American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-6, Issue-12, pp-230-240
www.ajer.org
Research Paper Open Access

Analysisfor Electical Load Flow Studies in Port Harcourt, Nigeria, Using Newton Raphson Fast Decoupled Techniques.

*Idoniboyeobu, D.C.[1], Ibeni C.[2]
[12]*Department of Electrical Engineering, Rivers State University, Port Harcourt, Nigeria*
**Corresponding author: Idoniboyeobu D. C. ; idoniboyeobu.d@ust.edu.ng*

ABSTRACT
The load flow analysis study is a research conducted for Port Harcourt Town Zone 4, Rivers State power distribution network. It is necessary for planning, operation, future expansion of the network and exchange of power between utilities. The analysis was carried out to solve the problem of frequent power outages caused by heavy I^2R losses in the line.Low voltages were experienced at consumers end as well as, poor power factor at load end, over-loading of feeder transformers, inadequate size of conductors at consumers end of the network in Port Harcourt Town, 33KV Distribution Network A detailed survey was carried out on the Network and the bus admittance matrix formed. MATLAB programmable codes were written to solve the static load flow equations formulated using Fast decoupled and Newton Raphson algorithm based on the benefits of time and digital computer memory space. As a result the bus voltages and phase angles; network losses reduce; branch real and reactive power flow were obtained. The application software called Electrical Transient Analyzer Program (ETAP) was used to model the network and carry out simulation to compare the results. It was observed that, both results obtained were similar. The total net power received were 130.412 MW and 84.28MVar using Fast Decoupled Newton-Raphson load flow method in MATLAB Environment after injection of reactive power via Capacitor bank to the buses that were affected due to unacceptable voltage drop while the total net real and reactive power received using ETAP software were 126.7 MW and 93.8 MVar.. The total line losses on the network reduced from 4.7512MW and 10.0517MVar to 3.5821MW and 7.5785MVar respectively. A 24.6% reduction of the total real power losses was realized after injection of reactive power into the under-voltage buses, the bus voltage profiles were normalized as observed in results. The results obtained on each feeder will aid the system engineer during operation and future expansion of the network under consideration.

***Keywords**: Distribution Network, Fast Decoupled PowerFlowMethod,MATLAB, Phase angle of Voltages, Electrical Transient Analser Program (ETAP), Line loss minimization.*

Date of Submission: 09-12-2017 Date of acceptance: 16-11-2017

I. INTRODUCTION

In practice, the demand for electrical power always exceeds the supply especially in the developing countries like Nigeria, resulting to undesirable power sharing thereby causing wasteful power supply system.

Generally, in Nigeria, factors contributing to inefficient and unreliable power supply apart from low power generation may include poor or ineffective voltage control system, poor transmission networks, Highly overloaded transmission feeders due to lack of planning, faulty distribution system on the part of the electrical suppliers, voltage drop along the line and from the distribution system due to the flow of current and load variations on the consumer end, damage to substation, transmission and distribution network, short circuit or overloading of electrical mains, and tripping of power system. These shortcomings over the years have resulted to unreliable and spurious voltage variations and frequent power outages.An Efficient power supply system is one that seeks to overcome the above shortcomings and delivered better quality of power to local consumers and industrial users.

For distribution system the power flow analysis is a very important and fundamental tool. Its results play the major role during the operational stages of any system for its control and economic schedule, as well as during expansion and design stages. The purpose of any load flow analysisis to compute precise steady-state voltages and voltage angles of all buses in the network, the real and reactive power flows into every line and transformer, under the assumption of known generation and load.During the second half of the twentieth century, and after the large technological developments in the fields of digital computers and high-level programming languages, many methods for solving the load flow problem have been developed, such as Gauss-Siedel (bus impedance matrix), Newton-Raphson's (NR) and its decoupled versions. Nowadays, many improvements have been added to all these methods involving as sumptions and approximations of the transmission lines and bus data, based on real systems conditions.

The Fast Decoupled Power Flow Method (FDPFM) is one of these improved methods, which were based on as amplification of the Newton-Raphson's method. This method due to its calculations simplifications, fast convergence and reliable results became the most widely used method in load flow analysis. However, FDPFM for some cases, where high R/X ratios or heavy loading (Low Voltage) at some buses are present, does not converge well. For these cases, many efforts and developments have been made to overcome these convergence obstacles. Some of them targeted the convergence of systems with high R/X ratios, others those with low voltage buses. Though many efforts and elaborations have been achieved in order to improve the FDPFM, this method can still attract many researchers, especially when computers and simulations are becoming more developed and are now able to hand leand analyze large size system.

Load flow studies are important in planning, operation and future expansion of powersystems. The study gives steady state solutions of the voltages at all the buses, for a particular load condition. Different steady state solutions can be obtained, for different operating conditions, to help in planning, designing and operation, economic scheduling and exchange of power between utilities. Load flow analysis is to find the magnitude and phase angle of voltage at each bus, real and reactive power in each transmission line. The load flow problem consist of finding the power flow (real and reactive) and voltages of a network for a given bus conditions. Because of the non linearity of the algebraic equations, describing the given power system, their solutions are obviously, based on the iterative methods only.

