LOAD FLOW ANALYSIS AND LOAD FORECASTING OF NEPA 11KV DISTRIBUTION NETWORK WITHIN MINNA METROPOLIS

A FINAL YEAR PROJECT

BY

SALIFOU SANDAGOU
90/1565

DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING
FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA
NIGER STATE, NIGERIA

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DECLARATION

I hereby declare that this project work is the result of my own research and has never been submitted by anybody anywhere. It was conducted under the supervision of Professor S O Ajose, (HOD), Department of Electrical and Computer Engineering, Federal University of Technology, Minna, Nigeria.

Salifou Sandagou (90/1565)

APPROVAL PAGE

I hereby certify that I have supervised, read and approved this project work which I found to be up to standard for the partial fulfilment of the award of Bachelor's Degree in Electrical & Computer Engineering.

______________________	______________________
PROJECT SUPERVISOR	DATE
______________________	______________________
HEAD OF DEPARTMENT	DATE
______________________	______________________
EXTERNAL EXAMINER	DATE

DEDICATION

This work is humbly dedicated to Almighty Allah, to my loving parents and the entire members of the family.

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My sincere gratitude goes to my parents for their love and support. I specially thank my junior brother, Boubacar for the financial and moral support he gave me during my studies.

I would also like to thank my project supervisor, Professor S O Ajose for his timely advice and his encouragement during the conduction of this work.

My thanks also go to my classmates, friends for their different advice and support.

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I specially thank Mr. Jibril from the computer science department for helping me to write the computer program.

ABSTRACT

This report presents the load flow analysis and load forecasting for NEPA 11 Kv distribution network within Minna Metropolis.

The theory of load flow and load forecasting has been discussed. The various methods of load flow problems solutions are covered through this theory. The various types of load forecasting are also covered.

And finally, the load flow analysis is applied to NEPA 11KV distribution network within Minna Metropolis, where the different quantities associated with the various luses, that is, the voltages, the power real and reactive etc ... have been calculated.

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CHAPTER ONE.

INTRODUCTION

1.1 Introduction

It is essential to have information about the continuous evaluation of the current performance of a power and to analyse the effectiveness of alternative plans for system expansion to meet increased load demand. This analysis requires calculation of numerous load flows for both normal and emergency operating conditions, hence the necessity of load flow analysis. Load flow analysis is, therefore, the basic calculation required to determine the characteristics of the steady state of electric systems operating under normal conditions.

On the other hand, a reliable and sufficient power system requires comprehensive and careful operation planning. The planning of the future development of power system is essential because satisfactory operation of the system depends on knowing the effects of interconnections with other power systems, new loads, etc--- it is also important to know the variations of loads on the system at any particular time. From this, we can see that the need of load forecasting also arises. Load forecasting is the prediction of future's load based on the past or today's data.

The aim of this present project work, is therefore, to describe the theory of load flow analysis and load forecasting and apply load flow analysis to NEPA 11kv network distribution within Minna metropolis.

1.2 Distribution networks.

Distribution networks differ from transmission networks in several ways, quite apart from voltage maguitude. The unmber of branches and sources is much higher in distribution networks and the general structure is different. A typical distribution system consists of a step-down (132/11kv) on load tap-

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

(v). Effect of temporary loss of generation and transmission circuits on system loading.

(vi). Optimum system running conditions and load distribution

(vii). Optimum system losses.

(viii). Optimum rating and tap range of transformers

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

2.1.2 Bus Classification

Three types of buses are represented in load flow calculations. 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 these four quantities are specified. These buses are:

(i). Voltage-controlled bus

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

(ii). Load bus

A this bus the real and reactive components of power are specified. It is desired to find out the voltage magnitude and phase angle through the load flow solution. In a physical power system, this corresponds to a load center such as a city or an industry, where the customer demands his power requirements both P and Q are assumed to be unaffected by small variations in bus voltage.

led to the load flow programs for large power system studies still employ methods using the bus admittance matrix . This approach remains the most economical from the point of view of computer time and memory requirements.

2.1.3.1 Load flow equations formulation using modal matrix method.

The load flow equations can be formulated using modal matrix method. We shall first consider a three-bus system to derive the load flow equations and, they are thus generalized for an n-bus system. For instance, consider the figure 2.1.1.

