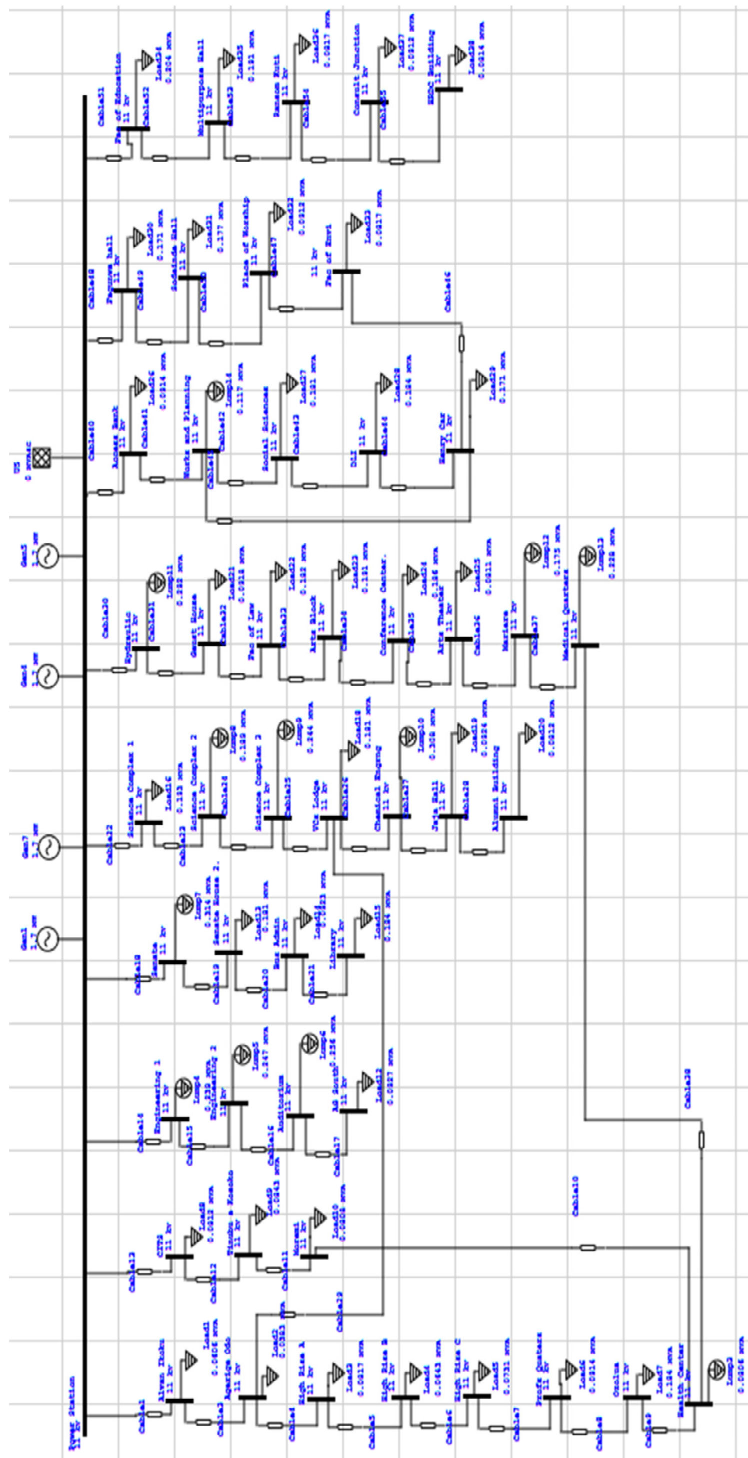

Figure 3: Single line diagram of University of Lagos power distribution network using ETAP software

The various bus number configuration is as shown in Table 1 for the purpose of evaluating the line and bus parameters of the buses in the UNILAG power distribution network. Thus, the total load demanded by the UNILAG Campus is assessed via this table. Also, the load demand by various major load centres within the Campus is captured in the Table.