In this study, we used the Newton Raphson method and fast decoupled method BGNfor our analysis. This method gave the solution of non- linear simultaneous equations in rectangular or polar form. Time taken for the one iteration is high. Number of iterations required to get the convergent criteria are limited as 3.5 and does not depend on number of buses. Total time taken to get the convergent criteria is less. The selection of slack bus does not affect the convergent criteria. Newton Raphson and fast decoupled method is applicable for large power system applications. The power system is a large interconnected system where various buses are interconnected by a transmission line. At any bus, complex power is injected into the bus by generators and complex power is drawn by the loads. The complex power injected into the bus is equal to the sum of complex power flows out of the bus via a transmission line.

The research is to analyze Port Harcourt, Zone 4, Rivers State power network using Newton Raphson and Fast Decoupled method Load flow studies.The Port Harcourt, Zone 4, Rivers State 33kV distribution power network located at heart of the city, Plot 1/8 Amadi flat, Nzimiro, off Aba Road, Old GRA Port Harcourt, Rivers State comprises of 4- distribution transformers with a total installed capacity of 165MVA. The distribution network has nine (9) feeders which serve Port Harcourt metropolis namely; UST feeder, Secretariat feeder, Borokirifeeder, Silver Bird feeder, UTC feeder, Owerri Rd-Nzimirofeeder, Trans Amadi-Nzimirofeeder and Old Diobu-Nzimirofeeder. At the construction of the 33kv distribution substation, supply of power was stable.However, challenges emerge as the city expands; low voltages experienced in some areas which led to installation of transformers without planning resulting to the overloading of the various feeders in areas under consideration and also drop in voltage due to the distance covered by the transmission line which serves the state. Despite these challenges, there is the insufficient megawatt from the National grid to the state.

1.1 The aim of this ResearchWork

The aim of this research work is carryout Load Flow Analysis of Port Harcourt Electricity Network using Fast Decoupled and Newton Raphson Technigues, for improved performance.

1.2 Objective of this Research Work

The objectives of this research work isto carry out the following:

- Obtain appropriate data from field survey and Port Harcourt Electricity Distribution (PHED)Nstaff.
- Develop a Load Flow algorithm usind Fast Decoupled and Newton Raphson method.
- Develop a program using MATLAB to solve derived equations.
- Determine Power Flows and losses in lines.

II. LITERATURE REVIEW

Load flow analysis forms an essential pre-requisite for power system studies. Considerable research has already been carried out in the development of computer programs for load flow analysis of large power systems. However, these general purpose programs may encounter convergence difficulties when a radial distribution system with a large number of buses is to be solved and, hence, development of a special program for distribution studies becomes necessary. There are many solution techniques for load flow analysis. The solution procedures and formulations can be precise or approximate, with values adjusted or unadjusted intended for either on-line or offline application, and designed for either single-case or multiple-case applications [1].

Power flow method is a fundamental tool in application software for distribution management system. In the past decades, a mass of methods to solve the distribution power flow problem have been developed and well documented. These methods can be roughly categorized as node-based methods and branch-based methods. The first category used node voltages or currents injection as state variables to solve power flow problem. In this category, the most notable methods include network equivalence method, Z-bus method, Newton-Raphson's algorithm, Fast Decoupled algorithm. The second category utilized branch currents or branch powers as state variables to solve power flow problem. The backward/forward sweep based methods and loop impedance methods can be categorized in this group [2].

2.2 Fast Decoupled Power Flow for Unbalanced Radial Distribution Systems.

According to Zimmerman and Chiang [3], certain applications, particularly in distribution automation and optimization of a power system, require repeated load flow analysis; and sees load flow as a very significant and essential tool for the analysis of any power system and been used in operation as well as planning stages. Since the invention and wide spread use of digital computers, beginning in the 1950's and 1960's, many methods for solving the load flow problem have been developed. Most of the methods have "grown up" around transmission systems and, over the years, variations of the Newton method such as the fast decoupled method have become the most widely used. Unfortunately, the assumptions necessary for the simplifications used in the standard fast decoupled Newton method often are not valid in distribution systems where Resistance/Reactance ratios can be much higher. However, in their paper, it was mentioned that some of the methods based on the general interconnected topology of a typical transmission system; a comprehensive models of a network includes lines, switches, transformers, shunt capacitors, co-generators, and several types of loads, etc.

They further presented a new problem formulation of three-phase distribution power flow equations taking into account the radial arrangement of the distribution network. From the new problem formulation, the numbers of power flow equations as compared with the conventional formulation were significantly reduced.
Also, both numerical and structural properties of distribution systems were exploited resulting in fast decoupled solution algorithm. The proposed solution algorithm is evaluated on three-phase unbalanced 292-bus and 394-bus test systems with very promising results [3].

2.3 Diakoptic Theory BasedOnFast Decoupled Load Flow Algorithm

Adiakoptic theory based on fast decoupled load flow algorithm which is suitable for distributed computing. If computations for different subsystems of an integrated system are done concurrently using a number of processors load flow study can be done in a shorter time. Moreover, if distributed processing is done in real time, data is to be collected from local points only and a comparatively smaller data base is to be updated locally at regular intervals. Transmission of data over long distance to the central processing computer can thus be reduced [4].

