LOAD FLOW ANALYSIS
FOR N.E. P. A. IIKV DISTRIBUTION NETWORK WITHIN LOKOJA TOWN.

BY

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A PROJECT REPORT SUBMITTED IN PARTIAL
FULFILMENT OF THE REQUIREMENTS FOR THE
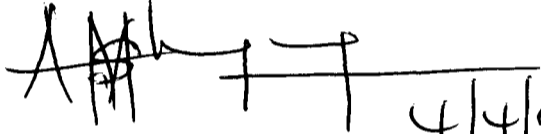AWARD OF BACHELOR OF ENGINEERING (B.ENG)

DEGREE IN THE

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MARCH, 2000

CERTIFICATION

This is to certify that this project titled "Load flow analysis of Lokoja town" was carried out by Shaibu Enebe Dada under the supervision of MALLAM M.S. Ahmed and submitted to Electrical and computer Engineering Department, Federal University of Technology, Minna in partial fulfilment of the requirements for the award of Bachelor of Engineering (B.Eng.) degree in Electrical and computer Engineering.

Engr. M.S. Ahmed
Project Supervisor

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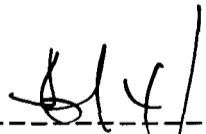
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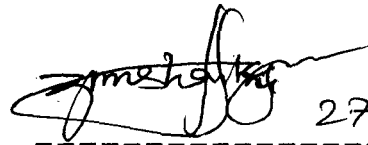
Sign & Date

DECLARATION

I hereby declare that the project work is an original concept wholly carried out by me, under the supervision of Mal. M.S. Ahmed of the department of Electrical/computer engineering, Federal University of Technology Minna.

Shaibu Enebe Dada.   27/3/2000
—————————————   —————————————
Student   *Sign & Date*

DEDICATION

This project work is dedicated to God Almighty for his unflinching love, protection and provision. Also to my late father to my late father Mr. Aguva J.E Shaibu.

ABSTRACT

In this project work, the electrical network distribution in Lokoja town is explained followed by the load flow problem and equation formulation using different methods. The load flow analysis is applied to 11kv distribution network. The data for load flow simulation program is prepared.

The simulation program is written in C-language which is more reliable than other computer languages.

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CHAPTER ONE

INTRODUCTION

Load flow analysis (L.E.A.) is the collective term for a nuber of computer aided analysis procedures aiming at determining the actual power flow patterns in a system and more importantly how to control those patterns.

As a result of development which lead to increase in load, it is therefore, necessary to have information about the continuous evaluation of present performance of a power and to analyse the effectiveness of alternate plans for system expansion to meet the increase in load demand. Hence the calculation of numerous load flow for normal and emergency operating conditions is required for this analysis.

Furthermore, a reliable and sufficient power system requires comprehensive and careful operation planning.

Loadflow program is one of the major tools of system planning and is utilized expensively. Important to the system planners are that input data errors be minimized and that there be an easy and rapid turn around for answers when the frequency of programme use is high. to accomplish this, interactive capability is provided with the ability to store base cases or numerous power system models on the coputers disks. The storage capability provide many different cases that the planning engineer can access for studying or varying a particular system condition. Load flow enables the power system planning engineer to simulate and solve various power system expansion alternatives in an internactive mode. It utilize a graphics colour terminal specified with a special set of graphic characters that present result in the form of system one-tone diagrams. The multicolour feature of the terminal is used to indicate heavily loaded lines, bus voltages outside normal limits and open circuit

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breaker. The engineer working at such a terminal may with mouse and alphanumeric keyboard remove, add, or change elements of the system being studied and request a solution from the host computer.

DISTRIBUTION NETWORK

Distribution network unlike transmission network, consists of a step-down (3311)kv on load tap-changing transformer at a bulk supply point feeding a numerous of cables which can vary in length from few hundred meters to several kilometres. A series of step down 3-$\emptyset$ transformer, 11/0.4/5kv are spaced along the routes and from these, the consumers, are supplied with 3-$\emptyset$ four wire network, 2-$\emptyset$ three wire network and single $\emptyset$ one wire network with each phase supply Lokongoma-housing estate, some industrial customers are directly supplied from 11 kv network e.g. Felele quarry industry.

AIMS AND OBJECTIVE

The motive of this project is to plan for the future development of power system. This is important because satisfactory operation of the system depends on the knowledge of the effect of interconnections with other power system or new additional loads on the system at any particular time. Hence this lead to load forcasting which is the prediction of future's load base on both the previous and present data.

The purpose of this project work is to describe the theory of load flow analysis and to apply the theory of load flow analysis to electrical network distribution in Lokoja town.

Here are some of the most important objective of load flow analysis.

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1. Determination of real & reactive power flow in the distribution lines of a system base on certain prior assumptions regarding loads, & generations.
2. Computation of the voltage at all system buses.
3. Checking that no distribution line is overloaded, over loading means the operation too close to its distribution limit or (in the case of under ground cable over heating).

LITERATURE REVIEW

In the past, before the invention of computer, load flow analysis were made on alternate current (a.c) calculating boards which provide small-scaled single voltage sources. It was very tedious and time consuming to set-up the connection, making adjustment and reading data. Now digital computer provide the solution of load flow studies on complex systems. For example, the computer program may handle more than 1500 buses, 2500 lines, 500 transformers with tap-changing under load and 25 phase-shifting transformers. Complete results are printed quickly and economically.

The simulation program associated with the load flow program are a system of linked programs that have the following capabilities.

1. Basic programs involving calculation of voltage, power flow, angles, and interchanges between areas of a power system.
2. A network reduction program to represent large network as equivalents conjuction with the specified area to be studied.
3. A distribution - factors program that indicates the sensitivity of response of the various circuits to

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outages of specified transmission lines, used to predict thermal limits with linear (super position) techniques.