Table 1: Buses and load results for University of Lagos power distribution network

| S/N | Bus ID | kV | Newton Raphson Method | | | | Gauss Seidel Method | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Voltage | | Load | | Voltage | | Load | |
| | | | % Mag. | Ang.(0) | kW | kVAr | % Mag. | Ang.(0) | kW | kVAr |
| 1 | Access Bank | 11 | 101.703 | 10.051 | 78.666 | 52.434 | 101.703 | 10.051 | 78.666 | 52.434 |
| 2 | AG South | 11 | 95.157 | 11.065 | 71.978 | 43.185 | 95.157 | 11.065 | 71.978 | 43.185 |
| 3 | Agerige Odo | 11 | 101.865 | 10.020 | 34.079 | 20.447 | 101.865 | 10.020 | 34.154 | 20.238 |
| 4 | Alumni Building | 11 | 99.069 | 10.491 | 68.338 | 41.002 | 99.068 | 10.469 | 68.388 | 40.832 |
| 5 | Alvan Ikoku Road | 11 | 101.935 | 10.009 | 54.669 | 31.245 | 101.935 | 10.008 | 54.657 | 31.281 |
| 6 | Arts Block | 11 | 101.758 | 10.031 | 168.760 | 103.124 | 101.758 | 10.031 | 168.786 | 103.071 |
| 7 | Arts Theater | 11 | 101.708 | 10.039 | 69.808 | 46.530 | 101.708 | 10.039 | 69.816 | 46.514 |
| 8 | Chiller Auditorium | 11 | 95.327 | 11.036 | 132.349 | 105.879 | 95.327 | 11.036 | 132.349 | 105.879 |
| 9 | Fac. of Mgt Sc. | 11 | 94.953 | 11.345 | 70.877 | 43.609 | 94.953 | 11.345 | 70.877 | 43.609 |
| 10 | Chemical Engrng | 11 | 99.496 | 10.420 | 169.497 | 122.038 | 99.494 | 10.397 | 173.161 | 111.794 |
| 11 | CITS | 11 | 101.996 | 10.001 | 72.436 | 43.460 | 101.996 | 10.001 | 72.439 | 43.452 |
| 12 | Conference Center | 11 | 101.787 | 10.031 | 160.017 | 97.780 | 101.787 | 10.031 | 160.017 | 97.780 |
| 13 | UNILAG Consult Junction | 11 | 98.053 | 10.694 | 75.188 | 45.111 | 98.052 | 10.694 | 75.206 | 45.092 |
| 14 | DLI | 11 | 101.385 | 10.110 | 158.567 | 103.087 | 101.385 | 10.110 | 158.568 | 103.087 |
| 15 | Engineering 1 | 11 | 97.032 | 10.643 | 133.661 | 86.880 | 97.032 | 10.643 | 133.660 | 86.880 |
| 16 | Engineering 2 | 11 | 96.895 | 10.671 | 140.232 | 86.811 | 96.895 | 10.671 | 140.233 | 86.811 |
| 17 | Fac. of Education | 11 | 101.758 | 10.030 | 179.466 | 111.412 | 101.758 | 10.030 | 179.467 | 111.410 |
| 18 | Fac. of Environment. Sc. | 11 | 101.445 | 10.097 | 72.097 | 43.257 | 101.445 | 10.097 | 72.098 | 43.257 |
| 19 | Fac. of Law | 11 | 101.766 | 10.030 | 160.835 | 98.280 | 101.766 | 10.030 | 160.828 | 98.296 |
| 20 | Fagunwa Hall | 11 | 101.897 | 10.019 | 151.502 | 92.578 | 101.897 | 10.019 | 151.502 | 92.578 |
| 21 | Guest Houses | 11 | 101.824 | 10.022 | 81.617 | 48.968 | 101.824 | 10.022 | 81.615 | 48.972 |
| 22 | Health Centre | 11 | 101.758 | 10.036 | 48.096 | 27.484 | 101.758 | 10.036 | 48.116 | 27.421 |
| 23 | Henry Carr Hall | 11 | 101.451 | 10.096 | 150.180 | 91.769 | 101.451 | 10.096 | 150.181 | 91.769 |
| 24 | High Rise A | 11 | 101.812 | 10.029 | 72.619 | 43.570 | 101.811 | 10.029 | 72.726 | 43.342 |
| 25 | High Rise B. | 11 | 101.801 | 10.031 | 56.508 | 35.317 | 101.801 | 10.030 | 56.471 | 35.383 |
| 26 | HRDC Building | 11 | 98.013 | 10.700 | 65.069 | 43.371 | 98.013 | 10.700 | 65.060 | 43.379 |
| 27 | Hydraulic Laboratory | 11 | 101.985 | 10.002 | 158.211 | 123.818 | 101.985 | 10.002 | 158.211 | 123.819 |