2.4 Fast Decoupled Load Flow with Optimal Axes Rotation

In the opinion of Firmino de Medeiros and Joselia[5], calculation of load flow problem using fast decoupled method presents advantages on reduction of digital computer core and CPU time requirements. These last characteristic takes greater importance by supervisory system applications. Over the years in applying the method, experience show that decoupling theories are valid for over-head transmission lines but neither for distribution networks, nor for underground cable systems. Their paper presents a method, based on decoupling theory, independent of average values of X/R of the network. The new method is much faster than the Newton's method, even reaching quick convergence by those cases where fast decoupled method does not converge.

However, the needs to implement fast programs for load flow calculation, decoupled methods were developed, starting from Newton-Raphson algorithm. The decoupling theories or methods are based between real power (P) and voltage angle (δ), and reactive power (Q) and voltage magnitude (V) in the iteration's equations of Newton's method. The great advantage due to the decoupling consists in computer time economy by solving two linear equation systems of order (n-1), instead of just one system of order (2n-2). Previous researches have demonstrated that convergence of the traditional decoupled method is dependent on the average value of the ratio between branches' equivalent series reactance and resistance of the whole system. X/R ratio values of numerical order 3 imply an extremely favourable condition to the convergence and more [5].

2.5 The General Purpose Fast Decoupled Power Flow

In the general purpose fast decoupled power flow, almost all the relevant known numerical methods used for solving the non linear equations have been applied in developing power flow models. Among various methods, power flow models based on the Newton-Raphson (NR) method have been found to be most reliable. Many decoupled polar versions of the NR method have been attempted for reducing the memory requirement and computation time involved for power flow solution. Among decoupled versions, the fast decoupled load flow (FDLF) model developed [6].

2.6 Application of Fast Decoupled Load Flow Method for Distribution Systems with High R/X Ratios Lines

Ochi, et al, [7] in their work proposed, 'a fast decoupled load flow calculation method for distribution systems with high R/X ratio'. The method was based on a coordinate transformation in Y-matrix for Jacobian matrix in the load flow method. When compared with Newton-Raphson method, a short computation time was realized. However, it worsens convergence characteristics. In order to overcome the problem, a coordinate transformation in Y-matrix of the Fast Decoupled method for better convergence in processes [7].

2.7 Power Flow Solution Algorithm for Radial Distribution Feeders

According to Abu-Mouti and EI-Hawary [8], Power Flow Algorithm is designed for transmission network rather than distribution networks. They said, in literature much of the algorithm have been modified. However, the solution methods have advantages and disadvantages such as time consuming and storage capacity, divergence, etc. The requirement for reliability, accuracy, less storage capacity and fast algorithm play an important role in any new proposed distribution load flow analysis. In their work, they mentioned that, new distribution power flow algorithm must consider large systems so that the storage capacity needs to be low to achieve the solution fast and in less iteration for both offline and online application [8].

2.8 Comparison between Load Flow Analysis Methods in Power System Using MATLAB

From the conclusive point of view of this paper: 'comparison between load flow analysis methods in power system using MATLAB'was carried out by Kriti [9]. The analysis, designing and comparison between different load flow system solving techniques such as Gauss-Seidel Method, Newton-Raphson Method, etc., in Power System using MATLAB was successfully done and observed the desired result. In Gauss-Seidel method rate of convergence is slow. It can be easily program and the number of iterations increases directly with the number of buses in the system whereas using Newton-Raphson method the convergence is very fast and the number of iterations is independent of the size of the system; the solution accuracy is high as obtained. It was stated that, in NR method, convergence is not sensitive to the choice of slack bus. Also, looking at a large number of load flow methods been available in literature; it has been observed that only the Newton-Raphson and the Fast Decoupled load-flow methods are most popular. The fast decoupled load flow is definitely superior to the Newton-Raphson Method from the point of view of speed and storage, he added [9].

2.9A Promising Method for Uncertain Load Flow Studies

The power flow studies are used to determine the steady state or operating conditions of power systems for specified sets of load and generation values. But when the input conditions are uncertain, numerous scenarios are analyzed to cover the required range of uncertainty, and reliable solution algorithms that incorporate the effect of data uncertainty into the power flow analysis are needed.The probabilistic methods are tools for planning studies. These present various shortcomings due mainly to non-normal probability distribution and the statistical dependence of the input data as well as the problems associated with accurately identifying probability distribution for some input data [10]. According to the authors, Miranda and Matos, [19], the second family of the load flow algorithms incorporating uncertainty has been developed more recently and utilizes fuzzy sets for its modeling.

2.10 Load Flow Analysis using PSAT software for Test System Simulation

According to Kipkirui and Abungu[11] in his work proposed decoupled load flow method using MATLAB 7.6 to develop a reliable and effective program and PSAT (Power System Analysis Toolbox) as a validating tool. The procedural methods calculate and analyzed a well-conditioned load flow study with minimal losses on the buses, branches and the minimal number of iteration required for convergence was noted. IEEE 14 bus system/ network were used as the test system the research work by Kipkirui and Abungu [11].

2.11Power Flow Analysis of Abule-Egba 33-kV Distribution Grid System with Real Network Simulations

The planning, design and operation of power systems requires load flow computations to analyze the steady - state performance of the power system under various operating conditions.To overcome the computational problems of power-flow solution, a fast Decoupled Newton Raphson technique is used to carry out simulation.The very low bus voltages and poor power magnitude obtained from this study without voltage compensation at Agbefa 11KV Feeder revealed the reality of the epileptic poor power supply at the Abule -Egba part of Lagos State, Nigeria. In order to augment this disturbing situation, it is recommended that relevant stake holders imbibe the reduction of power loss in distribution Networks via correct sizing and location of reactive power support. Abdulkareem [12] submitted that the findings are not properly applied or sized, the reactive power from capacitor banks can create even more losses and high voltages that can damage light load.