4. The series of programs associated with the stored load flow files which permit accessing a particular case and

5. The var allocation program which selects the Minimum amount of kilovars of compensation necessary to maintain bus voltages within specified limits under normal and or emergency dispath, and performance improvement.

METHODOLOGY

The information contained in this project work is compiled by various methods which include personal experience, contribution of the N.E.P.A. Officers which vital informations.

During the three months and six months industrial trianing which undergone in National Electric power authority at Lokoja town a lot of experience is gained. At that time, I am able to know the distribution network components and their operatios. I also had experience on how the 33kv from the transmission station is steped down to 11kv at the control station and distributed to various sub-station where it is further steped down to 415v for the consumers' use. Dring this period, a lot of data about distribution network were obtained.

Informations were gathered from the N.E.P.A. officers; these include Engr. I.D. Dikko the distribution manager, Engr. S. Adepitan the planning construction and maintenance PC&M manager. They provided the data that I made use of in this booklet.

PROJECT OUT LINE

This project work is divided into four chapters. Chapter one is the introduction where load flow is defined. Chapter two deals with the theory of load flow. In this chapter, the various method of solutions of load flow problems are discussed. In chapter three we apply the load flow analysis to N.E.P.A. 11kv distribution network within Lokoja town and the results are commended in chapter four, finally the general conclusion is drawn.

CHAPTER TWO

2.1 THEORY OF LOAD FLOW

Under normal conditions electrical distribution system in its steady state mode and basic calculation required to determine the characteristics of this state is called load flow or power flow. Therefore load flow calculations provide power flows and voltages for a specified power system subject to the regulating capacity of generators, condensers, and tap-changing under load transformers as well as specified net inter change between individual operating systems. The information is essential for the continuous evaluation of present performance of a power system and for analysing the effectiveness of alternative plans for system expansion to meet increased load demand. The analysis requires the calculation of numerous load flows for both normal and emergency operating conditions. Loads are normally specified by the small variations of voltage and frequency expected during normal steady state operation.

The load flow problem consists of the calculation of power flows and voltages of a network for a specified terminal on bus conditions. A single phase representation is adequate since power systems are usually balanced.

The load flow studies are performed to investigate the following:

i.   Flow of active and reactive powers in the branches of the network.

ii.   Busbar voltages.

iii. Effective of rearranging circuits and incoporating new circuits on system loading.

iv.   Effect of temporary loss of generation and transmission circuits on system loading.

v.   Effect of inejecting in in-phase and quadrature boost. voltage on system loading.

vi.   Optimum system running conditions and distribution

vii.   Optimum system losses.

viii.   Optimum rating and tap change of transformers

ix.   Improvement from change of conductor size and system voltage.

2.20 BUS CLASSIFICATION

Three types of buses are represented in load flow calcu-. lations. Associated with each bus are four quantities which are the real and reactive power, the voltage magnitude and the phase angle. At a bus two of there four quantities are specified. These buses are,

2.2.1 (i) Voltage - Control Bus

Here the voltage magnitude V. corresponding to the generation and real power P. Corresponding to its ratings are specified. It is required to find out the reactive power geeration Q and the phase angle of the voltage. This types of bus generally corresponds to either a generator where P is is fixed by turbine governor and V is fixed by automatic voltage regulations acting on the machine excitation, or a bus where the voltage is fixed by supplying reactive power from static shurt capacitors or retating synchronous compensators, example at substations.

2.2.2 (II) LOAD BUS

In this bus the real and reactive components of power are specified. It is desired to find out the voltage

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magnitude and phase angle through the load flow solution. In a physical power system, this corresponds to a load centre such as a city or an industry, where the customer demands his requirements both P and Q are assumed to be unaffected by small variation in bus voltage.

2.2.3. (iii) *The slack or swing bus*

This bus arises because the system loses is not known precisely in advance of the load flow calculation. Therefore the total injected power cannot be specified at every single bus. It is usual to choose one of the available voltage-controlled buses as slack, and to regard its acture power as unknown. The slack bus is usually assigned as the system phase reference, and its complex voltage is therefore specified, that is, the voltage magnitude V and the phase angle & are specified whereas reactive and real powers are obtained through the load flow solution.

2.3 LOAD FLOW EQUATION FORMULATION

The Mathematical formulation of load flow problem results on a system of algebraic non-linear equations. This equations can be established by using either the bus or loop frame of reference. The coefficients of the equations depend on the selection of the independent variable, that is voltages or currents. Thus either the admittance or impedance network matrix can be used.

Early approaches to digital solution of load flow employed the loop flame of reference in admittance. The loop admittance matrix was obtained by a matrix inversion. These methods did not have wide spread application because of the tedious data preparation required to satisfy the network loops. Furthermore, the required matrix inversion was time-consuming and to be repeated for each subsequent case involving network changes. Later approaches uses the

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bus gained wide spread application because of the simplicity of data preparation and the ease with which the bus admittance matrix could be formed and modified for network changes in subsequent cases. Also combinations of voltages and currents have been used as the independent variations. This formulation uses a hybrid matrix consisting of impedance, admittance, current ratio and voltage ratio elements. The ability to formulate effeciently the network matrix has led to the load flow programs for large power system studies still employ methods using the bus admittance matrix. This approach remains the most economic from the point of view of computer time and memory requirements.