T.O. Akinbulire et al. / Nigerian Research Journal of Engineering and Environmental Sciences
4(1) 2019 pp. 268-281

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 28 | Jaja Hall | 11 | 99.481 | 10.422 | 76.090 | 50.717 | 99.480 | 10.400 | 74.397 | 55.453 |
| 29 | Library | 11 | 94.076 | 11.521 | 136.529 | 88.759 | 94.076 | 11.521 | 136.529 | 88.759 |
| 30 | Mariere Hall | 11 | 100.713 | 10.216 | 102.429 | 61.458 | 100.713 | 10.216 | 102.433 | 61.448 |
| 31 | Medical Quarters | 11 | 100.693 | 10.220 | 122.901 | 95.590 | 100.693 | 10.220 | 122.899 | 95.594 |
| 32 | High Rise C. | 11 | 101.767 | 10.037 | 62.995 | 41.989 | 101.767 | 10.036 | 62.995 | 41.986 |
| 33 | Moremi Hall | 11 | 101.808 | 10.028 | 69.687 | 46.449 | 101.808 | 10.028 | 69.690 | 46.444 |
| 34 | Multipurpose Hall | 11 | 101.645 | 10.052 | 157.868 | 118.401 | 101.645 | 10.052 | 157.869 | 118.400 |
| 35 | Ozolua Road | 11 | 101.732 | 10.042 | 159.654 | 103.794 | 101.732 | 10.042 | 159.659 | 103.777 |
| 36 | Worship Place | 11 | 101.781 | 10.040 | 81.014 | 48.607 | 101.781 | 10.040 | 81.014 | 48.607 |
| 37 | Professorial quarters | 11 | 101.737 | 10.041 | 78.719 | 52.469 | 101.737 | 10.041 | 78.711 | 52.498 |
| 38 | Ransome Kuti Road | 11 | 101.556 | 10.067 | 72.254 | 43.351 | 101.556 | 10.067 | 72.254 | 43.352 |
| 39 | Science Complex 1 | 11 | 101.932 | 10.009 | 163.171 | 116.565 | 101.932 | 10.009 | 163.373 | 115.997 |
| 40 | Science Complex 2 | 11 | 101.918 | 10.011 | 110.039 | 68.775 | 101.918 | 10.010 | 110.134 | 68.510 |
| 41 | Science Complex 3 | 11 | 101.901 | 10.013 | 137.535 | 96.275 | 101.901 | 10.013 | 137.544 | 96.227 |
| 42 | Senate House 1 | 11 | 101.891 | 10.017 | 171.909 | 130.650 | 101.891 | 10.017 | 171.909 | 130.650 |
| 43 | Senate House 2 | 11 | 101.719 | 10.038 | 153.076 | 116.642 | 101.719 | 10.038 | 153.071 | 116.652 |
| 44 | Fac. of Social Sciences | 11 | 101.400 | 10.107 | 158.802 | 97.038 | 101.400 | 10.107 | 158.802 | 97.038 |
| 45 | Sodeinde Hall | 11 | 101.832 | 10.031 | 156.782 | 95.432 | 101.832 | 10.031 | 156.782 | 95.432 |
| 46 | Tinubu Close & Kosoko Drive | 11 | 101.859 | 10.021 | 74.169 | 46.355 | 101.859 | 10.021 | 74.164 | 46.368 |
| 47 | VC's Lodge | 11 | 101.851 | 10.021 | 160.218 | 97.903 | 101.851 | 10.021 | 160.167 | 98.049 |
| 48 | Works and Planning | 11 | 101.468 | 10.094 | 68.592 | 41.155 | 101.468 | 10.094 | 68.590 | 41.155 |