2.12 Load Flow Analysis using ETAP Software for Network Simulation

In a bid for "planning and coordination of relay in distribution system using ETAP", Jayaprakash, et al[16], carried out a load flow analysis to investigate the performance of the electrical system during normal and abnormal operating conditions, providing information needed to: Optimize circuit usage; develop practical voltage profiles; minimize MW and MVar losses; develop equipment specification guidelines; and identifies transformer tap settings. 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. [13].

2.13Power Flow Analysis of Power System Using the Power Perturbation

Power flow analysis is a very important tool in power system analysis. The operation and planning of power system depends upon the effective use of the load flow technique. Some opinions are of the view that most of the existing algorithms were developed to reduce the computational burden by reducing the number of equations, approximating the Jacobian matrix and other variables.A new power flow technique known as the perturbation theory of which its objective is that it attempts to enhance the convergence rate by partially linearizing the power flow equation where more attention is on the voltage magnitude (V) and the phase angle (δ) in each iterations.In fact, this technique gives faster, smarter and more accurate results having being tested the technique on the IEEE 5-bus, 14-bus, 30-bus and 118-bus system than the conventional Gauss- Seidal technique of load flow calculation. This has been displayed by Tinney and Hart[14], Carlos, *et al*[15] and Antonio, *et al* [16].

2.14 Load Flow Analysis on IEEE 30 Bus Systems

The Newton-Raphson or the Gauss Seidel methods are conventional techniques for solving the load flow problem .With the load flow studies, the voltage magnitudes and phase angles can be ascertained at each bus in the steady state and can be computed within a specified limit. This has been demonstrated by Ghosh [17] and Jamali [18].

.

III. MATERIALS AND METHOD

3.1 Materials

In this research work, the materials required for the analysis are: line input data; bus input data; MATLAB software; a personal computer; MATLAB programming codes using Fast decoupled load flow algorithms. Also, ETAP software shall be used for comparison/validation. The Fast Decoupled Load Flow method was applied for the distribution network under consideration. The Fast Decoupled method is the modified version of Newton Raphson Load flow method. The network was modeled in Electrical Transient Analyzer program (ETAP software) for simulation purposes using fast decoupled.

3.2Methods used to Solve Static Load Flow Problems

It is important to note that the voltages and power flows in an electrical system can be determined for a given set of loading and operating conditions. This is known as the power flow problem. Power flow analysis is used extensively in the planning, design and operation of electrical systems, etc. Some basic information obtained from load flow studies are magnitude of voltages (V), phase angle of voltages (δ), active powers (P), reactive powers (Q), line power losses (Lpl), etc. The solution of static load flow problem is difficult because of nonlinear characteristics of the equations, as bus voltages are involved in product form and sine, cosine terms are also present. Hence, solutions are possible only through iterative numerical techniques using the methods below.

The following methods used solving static load flow equation includes:

1. Gauss Seidel Load Flow Method (GSLFM);

2. Newton-Raphson Load Flow Method (NRLFM);
3. Fast Decoupled Load Flow Method (FDLFM).

3.2.1 Brief Comparison between the methods mentioned above:

The (NRLFM) method is superior to the (GSLFM) method because it displays faster convergence characteristics. However, the (NRLFM) method suffers "flat start" as one of its disadvantages, since the solution at the beginning can oscillate without converging towards the solution. In order to avoid this problem, the load flow solution is often started with a (GSLFM) algorithm followed by the (NRLFM) algorithm after a few iterations. Meaning, to start NRFL, GSLF algorithm shall be used to start flat the iteration processes.
Also, fast decoupled Newton-Raphson load flow method is a modification on Newton-Raphson that exploits the approximate decoupling of active and reactive power flows in well-behaved power networks; and additionally fixes the value of the Jacobian during the iteration in order to avoid costly matrix decompositions. It is an approximate but faster method for the load flow calculation as compared to Newton-Raphson load flow method, and Gauss Seidel load flow method demonstrated by Kriti [9].

3.3Power Flow Solution

Power flow studies, commonly known as load flow, form an important part of power system analysis. They are necessary for planning, economic rescheduling, and control of existing system as well as planning its future expansion. The problem consists of determining the magnitudes and phase angle of voltages at each bus and active and reactive power flow in each line. In solving a power flow problem, the system is assumed to be operating under balanced conditions and a single phase model is used. Four quantities are associated with each bus; the voltage magnitude $|V|$, phase angleδ, real power P, and reactive power Q.

The system buses are generally classified into three types; Load buses at a node, the active and reactive powers are specified. The magnitude and phase angle of the bus voltages are unknown. These buses are called P-Q buses. Regulated/controlled buses are the generator buses. They are also known as voltage-controlled buses. At these buses, the real power and voltage magnitude are specified. The phase angles of the voltage and reactive power are to be determined. The limits on the value of reactive power are also specified. These buses are also specified. These buses are called P-V buses. Slack bus, also known as swing bus, is taken as reference where the magnitude and phase angle of the voltage are specified. This bus makes up the difference between the scheduled loads and the generated power that is caused by loses in the network.