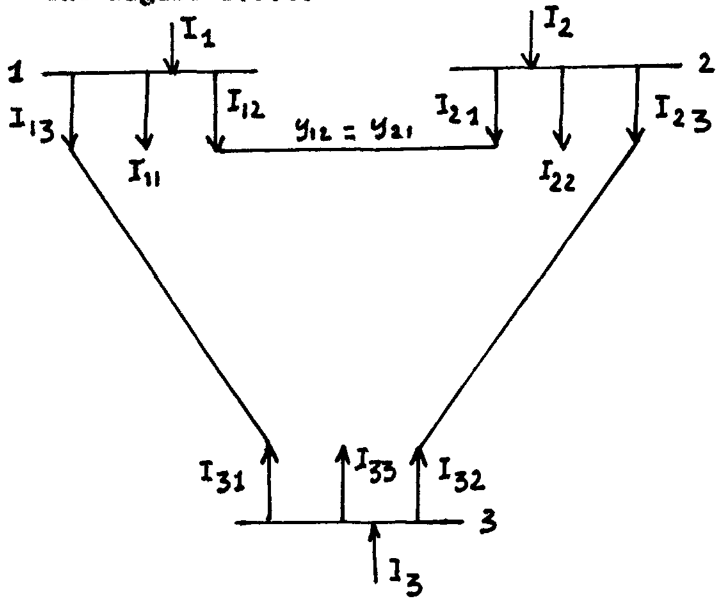


fig. 2.1.1 Three-bus system.

At nod~~e~~ 1

$$\begin{aligned} I_1 &= I_{11} + I_{12} + I_{13} \\ &= V_1y_{11} + (V_1 - V_2)\, y_{12} + (V_1 - V_3)y_{13} \\ &= V_1(y_{11} + V_1y_{12} - V_2y_{12} + V_1y_{13} - V_3y_{13} \\ &= V_1(y_{11} + y_{12} + y_{13}) - V_2y_{13} - V_3y_{13} \\ &= V_1Y_{11} + V_2Y_{12} + V_3Y_{13} \quad \text{------------------(1)} \end{aligned}$$

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

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

$$Y_{12} = -\, y_{12}$$

$$Y_{13} = -\, y_{13}$$

Where Y_{12} and Y_{13} is the self admittances of bus 1.

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

(iii). It is complex

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

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

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

2.1.3.3 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 no difficulty.

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

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

(vii). Off nominal transformer taps can easily be represented.

(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-conditined problems, 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 a computer program of the load flow algorithm. The type of solution required for a load flow also determines the method used:

accurate or 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.

2.1.4.2 Data for load flow studies.

Either the bus self-and mutual admittances which compose the bus admittance matrix Y_{bus} or the driving point out transfer impedances which compose Z_{bus} 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-line diagram of the system. Values of series impedances and shunt admittances of transmission lines 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.

Operating conditions must always be selected for each study. At each bus, except one, the real power into the network must be specified. The power drawn by a load is negative power input to the system. The other power inputs are from generators and positive or negative power entering over interconnections - In addition, at these buses either the net flow of reactive power into the network or the magnitude of the voltage must be specified, that is at each bus a decision is required whether the voltage magnitude or the reactive power flow is to be maintained constant. The usual case is to specify reactive power at load buses and voltage magnitude at generator buses, although sometimes reactive power is specified for the generators. In digital computer programs, provision is made for the calculation to consider voltage to be maintained constant at a bus.

2.1.4.3 Direct methods of solution

These basically invert the admittance matrix, a process consuming both in time and computer storage. Many methods are available and these include Gaussian elemination. Direct methods solve only linear systems, that is:

$[I] = [Y][V]$ where $[I]$ is specified. The fact that powers are specified makes, in practice, the problem non linear. A new value for I must be obtained from $S = VI^*$ after each direct solution and this value used to obtain a new one.

When solving the set of equations $[A][x] = [b]$ the residual vector $r = [b] - [A]\ [x]$ is not zero because of rounding errors. Troubles arise when ill-conditioned equations are obtained in which although the residual is small the solution may be inacurate. Such matrices are often large and sparse and for most rows the diagonal element is equal to the sum of the

the non-diagonal elements and of opposite sign. We can therefore say that the direct method is not accurate when dealing will large power systems. Hence the introduction of the iterative methods.

2.1.4.4 Iterative methods of solution.

As the load flow equations (eqn 11) are nonlinear, they can be solved by an iterative method. These iterative methods include:

(i). Gauss's method

(ii). Gauss - Seidel method

(iii). Newton - Raphson method

But before these methods are explained, a specific example is taken and these methods are applied for the solution of load flow equations. Let us consider the figure 2.1.2 below.