2.3.1 Load flow equations formulation using nodal matrix method

The load flow equations can be formulated using nodal matrix method. We shall first consider a three bus system to device the load flow equations, and, they are thus generalized for an n-bus system for instance, consider the figure below.
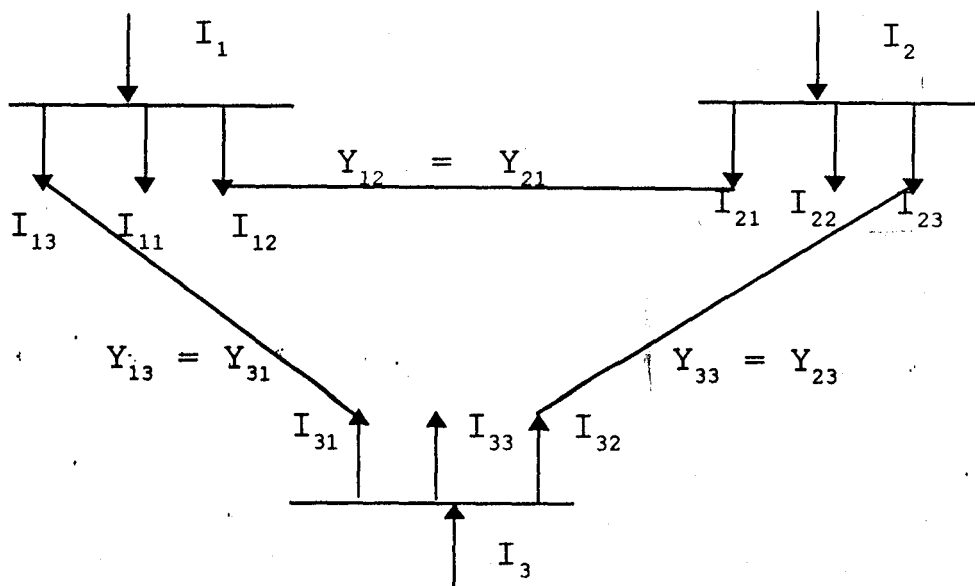
FIG 1 THREE BUS SYSTEM

At node 1
$$I_1 = I^{11} + I_{12} + I_{13}$$
$$= V_1Y_{11} + (V_1 - V_2)Y_{12} + (V_1 - V_3)Y_{13}$$
$$= V_1Y_{11} + V_1Y_{12} - V_2V_{12} + V_1Y_{13} - V_3Y_{13}$$
$$= V_1(Y_{11} + Y_{12} + Y_{13}) - V_2Y_{13} - V_3Y_{13}$$
$$= V_1Y_{11} + V_2Y_{12} + V_2Y_{13} \text{ ----- (1)}$$

Where Y_{11} is the shunt charging admittance at bus 1

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and

$$Y_{11} = Y_{11} + Y_{12} + Y_{13}$$

$$Y_{12} = - Y_{12}$$

$$Y_{13} = - Y_{13}$$

Where Y12 and Y13 is the self admittance of bus 1

Similarly nodal current equations for the other nodes can be written as follows:-

$$1_2 = V_1Y_{21} + V_2Y_{23} \quad ----- (2)$$

$$1_2 = V_1Y_{31} + V_2Y_{32} + V_3Y_{33} \quad ------ (3)$$

These can be written on matrix form as follows:

$$
\begin{bmatrix} 1_1 \\ 1_2 \\ 1_3 \end{bmatrix}
=
\begin{bmatrix} Y_{11} & Y_{12} & Y_{13} \\ Y_{21} & Y_{22} & Y_{23} \\ Y_{31} & Y_{23} & Y_{33} \end{bmatrix}
\begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix}
\quad ------ (4)
$$

or in complex form, these equations can be written as

$$1P = \sum_{q=1}^{n=3} Y_{pq}V_q. \quad P = 1 \text{ to } 3. \quad --- (5)$$

From this the nodal current equations for n-bus system where each node is connected to all other nodes is written in the form

$$1_p = \sum_{q=1}^{n} Y_{pq} V_q, \quad P = 1, 2, \dots --- n \quad (6)$$

or in matrix form.

$$
\begin{bmatrix} 1_1 \\ 1_2 \\ \vdots \\ \vdots \\ \vdots \\ 1_n \end{bmatrix}
=
\begin{bmatrix} Y_{11} & Y_{12} & ---Y_{1n} \\ Y_{21} & Y_{22} & Y_{2n} \\ \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots \\ Y_{n1} & Y_{n2} & -- Y_{nn} \end{bmatrix}
\begin{bmatrix} V_1 \\ V_2 \\ \vdots \\ \vdots \\ \vdots \\ V_n \end{bmatrix}
\quad ---- (6a)
$$

2.3.2 PROPERTIES OF NODAL ADMITTANCE MATRIX

The nodal admittance matrix has the following properties

(i)   It is a square matrix of order nxn

(ii)   It is symmetrical, since $Y_{ki} = Y_{ik}$ where K and i are nodal numbers.

(iii)   It is complex.

(iv)   Each of diagonal element Y_{ki} is the negative of the branches admittance between notes K and i, and is frequency at value zero.

(v) Each diagonal element Y_{kk} is the sum of admittance of the branches which terminate on nodee K, including branches to ground.

(vi) Because in all but the smallest practical networks vary few non zero mutual admittances exist, the matrix Y is highly spares.

2.3.3 *Advantages of Nodal admittance Matrix Method.*

The nodal analysis has been found to be particularly suitable for digital computer work, and is almost exclusively used for routine network calculations. It has the following advantages.

(i)   The numbering of nodes, performed directly from a system diagram, is very simple.

(ii)   Data preparation is easy.

(iii)   The number of variables and equations is usually less than with much method for power networks.

(iv)   Network crossover branches present not difficulty

(v)   Parallel branches do not increase the number of variables or equations.

(vi)   Node voltage are available directly from the solution, and branch currents are easily calculated.

(vii)   Off normal transformer tape can easily be represented

2.3.4. Developement of Load Flow Equation

The nodal current equations for n bus system can be remittencas as:

$$I_p = Y_{pq}V_q + \sum_{q=1}^{n} Y_{pq}Vq, \quad P-1,2, \text{ --- } n \quad (6)$$

$$I_p = Y_{pq}V_q + \sum_{\substack{q=1 \\ q \neq p}}^{n} Y_{pq}Vq \text{ ----- } (7)$$

$$\therefore V_p = \frac{I_p}{V_{pq}} - \frac{I}{V_{pq}} \sum_{\substack{q=1 \\ q \neq P}}^{n} \text{ ---- } (7)$$

$$V_p * I_p = P_p - JQ_p \text{ ----- } (9)$$

$$1_p = \frac{P_p - JQP}{V*_p} \text{ ---- } (10)$$

Where $V*_p$ is at bus P the complex conjugate of V_p. (Voltage at bus P).