3.4General Purpose Newton-Raphson's Method of Power Flow Analysis

Newton Raphson method is used for solving nonlinear algebraic equations. This is a successive approximation procedure based on initial estimate of unknown and uses Taylor series.

3.4.1Power Flow Equation

Typical Bus of a Power System network is shown in figure 1.

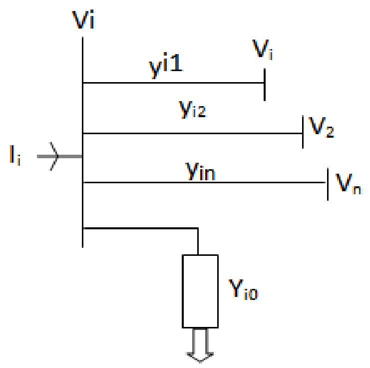

Figure 1 Typical Bus of a Power System Network

Applying Kirchhoff current law (kcl) at this node

$I_i = (y_{i0} + y_{i1} + y_{i2} + \ldots y_{in})\,Vi - yi1\,V_1 - yi2\,V_2 - \ldots - y_{in} V_n$(1)

$$I_i = V_i \sum_{j=0}^{n} Y_{ij} - \sum_{j=0}^{n} Y_{ij} V_j \quad where \quad j \neq i \qquad (2)$$

$$P_i + jQ_i = V_i\, I_i^*$$

Substituting Ii from above equation into eqation2

$$(P_i - jQ_i)/V_i^* = V_i \sum_{j=0}^{n} Y_{ij} - \sum_{j=0}^{n} Y_{ij} V_j \quad where \quad j \neq i \qquad (3)$$

Equation 2 can be written as below

$$I_i = \sum Y_{ij} V_i$$

Above equation in polar form

$$I_i = \sum |Y_{ij}||V_j| \angle \theta_{ij} + \delta_{ij}$$

The complex power at bus I is

$$P_i - jQ_i = |V_i| \angle -\delta_i \sum |Y_{ij}| \angle \theta_{ij} + \delta_{ij}$$

Separating real and imaginary parts

$$P_i = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j) \qquad (4)$$

$$Q_t = -\sum_{j=1}^{m} |V_i||V_j||Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j) \qquad (5)$$

Above two equations constitute a set of non- linear algebraic equations in terms of independent variables, voltage magnitude in per unit, and phase angle in radians. Expanding above two equations in Taylor series about initial estimate and neglecting all higher order terms results inset of equations of short form is given as follows:

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J\delta & J_4 \end{bmatrix} \begin{bmatrix} \delta\Delta \\ \Delta |V| \end{bmatrix}.$$

The diagonal and off diagonal elements of J1 are

$$\frac{\partial Pi}{\partial \delta i} = \sum_{j \neq j}^{n} |V_i||V_j||Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j) \qquad (6)$$

$$\frac{\partial Pi}{\partial \delta i} = -|V_i||V_j||Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j) \quad j \neq i \qquad (7)$$

The diagonal and off diagonal of J4 are

$$\frac{\delta Qi}{\delta |V_i|} = -2|V_i||Y_{ii}| \sin \theta_{ii} - \sum_{i \neq j} |V_i||Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j) \qquad (8)$$

$$\frac{\partial Qi}{\partial |V_i|} = -|V_i||Y_{ii}| \sin(\theta_{ij} - \delta_i + \delta_j) \qquad (9)$$

The terms $\Delta Pi^{(k)}$ and $\Delta Qi^{(k)}$ are the differences between the scheduled and calculated values, termed as power residual, given by

$$\Delta Pi^{(k)} = Pi^{(sch)} - Pi^{(k)} \qquad (10)$$

$$\Delta Qi^{(k)} = Qi^{(sch)} - Qi^{(k)} \qquad (11)$$

The new estimates for bus voltage are

$$\delta i^{(k-1)} = \delta i^{(k)} - \Delta Pi^{(k)} \qquad (12)$$

$$|Vi^{(k+1)}| = |Vi^{(k)}| + \Delta |Vi^{(k)}| \qquad (13)$$

3.4.2Formulation of Power Flow Equations

The power system is a large interconnected system with several buses connected through transmission lines. The power flow problem involves the computation of magnitude and phase angle of voltages at each bus, real and reactive power flow in all branches in the power system under steady-state condition. The first step in power flow study is the formation and calculation of bus admittance matrix which is constructed from transmission line data. However, a case study is taking from Port Harcourt Town (zone 4) on the 33kV Distribution Network (outgoing feeders); Transformers total installed capacity is 165MVA**.** Table 1shows breakdown of the distribution transformers attached to the injection station and figure 3, is the 33kV Distribution Network for Port Harcourt Town Injection substations.

3.5 Line Parameter of 33KV Distribution Network

Considering Line Parameter of 33KV Distribution Network, the Conductors are overhead and horizontally arranged. Spacing between conductors physically seen in Nigerian 33kV distribution network is 0.88m. (i.e. D = 0.88m).

UST Feeder (33kV) on Bus 2 @ 15.15km to injection substation.