The proficiency of the Newton Raphson method is tested on the UNILAG power distribution network. Table 2 shows the cables that has considerable amount of voltage drop. The essence of this is to provide information that would assist in identifying the points at which compensation would be required

Table 2: Newton Raphson Branch flow results for the 50-bus UNILAG distribution network with voltage drops along the line

| S/N | Branch ID | From-To Bus Flow | | To-From Bus Flow | | Losses | | % Bus Voltage | | Vd % Drop |
|---|---|---|---|---|---|---|---|---|---|---|
| | | kW | kVAr | kW | kVAr | kW | kVAr | From | To | Vmag |
| 1 | Cable 14 | -483.306 | -324.083 | 511.8399 | 334.9552 | 28.53359 | 10.87258 | 97.03213 | 102 | 4.967875 |
| 2 | Cable 20 | -208.954 | -132.772 | 227.1975 | 137.1545 | 18.24355 | 4.382099 | 94.95313 | 101.7871 | 6.83393 |
| 3 | Cable 26 | -314.284 | -213.852 | 323.2391 | 216.6709 | 8.954795 | 2.819387 | 99.49562 | 101.8509 | 2.355321 |
| 4 | Cable 54 | -140.287 | -88.4918 | 146.2923 | 90.05973 | 6.005192 | 1.567909 | 98.05254 | 101.5557 | 3.503142 |
| 5 | Cable 16 | -204.477 | -149.104 | 208.8007 | 150.2326 | 4.323297 | 1.128779 | 95.32687 | 96.89519 | 1.568321 |
| 6 | Cable 40 | -668.265 | -413.409 | 670.5919 | 414.0164 | 2.326452 | 0.607419 | 101.7025 | 102 | 0.297464 |
| 7 | Cable 36 | 160.7655 | 111.826 | -158.85 | -111.223 | 1.915162 | 0.602982 | 101.7076 | 100.7128 | 0.99489 |
| 8 | Cable 41 | 589.5997 | 360.9754 | -587.97 | -360.584 | 1.629791 | 0.391476 | 101.7025 | 101.468 | 0.234525 |
| 9 | Cable 21 | 138.0767 | 89.16342 | -136.529 | -88.7593 | 1.54786 | 0.404134 | 94.95313 | 94.07573 | 0.877402 |
| 10 | Cable 51 | -556.626 | -363.416 | 558.1377 | 363.9917 | 1.511672 | 0.576015 | 101.758 | 102 | 0.241976 |
| 11 | Cable 31 | -795.593 | -525.637 | 797.0382 | 526.1873 | 1.444827 | 0.550544 | 101.8243 | 101.9854 | 0.16114 |

From Table 3, it is evident that the GS branch flow results are the same with the NR results to the second decimal place, therefore this shows that the results depict the actual solutions. It can also be seen that the maximum percentage voltage drops in the network is about 6%. This influences the power delivery proficiency of the network. Since the reactive power is useful in providing voltage levels required for the active power to perform the work done in the electrical network.

Table 3: Gauss Seidel Branch Flow results for the distribution network with voltage drop along the line