Substituting for 1_p in equation (8) we get for V_p:

$$V_p = \frac{1}{Y_{pq}} \left[\frac{P_p - JQP}{V*_p} - \sum_{\substack{q=1 \\ q \neq p}}^{n} Y_{pq}V_q \right], \quad P = 1,2, \text{ -- } n, \text{ -- } (11)$$

Where P and q are node numbers.

1p has been substituted by the real and reactive power because normally in a power system there quantities are specified.

2.4 solution Techniques to load flow equations

The solution of algebric equations describing the power system are based on an iterative technique because of their non linearity. The solution must satisfy Kirchoff's laws, that is the algebric sum of all flows at a bus must equal zero, and the algebriac sum of all voltages in a loop must

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equal zero. The solution is expected to provide information of voltage magnitudes and angles active and reactive power flows in the individual transmision units, losses, and the reactive power generated or at voltage- controlled busses.

The complexity of obtaining a formal solution for load flow in power system arises because of the differences in the type of data specified for the different equations is not difficult the closed form of solution is not practical. Digital solutions of the load flow problems flow the iterative process by assigning estimated values to the unknown bus voltages and calculaing a new value for each bus voltage from the estimated value at the other buses, the real power specified, and the specified reactive power or voltage magnitude. A new set of values for voltage is thus obtained for each bus and used to calculate another set of bus voltages. It is each calculation of a new set of voltages that is called an iteration. The iterative process is repeated until the changes at each bus are less than a specified minimum value.

Two types of methods of load flow equations solution exist.

These are the direct method and the interative method.

2.5 PROPERTIES REQUIRED IN LOAD FLOW

Five main properties are required of a load flow solution method.

These include:

(i)   High computational speed

This is especially important when dealing with large system, real time application (no-line), multiple case load flow much as in system security assessment, and also in interative application.

(ii)   Low computer storage

This is important for large systems and in the use of computers with small core storage availability, example mini-computers for on-line application.

(iii) Reliability of solution may be obtained for ill-conditioned problem, in outage studies and for real time applications.

(iv)   Versability

An ability on the part of load flow to handle conventional and special features (example : adjustment of tap ratios on transformers, different representations of power systems, apparatus), and its suitability for incorporation into more complicated process.

(v)   Simplicity

The ease of coding is computer programme of the load flow algorithms. The types of solution required for a load flow also determines the method used.

accurate approximate

unadjusted or adjusted

off-line or on-line

Single case or multiple cases.

The first columns are requirements needed for optimal load flow and stability studies, and the second columns those needed for assessing security of a system. Obviously, solutions may have a mixture of these properties from either column.

2.6   DATA FOR LOAD FLOW STUDIES

Either the bus self-and mutual admittances which compose the bus admittance matrix Y or the driving point out trans-

former impedances which compose 2bus may be used in solving the load flow problem. The starting point in obtaining the data which must be furnished to the computer is the one-blue diagram of the system. values of series impedances and shunt admittance of transmission blues are necessary so that the computer can determine all the Y_{bus} or Z_{bus} elements. Other essential informations include transformer ratings, and impedances, shunt capacitors ratings and transformer tap settings.

Operation conditions must always be selected for each study.

2.7.8 INTERATIVE METHODS OF SOLUTION

As the load flow equations (II) are non linear, they can be solved by an iterative method. These iterative methods include:

(i)   Gauss's method

(ii)   Gauss-sidel method.

(iii) Newton-Raphon method.

But before the these methods are explained, a specific example is taken and these methods are applied for the solution of load flow equations. Let us contener the figure below.
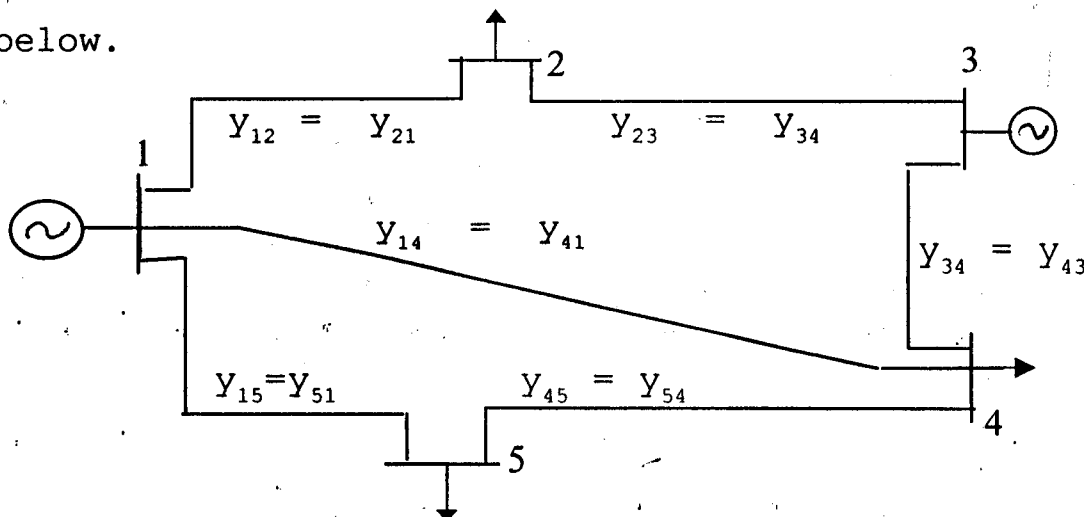
FIG 2 FIVE BUS SYSTEM