Where:
Conductor Cross Sectional Area, A = $182mm^2$ACSR/GZ. (Aluminum conductor steel reinforced with galvanized).
GMD is the geometric mean distance of conductor in m
r is the radius of conductor in metre (m)
D is the distance between adjacent conductor (D=0.88m).
G_0 is the conductance of the line in Siemens
B_0 is the susceptance of the line in Siemens

Radius of conductor, R = $\sqrt{\frac{A}{\pi}}$ m (14)

R = $\sqrt{\frac{182x10^{-6}}{\pi}} = 0.00761$ m

GMD = $\sqrt{D_{RY}xD_{YB}xD_{RB}} = 1.26D$ (15)

D_{GMD} = 1.26D (16)
D_{GMD} = 1.26 x 0.88 = 1.1088m or 1.109m
Resistivity of Aluminum, $\rho = 2.826\,x10^{-8}\Omega.mat20^0C$

Table: 1 Feeders and Number of 33KV Injection Substation for Zone 4

Port Harcourt Town 33KV Feeder (At Amadi Junction-Nzimiro St.)			**33/11KVInjection Substations**	
Fdr ID	**Name**	**Transformer installed Capacity**	**Name**	**Transformer installed Capacity**
1	UST feeder	30 MVA	RSUST Agip NAOC	2x15 MVA 1x7.5 MVA 2x3 MVA
2	Secretariat Feeder	45 MVA	Secretariat Marine Base Juanuta	2x7.5 MVA 2x15 MVA 1x2.5 MVA
3	Borokiri Feeder	60 MVA	Borokiri Eastern Bypass	1x15 MVA 1x15 MVA
4	Silver Bird Feeder		Silver Bird Kidney Island	1x15 MVA 1x1.5 MVA
5	UTC Feeder		UTC Water Works	1x15 MVA 1x15 MVA
6	Rumuolumeni Feeder		UOE SCH of Nursing Naval Base Master Energy	1x7.5 MVA 1x15 MVA 2x2.5 MVA 1x1.5 MVA
7	NzimiroFeeder, etc.	30 MVA	Nzimiro-Old Diobu,Owerri Rd,etc	3x15 MVA

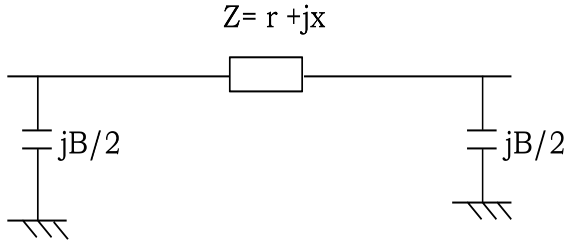

Figure 2: Per Phase Π Representation of a Line

3.7.1Mathematical Model of Fast Decoupled power Flow method

In a power system network, the net injected active and reactive powers at an ith bus are given by:

$$P_i = \sum_{j=1}^{nb} |V_i||V_j|\left(G_{ij}\cos\theta_{ij} + B_{ij}\sin\theta_{ij}\right) \quad (17)$$

$$Q_i = \sum_{j=1}^{nb} |V_i||V_j|\left(G_{ij}\sin\theta_{ij} - B_{ij}\cos\theta_{ij}\right) \quad (18)$$

Where Vi and Vj, voltage magnitudes at the i^{th}andjthbuses, respectively; Gij+ jBijis the ijthelement of the Y-bus; and nb, total number of buses.

3.10 Capacitor/Reactor Bank

Due to line losses and other line constraints, line compensators are introduced in a network to minimize the losses. Shunt capacitors are applied across an inductive load so as to provide part of the reactive VARs needed by the load to sustain the voltage within desirable limits. Also, the shunt reactors are applied across capacitive loads or in light load conditions to absorb some of the leading VARs for achieving voltage control. Capacitors are connected either directly to a bus or through tertiary winding of the main transformer and are placed along the line to minimize losses and the voltage drop. The shunt capacitor improves the power factor of the load. These shunt capacitor banks inject reactive power into the network or line to compensate for line losses.

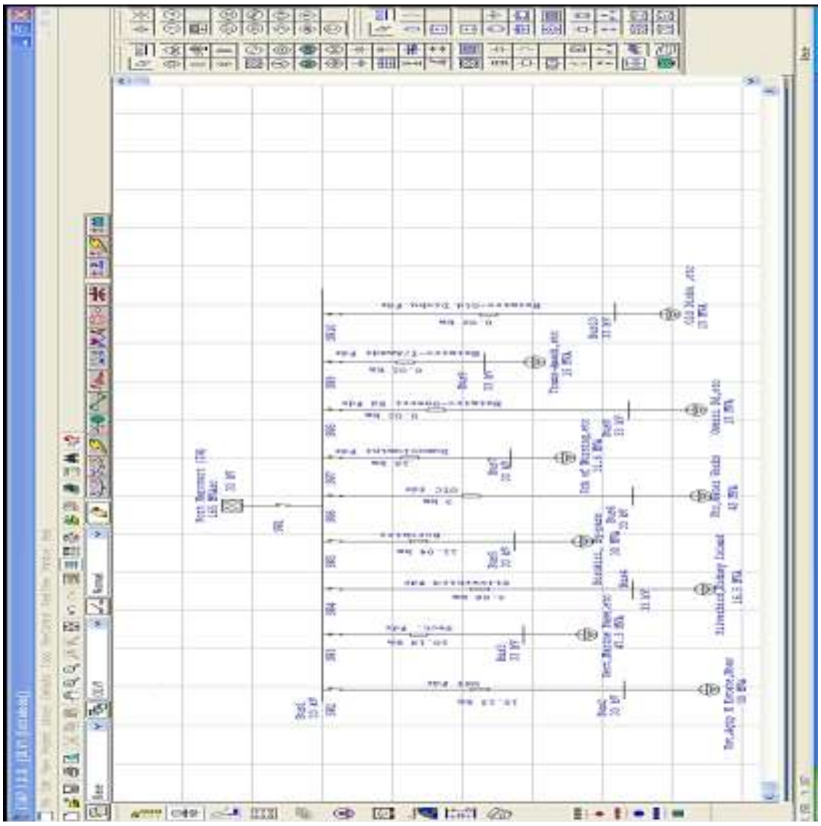

Figure 3: 33KV Distribution Network for Port Harcourt Town Injection substations (Lumped Load)