| S/N | Branch ID | From-To Bus Flow | | To-From Bus Flow | | Losses | | % Bus Voltage | | Vd % Drop Vmag |
|---|---|---|---|---|---|---|---|---|---|---|
| | | kW | kVAr | kW | kVAr | kW | kVAr | From | To | |
| 1 | Cable14 | -483.306 | -324.083 | 511.8392 | 334.9552 | 28.53354 | 10.87257 | 97.03213 | 102 | 4.96787 |
| 2 | Cable20 | -208.954 | -132.772 | 227.1975 | 137.1545 | 18.24355 | 4.382099 | 94.95313 | 101.7871 | 6.83393 |
| 3 | Cable26 | -316.305 | -208.173 | 325.19 | 210.9709 | 8.885456 | 2.797556 | 99.49442 | 101.8509 | 2.356519 |
| 4 | Cable54 | -140.297 | -88.4812 | 146.3019 | 90.04918 | 6.005378 | 1.567958 | 98.05239 | 101.5557 | 3.503287 |
| 5 | Cable16 | -204.477 | -149.104 | 208.8006 | 150.2326 | 4.323293 | 1.128779 | 95.32687 | 96.8952 | 1.568321 |
| 6 | Cable40 | -668.267 | -413.409 | 670.5938 | 414.0161 | 2.326461 | 0.607421 | 101.7025 | 102 | 0.297465 |
| 7 | Cable36 | 160.7702 | 111.8123 | -158.855 | -111.209 | 1.915086 | 0.602958 | 101.7076 | 100.7128 | 0.994892 |
| 8 | Cable41 | 589.6014 | 360.9751 | -587.972 | -360.584 | 1.629797 | 0.391477 | 101.7025 | 101.468 | 0.234525 |
| 9 | Cable21 | 138.0767 | 89.16342 | -136.529 | -88.7593 | 1.54786 | 0.404134 | 94.95313 | 94.07573 | 0.877402 |
| 10 | Cable51 | -556.637 | -363.403 | 558.1485 | 363.9794 | 1.511683 | 0.57602 | 101.758 | 102 | 0.241979 |
| 11 | Cable31 | -795.617 | -525.585 | 797.062 | 526.1354 | 1.444801 | 0.550534 | 101.8243 | 101.9854 | 0.161141 |

From Table 2, the maximum percentage voltage drop occurred at cable 20 (about 6.8%), that is, the branch connecting senate building to Faculty of Management Sciences, and this is perhaps due to the high load demand in the senate building. This is basically due to the electric lift (which is inductive load by nature) that serves the eleven floors in the building. It can also be seen from Table 2 that the results of the percentage voltage drop using NR method is approximately to the same as that of GS method. This shows the accuracy of the load flow calculations; however, the GS method takes a longer number of iterations and higher tolerance to yield the same result as the NR technique.

In Table 3, the cable with the highest number of losses is the branch connecting the power station to Faculty of Engineering (cable 14), this might be as a result of machines used in the cluster of Engineering Laboratories situated within the Faculty. Most these electrical loads require very high starting currents resulting in frequent overheating of the cable supplying the Faculty; thereby increasing losses through heat dissipation.

To validate the results obtained above; the IEEE-bus systems were considered. In which case Table 4 and 5 show the comparative results of NR and GS methods in terms of number of iterations, convergence time, power mismatch, system losses and iteration tolerance for both IEEE-9 bus and IEEE-30 bus systems. It can be seen in Table 4 that for IEEE-9 bus system; NR power flow converges in one (1) iteration while the GS converges in two (2) iterations. GS method convergence time is faster than the NR method, this is because of the repetitive time required to calculate the Jacobian matrix in NR method. It can also be seen that the GS method requires higher tolerance than the NR method to yield a result equivalent to the NR method. In the same vein, that of the UNILAG power distribution network is considered. This is as presented in Table 6.

T.O. Akinbulire et al. / Nigerian Research Journal of Engineering and Environmental Sciences
4(1) 2019 pp. 268-281

Table 4: Comparative results of Newton Raphson and Gauss Seidel Power flow methods for IEEE-9 Bus power network

| Method | No of iterations | Convergence time (sec.) | MW Power mismatch | MVAr Power mismatch | Total MW losses | Total MVAr losses | Iteration tolerance |
|---|---|---|---|---|---|---|---|
| Gauss Seidel | 2 | 0.1024 | 0.00 | 0.00 | 4.661 | 92.212 | 0.00001 |
| Newton Raphson | 1 | 0.1135 | 0.00 | 0.00 | 4.661 | 92.212 | 0.001 |