This bus system has two generators at buses 1 and 3 and three load buses 2,4 and 5. The nadal admittance matrix is also given as follows:

$$Y_{pq} = \begin{bmatrix} Y_{11} & Y_{12} & 0 & Y_{14} & Y_{15} \\ Y_{21} & Y_{22} & Y_{23} & 0 & 0 \\ 0 & Y_{32} & Y_{33} & Y_{34} & 0 \\ Y_{41} & 0 & Y_{43} & Y_{44} & Y_{45} \\ Y_{51} & 0 & 0 & Y_{54} & Y_{55} \end{bmatrix}$$

By using this nodal admittance matrix along with equation (ii) the load flow equations for 5-bus system are written as follows;

Assuming bus 1 as the slack bus.

$$V_1 = V_1 \quad \text{specified fixed bus}$$

$$V_2 = \frac{1}{Y_{22}} (P_2 \ JQ_3) \frac{(Y_{21}V_1 + Y_{23}V_3)}{V_3^*}$$

$$V_3 = \frac{1}{Y_{33}} [\frac{P_3 - JQ_3)}{V_3^*} - (Y_{32}V_2 \ Y_{34}V_4)]$$

$$V_4 = \frac{1}{Y_{44}} [\frac{P_4 - JQ_4}{V_4^*} - (Y_{41}V_1V_1 + Y_{43}V_3 + Y_{45}V_5)]$$

$$V_5 = \frac{1}{Y_{55}} [\frac{P_5 - JQ_5}{V_5^*} - (Y_{52}V_1 + Y_{54}V_4)$$

TO understand the procedure for solution of these equations, simplifying assumption is made at the state that all the other buses except bus 1 are load, buses, that i's buses where P Q are specified. The admittances and voltages are used in these quation are complex quanntities and the number of non linear equations is (n-1) where n is the number of buses in the system.

2.8 GAUSS METHOD

In this method, the same set of voltage is used throughout a complete iteration instead of immediately substituting each new value obtained to calculate the voltage at the next bus the flow chart for load flow solution using Gauss method is given on page 25.

The procedure for the solution is as follows:

(1) Assume a flat voltage profile for all nodal voltage except the slack bus 1. set slack bus voltage to be a + jo.o. Assume a suitable value of convergence criterion E that is if the absolute value of the maximum change in voltage between any consecutive iterations is less than a pre-specified tolerance E, the convergence is achieved and the iteration procedure is terminated.

2. Set iteration count K = 0

3. Set bus count P = 1

4. Check for the slack bus, if it is not a slack bus go to the next step. Since voltage at the slack bus is fixed both in magnitued and phases it does not vary during iteration procedure and hence go to step 6 if it is a slack bus.

5. Calculate the bus voltage V^{k+1} using (ii) and the difference in the bus voltage.

$$V_p^{\ k} = V_p^{\ k+1} - V_p^{\ k}$$

6. Advance the bus count by 1 to evalueate other value of $V_p^{\ k+1}$ and $V_p^{\ k}$

7. Check if all buses have been taken into account. If yes, go to the next step; otherwise go back to step 4.

8 Determine the largest absolute value of change in voltage $Vmax^1$

9. If 1 $Vmax^1$ is less than a specified tolerance E. evaluate line flows and point the voltage and line flows. If not advance the ilteration count K = K+1 and go back to step 3.

CHAPTER THREE

In this chapter, the load flow analysis is applied to the N.E.P.A. 11kv distribution networks within Lokoja town. The whole Lokoja town is supplied with electricity by four different feeders.

3. THE N.E.P.A 11KV DISTRIBUTION NETWORK.

Lokoja town is supplied from Okene transmition station.
At the control station 7.5MVA and 2.5MVA are used to step-down the 33kv to forming feeder 1 and 2 respectively. These two feeders are named as.

(1) Feeder 1 (G.R.A. Feeder)

(2) Feeder 2 (Town - Ship feeder)

Feeder 1 or G.R.A feeder supplied the area comprising: government house, Adankolo Adankolo new layout and old layout, phase 1 & 2 housing Estate. New layout Lokongoma phase 11.

Feeder 2 or town-ship feeder supplied the following areas:
Felele, A.D.P. Old market, new market,
Chief Palace, Sanrikin Numa, Jakura marble,
Nitel, Mount partti and N.T.A Lokoja.

Apart from the two feeders there are also 2.5MVA 33/11kv injection substation which feed Army Barack in Lokoja and 2 x 500KVA S/S which supplied or feed Lokongoma housing Estate. At each substation (s/s) 11/0.415kv step-down transformers are used to supply the consumers. The diagram below illustrates this

FEEDER PILLAR
RED BUS
FUSE
BLUE BUS
YELLOW BUS
NEUTRAL BUS
CABLE
UPRISER CABLE
415v
415v
240v
DELTA STAR STEP-DOWN TRANSFORMER
11KV LINE
11KV
11KV
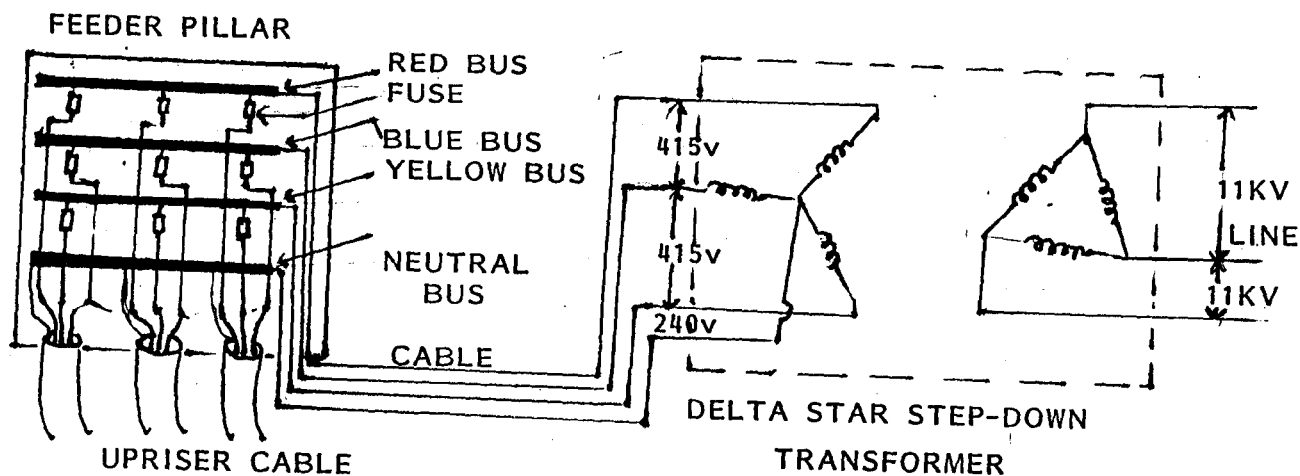
(Fig 3.1) A SUBSTATION