IV. RESULTS AND DISCUSSION

4.1Results

The results obtained are shown below using Fast decoupled N-R techniques embedded in ETAP software. Also, results of the network load flow and its parameters calculated using MATLAB program are shown below. The load flow analysis of the 33KV Distribution network considering Port Harcourt Town, Zone 4, see appendix for various resultssections from the application of the above mentioned methods and simulation of the network as follows:

Table 2: Result of the PHED Port-Harcourt Town (Zone 4) -10 Bus/9 Feeder System before Injection of Reactive Power. (**MATLAB**)

###FAST DECOUPLED LOAD FLOW ANALYSIS###

Bus	V	Angle	Injection		Generation		Load	
No	pu	Deg.	MW	MVar	MW	Mvar	MW	MVar
1	1.0000	0.0000	135.158	107.827	0.000	0.000	0.000	0.000
2	**0.9350**-	0.0428	-14.400	-10.800	0.000	0.000	14.400	10.800
3	**0.9487**-	0.0459	-22.800	-17.100	0.000	0.000	22.800	17.100
4	0.9914	- 0.0044	-7.900	-5.900	0.000	0.000	7.900	5.900
5	**0.9468**-	0.0304	-14.400	-10.800	0.000	0.000	14.400	10.800
6	0.9744	- 0.0129	-23.400	-17.600	0.000	0.000	23.400	17.600
7	**0.8985**-	0.0697	-18.700	-14.200	0.000	0.000	18.700	14.200
8	0.9999	- 0.0000	-9.602	-7.201	0.000	0.000	9.600	7.200
9	0.9999	- 0.0000	-9.602	-7.201	0.000	0.000	9.600	7.200
10	0.9999	- 0.0000	-9.602	-7.201	0.000	0.000	9.600	7.200
Total			**4.751**	**9.823**	**0.000**	**0.000**	**130.400**	**98.000**

Table 3: Load Flow Results after Injection of Reactive Power into the Feeders **(Matlab)**Phed Port-Harcourt Town (Z4) -10 Bus/9 Feeder Network

####FASTDECOUPLED LOAD FLOW ANALYSIS####

Bus	V	Angle	Injection		Generation		Load	
No	pu	Degree	MW	MVar	MW	Mvar	MW	MVar
1	**1.0000**-	0.0000	-133.993	13.335	0.000	0.000	0.000	0.000
2	**1.0074**-	0.0852	-14.400	9.200	0.000	0.000	14.400	10.800
3	**1.0026**-	0.0887	-22.800	12.900	0.000	0.000	22.800	17.100
4	**0.9910**-	0.0048	-7.900	5.900	0.000	0.000	7.900	5.900
5	**1.0061**-	0.0621	-14.400	9.200	0.000	0.000	14.400	10.800
6	**0.9733**-	0.0140	-23.400	17.600	0.000	0.000	23.400	17.600
7	**0.9869**-	0.1235	-18.700	7.800	0.000	0.000	18.700	14.200
8	**0.9999**-	0.0000	-9.604	7.196	0.000	0.000	9.600	7.200
9	**0.9999**-	0.0000	-9.604	7.196	0.000	0.000	9.600	7.200
10	**0.9999**-	0.0000	-9.604	7.196	0.000	0.000	9.600	7.200
	Total	3.582	7.348	0.000	0.000	130.400	98.000	

V. CONCLUSION AND RECOMMENDATIONS

5.1Conclusion

The analysis of this power flow analysis has clearly shown areas of attention. The power dispatched from the grid network to the transmission substation was not adequate therefore each injection substation has percentage of loading of the available power. From the simulation results, more power is required from the grid to the injection substations via Port Harcourt Town (Z4) control transmission substation. In the absence of adequate power supply from the grid network to the transmission substation down to the distribution injection substations, load shedding becomes the only option.

The total power losses amounting to **4.7512MW** and **10.0517MVar** on the 33KV distribution network necessitated upgrade of the network by sending more power from the grid to these primary distribution systems. However, the introduction of line compensator (Capacitor bank) at the affected buses (under voltage buses) improved the voltage profile. The losses on the feeders reduce to **3.5821MW** and **7.5785MVar**. A 24.6% of the real power loss reduction when capacitor banks were placed on the affected buses.The use of Fast Decoupled

Power Flow analysis in MATLAB and the application of ETAP software aids the analysis very accurately and proactive with less memory requirement.

5.2 Recommendation.

- Sequel to the results above of the result, I hereby recommend that the 33kV distribution network be expanded by incorporating or adding more transformers, protective systems, and capacitors banks as realized from the affected buses so as to keep the desirable voltage limits.
- The injection substations for the network under consideration should be made to operate at least 80 per cent of power supply to the secondary distribution network.
- The reactive power demanded locally at the bus injection substation can be used to minimized the line power loss associated with the network
- Periodic load flow analysis should be carried out by the electricity distribution company to ascertain the status of the network without over-stressing it.