Table 5: Comparative results of Newton Raphson and Gauss Seidel Power flow methods for IEEE-30 Bus power network

| Method | No of iterations | Convergence time (sec.) | MW Power mismatch | MVAr Power mismatch | Total MW losses | Total MVAr losses | Iteration tolerance |
|---|---|---|---|---|---|---|---|
| Gauss Seidel | 79 | 0.1540 | 0.176 | 0.072 | 17.550 | 32.990 | 0.00001 |
| Newton Raphson | 2 | 0.1756 | 0.00 | 0.00 | 17.563 | 33.045 | 0.001 |

It is also evident from Table 4 that the reactive power mismatch increased from 0.000 kVAr in IEEE-9 bus system to 72 kVAr for the 30-bus power system in the GS method while the NR method remained 0.00 kW in both cases. This however, shows that the accuracy of the GS method reduces with increase in the number of buses (Liu et al, 2019; Sereeter and Witteveen, 2019). On extending this comparative study to the UNILAG power distribution network; the results obtained are as showcased in Table 5.

From Table 6, it can be seen that the number of iterations of the GS method further increased to 177 for the 50 bus of University of Lagos power distribution network while that of the NR method had just 3 iterations. This shows that the number of iterations of the GS method is highly dependent on the number of buses while the NR method is approximately independent on the number of iterations. Thus, it is established that Newton Raphson is the more reliable method due to its least number of iteration and faster convergence compared to its counterpart Gauss Seidel method.

Table 6: Comparative results of Newton Raphson and Gauss Seidel Power flow methods for University of Lagos electric power distribution network

| Method | No of iterations | Convergence time (Sec.) | MW Power mismatch | MVar Power mismatch | Total MW losses | Total MVar losses | Iteration tolerance |
|---|---|---|---|---|---|---|---|
| Gauss Seidel | 177 | 0.2457 | 0.0061 | 0.017 | 0.0854 | 0.0267 | 0.00001 |
| Newton Raphson | 3 | 0.3276 | 0.00 | 0.00 | 0.0855 | 0.0267 | 0.001 |

## 4. CONCLUSION

The results obtained showed that Gauss Seidel method requires a considerably greater number of iterations to obtain a solution than Newton Raphson method which requires 3 to 5 iterations to reach an acceptable solution for a large power system. Also, for Gauss Seidel method, the number of iterations increases directly as the number of buses of the network while that of Newton Raphson method is independent of the system size. It can then be concluded that for the large distribution network, Newton Raphson method is faster, more reliable. Therefore, Newton Raphson is a better method for a distribution network having at least 20 buses. It can thus be concluded that the maximum percentage voltage drop occurred along cable 20 (about 6.83%)

which is the branch connecting Senate Building to the Faculty of Management Sciences; this is perhaps due to the high load demand in the adjoining buildings. Especially the Senate Building where there is an electric lift serving the Eleven (11) Floor building which is a highly inductive load by nature. Beyond the above, this study identified a number of cables with the highest power losses; among which the branch connecting the University's distribution power station to the Faculty of Engineering has the highest stake. The identity of which is cable 14 (with about 28.5kW losses). This might be as a result of the nature of heavy duty electrical machines being used in the cluster of Engineering Laboratories situated within this location. This observation may result in some of these electrical equipment require with high starting currents leading to overheating of the network and subsequently comparatively high losses that may result in system collapse. This also has influence on the system frequency of operation. With the help of this study, it has been established that the reactors may have to be installed to assist the cable 20 and cable 14 for improving the power system operation of the facilities within these two locations in the UNILAG campus.

## 5. ACKNOWLEDGEMENT

The authors wish to acknowledge the assistance and contributions of the staff, and former students as well as the Technical personnel in the Department of Electrical and Electronics Engineering, University of Lagos, Akoka Campus Yaba, Lagos Nigeria toward the success of this work.

## 6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

## REFERENCES

Adejumobi, I.A., Adepoju, G.A. and Hamzat, K.A. (2013). Iterative techniques for load flow Study: A comparative study for Nigeria 330 kV grid system as a case study. *International Journal of Engineering Advanced Technology*, *3*, pp. 153-157.