The table below show the different types of transformers and ther rating.

TABLE 3.1

33/11KVA	33/0.415KVA	11/0.415
7.5MVA 2X2.5MVA	50KVA 300KVA 200KVA 2 X 500KVA	2 X 50KVA 12 X 100KVA 13 X 200KVA 17 X 300KVA 3 X 315KVA 8 X 300KVA

TYPES OF TRANSFORMER AND THEIR RATING

The four busbars that comprise the N.E.P.A 11kv distribution network in Lokoja town are as follows:-

(i)   G.R.A BUS

(ii)   Town-ship bus

(iii) Army barack bus

(iv)   Lokongoma bus

For the purpose of the present project work the connection between these buses is shown below.
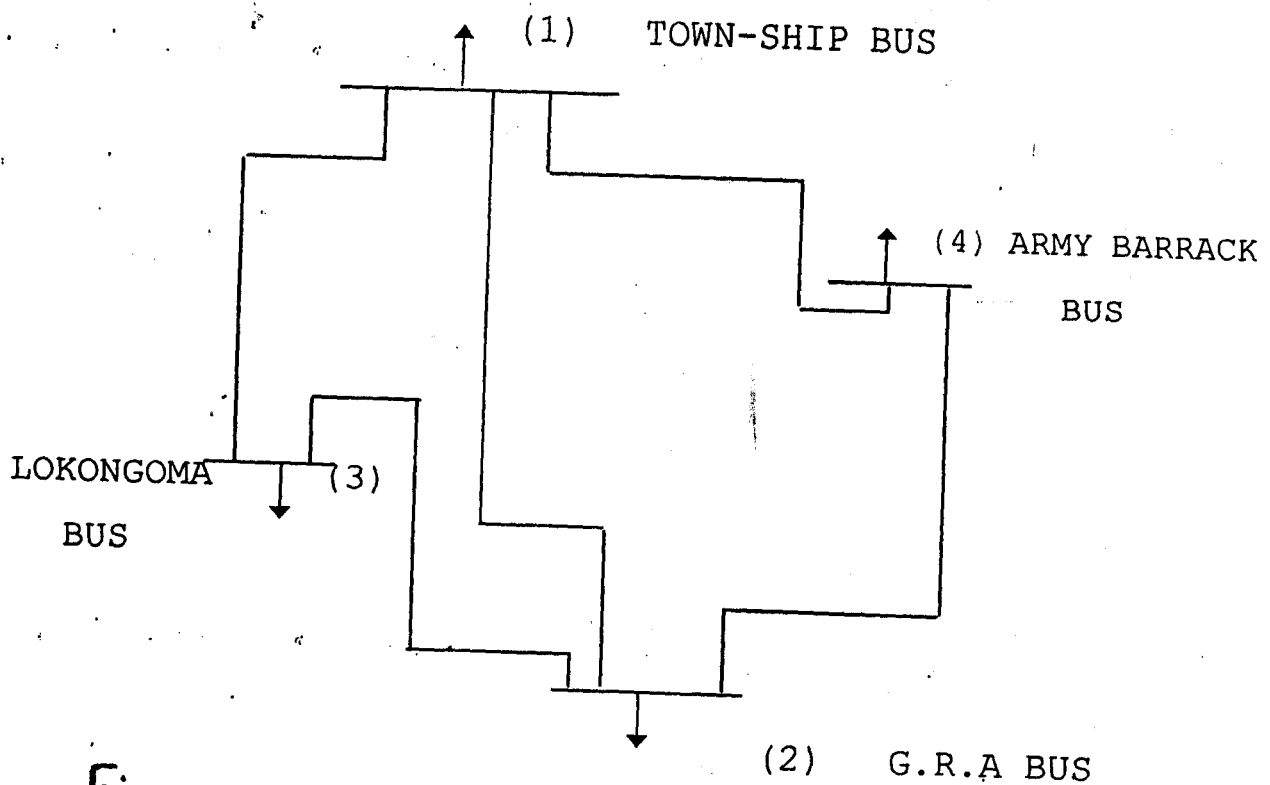
Fig. 3.2 BUS INTERCONNECTION

3.1 DATA PREPARATION

Since computer program is to be used for simulation, data has to be prepared. The datas include the resistance, the admittances and susceptances of the different lines connecting the different buses together. The values are obtained by measuring the lengths of the various lines. The formular used are as follows;

(i) To calculate the resistance of a conductor.