REFERENCES

[1]. Kuldeep,S.&Suman,B. (2009). Fast decoupled power flow for unbalanced radial distribution
[2]. system.Electrical& Instrumentation Engineering Department, Thapar University, Patiala-147004.
[3]. Afolabi,O.A.,Ali,W.H.,Cofie,P.,Fuller,J.,Obiomon,P. &Kolawole,E.S. (2015). Analysis of Load Flow problem in Power System Planning Studies. Energy and Power Engineering, 7,509-523. http://www.scirp.org/journal/epe.
[4]. Zimmerman, R.D. & Chiang, H.D. (1995). Fast Decoupled Power Flow for Unbalanced Radial Distribution Systems**,** Institute of Electrical &ElectronicsEngineering Transaction on Power Systems10, 4 November. Retrieved from 24th October, 2016, https://www.researchgate.net
[5]. Bandyopadhyay, G. &Syam, P (2003). Distributed Fast Decoupled Power Flow Analysis. Department of Electrical Engineering, BE College. Howrah, 84,183-188.
[6]. Firmino de Medeiros, M. &Joselia dos, A.L. (2007).Fast Decoupled Load Flow with Optimal Axes Rotation,Dep. de Eng. de Comp. UFRN, Natal, Brazil.
[7]. Amerongen,R.A.M.(1989). A general purpose version for the fast decoupled flow. Institute of Electrical& Electronics EngineeringTrans on Power System, 4, 2.
[8]. Ochi, T., Yamashita, D., Koyanagi, K., Yokoyama, R.(2013). The Development and Application of Fast Decoupled Load Flow method for Distribution systems with High R/X ratios Lines. In 2013 IEE PES Innovative Smart Grid Technologies Conference.
[9]. Abu-Mouti, F.S. & El-Hawary, M. E., (2007). "A New and Fast Power Flow Solution Algorithm for Radial Distribution Feeders Including Distributed Generations", Institute of Electrical &Electronics Engineering Transactions on Power Systems2668-2672.
[10]. Kriti, Singhal (2014).Comparison between Load Flow Analysis Methods in Power System using MATLAB, International Journal of Scientific & Engineering Research, 5, 5, May. Retrieved from http://www.ijser.org/
[11]. Su, C.L. (2005). Probabilistic load-flow computation using point estimate method.Institute of Electrical &Electronics Engineering Trans. Power Systems, vol. 20, no. 4, pp.1843-1851.
[12]. Kipkirui, K.S., &Abungu, N.O.(2009). De-coupled Load flow Study Method. University of
[13]. Nairobi, School of Engineering, Department of Electrical and information Engineering
[14]. http://eie.uonbi.ac.ke.
[15]. Abdulkareem, A., Awosope, C.O.A., Orovwode, H.E. and Adelakun, A.A. (2014). Power Flow Analysis of Abule-Egba 33kV Distribution Grid System with Real Network Simulations. Journal of Electrical and Electronics Engineering,9,(2): 67-80
[16]. 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, 252-256.
[17]. Tinney, W. F. &Hart, C. E. (2006). Power Flow Solution by Newton's Method. Institute of Electrical &Electronics Engineering Transactions on Power Apparatus and systems, 86, 1449-1460.
[18]. Carlos, A. F., Vander, M., Da, Costa (2005). A second Order Power Flow Based on Current Injection equation. Electrical Power& Energy System, (27), 254-263.
[19]. Antonio, G.E., Jose, L.M.R., Jesus R. S. (2004).Slack Bus Selection To Minimize The System Power Imbalance In Load Flow Studies. Institute of Electrical& Electronics Engineering Trans., 19, 987-995.
[20]. Ghosh, S. & Das, D. (1999). Method for Load—Flow Solution of Radial Distribution Networks. Proceedings Part C (GTD), 146, 6, 641-648.
[21]. Jamali, S., Javdan, M.R., Shateri, H. &Ghorbani, M. (2006). Load Flow Method for Distribution Network Design by Considering Committed Loads.Universities Power Engineering Conference, 4l,3, 856 — 860
[22]. Miranda, V., & Matos, M. (19990) Distribution System Planning with Fuzzy Models and Techniques, Proceedings of CIRED89, Bristol, UK.

About The Authors

Idoniboyeobu, Dikio Cliffordis an Associate Professor in the Department of Electrical Engineering, Rivers State University, Port-Harcourt. He holds B.Eng degreein Electrical Engineering, Ahmadu Bello University, Zaria; M.Scand PhD degrees in Electrical Engineering, University of Manchester, UK. He is COREN registered and a member of several Professional Organisations

Ibeni Christopher holds HND degree in Electrical Engineering, Federal Ploytechnic , Bauchi. He also holds a PGD and MTech Degrees in Electrical Engineering, Rivers State University, Port-Harcourt, Nigeria.

*Idoniboyeobu, D.C. "Analysisfor Electical Load Flow Studies in Port Harcourt, Nigeria, Using Newton Raphson Fast Decoupled Techniques. ." American Journal of Engineering Research (AJER), vol. 06, no. 12, 2017, pp. 230-240.