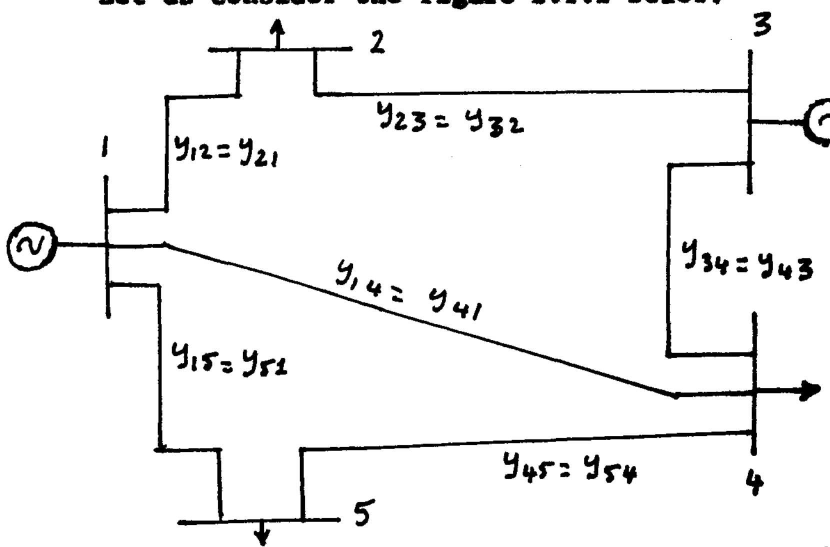


fig. 2.1.2: five bus system

This 5 bus system has two generators at buses 1 and 3 and three load buses 2, 4 and 5. The nodal 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 eqn (11), the load flow equations for the 5 - bus system are written as follows. Assumming bus 1 as the slack bus,

$$V_1 = V_1 \text{ specified fixed value}$$

$$V_2 = \frac{1}{Y_{22}} \left[\frac{P2 - jQ2}{V_2^*} - (Y_{21} V_1 + Y_{23} V_3) \right]$$

$$V_3 = \frac{1}{Y_{33}} \left[\frac{P - jQ3}{V_3^*} - (Y_{32} V_2 + Y_{34} V_4) \right]$$

$$V_4 = \frac{1}{Y_{44}} \left[\frac{P_4 - jQ4}{V_4^*} - (Y_{41} V_1 + Y_{43} V_3 + Y_{45} V_5) \right]$$

$$V_5 = \frac{1}{Y_{55}} \left[\frac{P_5 - jQ5}{V_5^*} - (Y_{51} V_1 + Y_{54} V_4) \right] \text{------------} \quad (12)$$

To understand the procedure for solution of these equations, simplifying assumption is made at the stage that all the other buses except bus 1 are load, buses, that is buses where P and Q are specified. The admittances and voltages as used in these equations are complex quantities and the number of nonlinear equations is (n - 1) where n is the number of buses in the system.

2.1.4.4.1 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 in appendix A.

Let $A_p = \dfrac{P_p - jQp}{Y_{pp}}$ for all $P = 1, 2, ----, n, P \neq S$ ———— (13)

Similarly let $B_{pq} = \dfrac{Y_{pq}}{Y_{pp}}$ for all $P = 1, 2, ---- n, P \neq S$

and $q = 1, 2, - - - n, q \neq p.$

With these simplifications, the voltage equation now becomes:

$$V_p^{k+1} = \frac{A_p}{(V_p^k)^*} - \sum_{\substack{q=1 \\ q \neq p}}^{n} B_{pq} V_p^k, \quad P = 1, 2, —, n, P \neq S \text{ —— } (14)$$

2.1.4.4.2 <u>Gauss - Seidel method</u>

The bus voltage equations (14) can be solved by the Gauss- Seidel method. In this method the new calculated voltage V_p^{k+1} immediately replaces V_p^k and is used in the solution of the subsequent equations. And the process is continued until changes in all bus voltages are negligible. After the solution has been obtained, the power at the slack bus and line flows can be calculated. The equation (12) in this case becomes.

$$V_2^{k+1} = \frac{1}{Y_{22}} \left[\frac{P_2 - jQ2}{(V_2^k)^*} \quad (Y_{21}V_1 + Y_{23}V_3^k) \right]$$

$$V_3^{k+1} = \frac{1}{Y_{33}} \left[\frac{P_3 - jQ3}{(V_3^k)^*} - (Y_{32}V_2^{k+1} + Y_{34}V_4^k) \right]$$

$$V_4^{k+1} = \frac{1}{Y_{44}} \left[\frac{P_4 - jQ4}{(V_4^k)^*} - \left(Y_{41}V_1 + Y_{43}V_3^{k+1} - Y_{45}V_5^k\right) \right]$$

$$V_5^{k+1} = \frac{1}{Y_{55}} \left[\frac{P_5 - jQ5}{(V_5^k)^*} - \left(Y_{51}V_1 + Y_{54}V_4^{k+1}\right) \right] \text{ ———— } (15)$$

The general load flow equation resultant from Gauss - Seidel method is given as below:

$$V_p^{k+1} = \frac{1}{Y_{pp}} \left[\frac{P_p - jQp}{(V_p^k)^*} - \sum_{q=1}^{p-1} Y_{pq} V_q^{k+1} - \sum_{q=p+1}^{n} Y_{pq} V_q^k \right] \text{ —— } (16)$$

The flow chart for Guass - Seidel method is given in appendix B.

fig. 2.1.4 Flow chart for Guass - Yeidel method.