The active resistance per kilometer R is given by:

$R\,\Omega/km = p/A$ where P is the resitristy of the conductor used. A is the cross - sectional area. Hence the total resistance of the particular line is obtained by multiplying R by the total length of the line in km.

ii) The reactance x_0

$$x_0\,/km = 0.144g\,\log_{10}\frac{D_{GMD}}{R} + 0.0152\ \text{where}$$

is the radius of conductor, $D_{GMD} - 1.26D$ for horizontally arranged conductors. Also the total reactance of the line is obtained by multiplying x_0 by the total length of the line in m

$$(\Omega)/km = \frac{7.58 \times 10^{-6}}{\log_{10}\dfrac{D_{GMD}}{R}}$$

Practical values of R = 0.155 /0/km.

x_0 = 0.41 /0/km

B = 7.59 $\mu\Omega$ /0/KM

These are used to obtain the data below

TABLE 3.2

Bus no	Bus no	lenght (km) (Ω)	Resistance (Ω)	Reactance (Ω)	Susceptance $\mu\Omega$
1	2	4.172	0.6467	1.7105	31.6655
1	3	24.428	3.7863	10.0155	185.4090
1	4	27.718	4.2963	11.3644	210.3962
2	3	4.786	0.7418	1.9623	36.35574
2	4	23.857	3.6978	9.7614	181.0746

USE OF PER UNIT VALUE

In this project work a base of 100 MVA is used. The base kv is 11kv. A base impedance is therefore calculated from the two.

$$\text{base impedance} = \frac{\text{base, kv}^2}{(\text{base MVA})} = \frac{11^2}{100} = 1.21$$

The value obtained is used to express the impedance of different lines per unit values.

The bus data, that is, the voltage, the active and reactive power associated with each bus are given in per unit value in the table 3.3 below.

TABLE 3.3			LOAD	
BUS	NAME	VOLTAGE	MW	MVAR
1	G.R.A	1.0 + j0.0	0.0128	0.0078
2	Town-ship	1.0 + j0.0	0.0085	0.0052
3.	Army Barrack	1.0 + j0.0	0.0085	0.0052
4.	Lokongoma	1.0 + j0.0	0.0034	0.0020

3.2.0 THE SIMULATION PROGRAM

A C- language program is used for the simulation of this project work. The program is given.

```
                    ┌─────────┐
                    │  START  │
                    └─────────┘
                         │
┌──────────────────────────────────────────────────────────┐
│ READ IN SYSTEM DATA AND FORM NODAL ADMITTANCE MATRIX       │
└──────────────────────────────────────────────────────────┘
                         │
┌──────────────────────────────────────────────────────────┐
│ ASSUME BUS VOLTAGES AS Vp=1+j0.0 FOR p=1,2,3,...,n          │
│            P≠S AND Vs=a+j0.0                                │
└──────────────────────────────────────────────────────────┘
                         │
         ┌──────────────────────────────┐
         │   SET ITERATION COUNT K=0     │
         └──────────────────────────────┘
                         │
         ┌──────────────────────────────────┐
         │ SET CONVERGENCE ITERATION /dVmax/=E │
         └──────────────────────────────────┘
                         │
              ┌─────────────────────┐
              │  SET BUS COUNT p=1   │
              └─────────────────────┘
                         │
                   ╱TEST FOR╲   YES
                   ╲SWING BUS╱ ──────►
                         │ NO
```

COMPUTE VOLTAGE EQUATION FOR BUS P

$$V_p^{k+1} = \frac{1}{Y_{pp}} \left[\frac{P_p - jQ_p}{V_k^p} - \sum_{\substack{q=1 \\ q \neq p}}^{n} Y_{pq} V_q \right] \quad \begin{array}{l} p=1,2,3,...,n \\ q=1,2,3,...,n \end{array}$$

```
         ┌──────────────────────────────────────────┐
         │ COMPUTE CHANGE IN VOLTAGE dV_p^k =V_p^{k+1}- V_p^k │
         └──────────────────────────────────────────┘
                         │
              ┌──────────────────────┐
              │ INCREASE BUS  p=p+1   │◄─────
              └──────────────────────┘
                         │
           NO    ╱CHECK IF ALL BUSES HAVE BEEN╲
         ◄───────╲   TAKEN INTO ACCOUNT       ╱
                  ╲        p=n ?              ╱
                         │ YES
┌──────────────────────────────────────────────────────────┐
│ DETRMINE THE LARGEST ABSOLUTE VALUE CHANGE IN VOLTAGE      │
│                   /dVmax/                                   │
└──────────────────────────────────────────────────────────┘
                         │
                    ╱ CHECK   ╲
   ┌──────────┐ NO ╱ IF /dVmax/≤ E ╲
   │SET K=K+1 │◄───╲            ╱
   └──────────┘     ╲         ╱
                         │ YES
┌──────────────────────────────────────────────────────────┐
│ COMPUTE LINE FLOWS AND SWING BUS POWER                     │
└──────────────────────────────────────────────────────────┘
                         │
                    ┌─────────┐
                    │   END   │
                    └─────────┘
```