Afandi, A.N., Fadlika, I. Gumilar, L. (2017). Power Flow Analysis of power system Topology Development for Advancing Electricity System of Local Interconnection. A conference Paper presentation at 4th International Conference on Science and Technology, Chennai, India.

Afolabi, O.A., Ali, W.H., Cofie, P., Fuller, J., Obiomon, P. and Kolawole, E.S. (2015). Analysis of the load flow problem in power system planning studies. *Energy and Power Engineering*, *7*(10), p. 509.

Akinbulire, T. O., Oluseyi, P.O., Awosope, C.O.A., Odekunle, M.O. and Idowu, O.M. (2010). Long-Term Electric Load Forecasting for the University of Lagos using Regression Analysis Method. *Journal of Engineering Research*, JER-15(1), pp. 69-79.

Borzacchiello, D., Chinesta,F., Malika, M.H., García-Blanco, R. and Diez, P. (2016). Unified formulation of a family of iterative solvers for power systems analysis. *Electric Power Systems Research,* 140, pp. 201–208.

Chatterjee, S. and Mandal, S. (2017). A novel comparison of Gauss-Seidel and Newton-Raphson methods for load flow analysis. A Conference Paper presentation at 2017 International Conference on Power and Embedded Drive Control (ICPEDC), pp. 1-7.

Dada, O. M., Daniyan, I.A., Azeez, T.M. and Adaramola, O.O. (2016). Audit of Electricity Generation in University of Lagos, *International Journal of Energy and Power Engineering,* 2(2), pp. 29-33.

Deepinder, K.M., and Supreet, K.S. (2016). Load Flow Analysis: A Review, International *Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, 5(3), pp. 2320 – 3765.

Glover, J.D. and Sarma, M.S. (2002) *Power System Analysis and Design*. 3rd Edition., Brooks/Cole, Pacific Grove.

Golkar, M.A. (2007). A novel method for load flow analysis of unbalanced three-phase radial distribution networks. *Turkish Journal of Electrical Engineering & Computer Sciences*, 15(3), pp. 329-337.

Gomez-Exposito, A. and Abur, A. (2004). *Power system state estimation: theory and implementation*. CRC press.

Hadi, S. (2010). Power System Analysis. 3rd Edition, PSA Publishing, North York.

Jagpreet, S. and Rajni, B. (2016). A Case Study: Comparison of Newton-Raphson and Gauss-Seidal Load Flow Solution Techniques in Distributed Transmission and Generation Electricity Networks. *International Journal of Advance Electrical and Electronics Engineering (IJAEEE),* 5(1), pp. 2278-8948

Keyhani, A., Abur, A. and Hao, S. (1989). Evaluation of power flow techniques for personal computers. *IEEE transactions on power systems*, *4*(2), pp. 817-826.

Liu, H., Brown, T., Andresen, G. B., Schlachtberger, D. P. and Greiner, M. (2019). The role of hydro power, storage and transmission in the decarbonization of the Chinese power system. *Applied Energy*, 239, pp. 1308-1332.

Montoya, O.D., Grisales-Noreña, L.F., González-Montoya, D., Ramos-Paja, C.A. and Garces. A. (2018). Linear power flow formulation for low-voltage DC power grids. *Electric Power Systems Research,* 163, 375–381.

Sedghi, M. and Aliakbar, G.M. (2012). Analysis and comparison of load flow methods for distribution networks considering distributed generation. *International Journal of Smart Electrical Engineering*, 1(1), pp. 27-32.

Sereeter B. and Witteveen, C.V.C. (2019). On a comparison of Newton–Raphson solvers for power flow problems. *Journal of Computational and Applied Mathematics*, 360, pp. 157–169.

Vijayvargia, A., Jain, S., Meena, S., Gupta, V. and Lalwanib, M. (2016). Comparison between different load flow methodologies by analyzing various bus systems. *International Journal of electrical engineering*, *9*, pp. 127-138.