2 2

```c
#include<stdio.h>
#include<conio.h>
#include<math.h>
#define itermax 150
#define n 4
float Y [7][7],YS[7][7],YP[7][7],Pac[7][7],Pre[7][7];
float V[7],Vinstar[7],A[7],Vold[7];
float tol,sum1,sum2,sum;
int p,q,iter,row,col;
int converged;

void read_data(void)
{
    Y[1][1]=3.60;Y[1][2]=2.13;Y[1][3]=0.51;Y[1][4]=0.24;
    Y[2][1]=2.13;Y[2][2]=3.18;Y[2][3]=0.47;Y[2][4]=0.25;
    Y[3][1]=0.51;Y[3][2]=0.47;Y[3][3]=1.79;Y[3][4]=0.24;
    Y[4][1]=0.24;Y[4][2]=0.25;Y[4][3]=0.24;Y[4][4]=0.73;

    YS[1][2]=2.13;YS[1][3]=0.51;YS[1][4]=0.24;
    YS[2][1]=2.13;YS[2][3]=0.47;YS[2][4]=0.25;
    YS[3][1]=0.51;YS[3][2]=0.47;YS[3][4]=0.24;
    YS[4][1]=0.24;YS[4][2]=0.25;YS[4][3]=0.24;

    YP[1][2]=0.024;YP[1][3]=0.015;YP[1][4]=0.035;
    YP[2][1]=0.024;YP[2][3]=0.016;YP[2][4]=0.032;
    YP[3][1]=0.015;YP[3][2]=0.016;YP[3][4]=0.02;
    YP[4][1]=0.035;YP[4][2]=0.032;YP[4][3]=0.020;

    A[1]=0.00;A[2]=0.015;A[3]=0.004;A[4]=0.0;

    Vinstar[1]=1.05;Vinstar[2]=1.0; Vinstar[3]=1.0;
    Vinstar[4]=1.0;

    tol=0.001;
}

void computeV(void)
{
    iter=0;
    do
    {
        iter++;
        for (p=1;p<=n;p++)
            Vold[p]=V[p];

        for (p=1;p<=n;p++)
        {
            sum=0;
            q=1;
            do{
                if (p!=q) sum+=Y[p][q] * V[q];
                q++;
            } while(q!=n);
```

```c
            V[p]=((A[p]/Vinstar[p])-sum)/Y[p][p];
            converged=abs(V[p]-Vold[p])<tol;
    }
    p=0;

    do{
            p++;
            converged=abs(V[p]-Vold[p])<tol;
    } while (p!=n && converged);

    } while (!converged && iter!=itermax) ;
    printf("\n");
    if (!converged) printf("no convergence to specified
tolerance after %d iterations",iter);
}

void computepower(void)
{
    for (p=1;p<=n;p++)
    {
            for (q=1;q<=n;q++)
            {
                if (p!=q)
                {

Pac[p][q]=V[p]*((V[p]-V[q])*YS[p][q]-V[p]*YP[p][q]/2)*0.85;

Pre[p][q]=V[p]*((V[p]-V[q])*YS[p][q]-V[p]*YP[p][q]/2)*0.62;
                }
            }
    }
}

        main()
{
    clrscr();
    row=3;
    gotoxy(20,10);
    puts("\nplease wait computation in progress");
    read_data();
    computeV();
    computepower();
    puts("\nBus voltages V");
    puts("-----------------------");
    for (p=1;p<=n;p++)
    {
            printf("\nV %d=%e",p,V[p]);
            puts("\npresss ENTER to continue");
            getchar();
    }
    clrscr();
    row=3;
    gotoxy(19,1);
    puts("Active Power\tReactive Power");
```

```c
            gotoxy(19,2);
            puts("-------------\t--------------");

        for (p=1;p<=n;p++)
        {
            for (q=1;q<=n;q++)
            {
                if(p!=q){
                    gotoxy(10,row);
                    printf("\nP%d%d =   %e \t \t
%e",p,q,Pac[p][q],Pre[p][q]);
                    row++;
                    if (row==20){
                        gotoxy(10,row+2);puts("\npress ENTER to
continue...");
                        row=3;
                        getchar();
                        clrscr();
                        gotoxy(19,1);
                        puts("Active Power\tReactive Power");
                        gotoxy(19,2);
                        puts("-------------\t--------------");
                    }
                }
            }
        }
        printf("\nMaximum number of iteration allowed is
%d",itermax);
        printf("\nNo of iterations after which convergence occured
is %d",iter);
        puts("\npress ENTER to exit...");
        getchar();
        return(0);
    }
```

Bus voltages V

V 1=0.000000
presss ENTER to continue

V 2=0.004717
presss ENTER to continue

V 3=0.000996
presss ENTER to continue

V 4=0.011756
presss ENTER to continue

Active Power   Reactive Power
-------------   --------------

P12 =   -0.000000e+00   -0.000000e+00
P13 =   -0.000000e+00   -0.000000e+00
P14 =   -0.000000e+00   -0.000000e+00
P21 =   4.005651e-05   2.921769e-05
P23 =   6.860454e-06   5.004096e-06
P24 =   -7.357959e-06   -5.366981e-06
P31 =   4.238000e-07   3.091247e-07
P32 =   -1.487442e-06   -1.084957e-06
P34 =   -2.194840e-06   -1.600942e-06
P41 =   2.613659e-05   1.906433e-05
P42 =   1.570400e-05   1.145468e-05
P43 =   2.462878e-05   1.796452e-05

Maximum number of iteration allowed is 150
No of iterations after which convergence occured is 1
press ENTER to exit...

CHAPTER FOUR

4.0 RESULT AND CONCLUSION

The simulation progrme result are printed out and the voltages associated with each bus are printed out first, followed by the print out of the real and reactive powers flowing between the various buses. There are four buses and therefore four different values are printed out.

For the line flows, the real and reactive power flowing in each line connecting one bus to another is printed out.

Bus 1 is connected to all other buses, to the computer prints the real and reactive power flowing bus 1 to each of the other three buses. The total bus power is obtained by summing the flows on the lines terminating at the bus.

The results printed out by computer are in per unit values.

A base of 100 MVA is used, Therefore the actual value is obtained by multiplying the p.u. value by the base value (10^8) get the real value in watts.

From the printout we can also see that there is no any generation, this is due to the fact that the system under study does not include any power generating.

4.1 CONCLUSION

A review of the objectives of this project is briefly discussed in this section. The project has taken a general look on load flow analysis.

The development of the simulation program written in C-language is the main area of contribution of this project work. Gauss method of solution is used. With this programme the user will be able to calculate the bus voltages, the real and reactive power associated with each bus in a power distribution network.

4.2   RECOMMENDATION

A lot of finance is needed to carryout such a practical work like this type. The state government and the local Government in particular should render financial assistance to the student to carryout such a project work. This proposition is to be taken into account for the next person to carry out this types of project.

Finally, it is my suggestion that National Electric Power Authority (N.E.P.A) especially Lokoja branch should assist financially.

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