The procedure for solution is outlined below.

1. Assume a flat voltage profile 1 + jo.o for all nodal voltages except the slack bus 1. Assume a suitable value of E the convergence criterion in if the absolute value of the maximum change in voltage between any two consecutive iterations is less than a prespecified value or tolerance E, the convergence is achieved and the iterative procedure is terminated.

1(a) Set iteration count K = 0

1(b) Set bus count P = 1

1(c) Check for slack bus. If it is a slack bus, go to step 4(a), otherwise go to next step.

2. Check which of the buses are voltage - controlled buses and which are load buses. For voltage - controlled buses go to next statement, otherwise go to step 4.

3. Replace the value of the voltage magnitude of voltage - controlled bus in that iteration by the specified value. Keep the phase angle same as in that iteration. Calculate Q for the generator bus. If Q lies between the lower and upper bounds, calculate the term (P - jQ) /V for this bus. Repeat this for all voltage - controlled buses and calculate this term and sustitute this term (V - jQ)/V in the load flow equation corresponding to the voltage controlled bus. Calculate the new value of voltage for the bus. It is to be noted that if there are more than one generator buses, the voltage magnitude of that bus only is replaced by its specified value, while calculating Q and P of a particular bus. The voltage of other generator buses will be corresponding to the value in that iteration.

In case any or all the voltage controlled buses violate the reactive power generation, the bus will be treated as a load bus and the magnitude

Constant that increases the amount of correction to bring the voltage closer to the value it is approaching. The multipliers that accomplish this improved convergence are called the acceleration factors. The difference between the newly calculated voltage and the best previous voltage at the bus is multiplied by the appropriate acceleration factor to obtain a better correction to be added to the previous value. The acceleration factor for the real component of the correction may differ from that for the imaginary component. For any system, optimum values for acceleration factor exist, and poor choice of factors may result in less rapid convergence or make convergence impossible. An acceleration factor of 1.6 for both the real and imaginary components is usually a good choice. However studies may be made to determine the best choice for a particular system.

2.1.4.4.4 Newton - Raphson method.

The load flow problem can be, can also be solved by using Newton-Raphon method, using a set of non linear equations to expresse the specified real and reactive powers in terms of bus voltages. The equations for the method are derived as follows:

We know that at any bus , the power is given by,

$$P_p - jQ_p = V_p^* I_p = V_p^* \sum_{q=1}^{n} Y_{pq} V_q$$

Let $V_{pq} = e_p + jf_p$

and $Y_{pq} = G_{pq} - j B_{pq}$

$$\therefore \quad P_p - jQp = (e_p + jfp)_* \sum_{q=1}^{n} (G_{pq} - jB_{pq})V_q$$

Let also $V = e + jf$

$$\therefore \quad P_p - jQ_p = (e_p + jf_p)^* \sum_{q=1}^{n} (G_{pq} - jB_{pq}) \cdot (e_q + jf_q).$$

$$= (e_p - jfp) \sum_{q=1}^{n} (G_{pq} - jB_{pq}) \quad (e_q + jf_q)$$

Separating the real and the imaginary parts we have

$$P_p = \sum_{q=1}^{n} \left\{ e_p\left(e_q G_{pq} + f_q B_{pq}\right) + f_p\left(f_q G_{pq} - e_q B_{pq}\right) \right\} \text{------} (17)$$

$$Q_p = \sum_{q=1}^{n} \left\{ f_p\left(e_q G_{pq} + f_q B_{pq}\right) - e_p\left(f_q G_{pq} - e_q B_{pq}\right) \right\} \text{------} (18)$$

$$\text{Also} \quad /V_p/^2 = e_p^2 + f_q^2 \text{ ------------------------ } (19)$$

This formulation results in a set of nonlinear simultaneous equations. The real and reactive powers P_p and Q_p are known and the real and imaginary com ponents of voltage e_p and f_q are unknown for all buses except the slack bus, where the voltage is specified and remains fixed. Thus there are 2(n-1) equations to be solved for a load flow problem where n is the number of buses. The Newton-Raphson method required that a set of linear equations be formed expressing the relationship between changes in real and reactive powers and the components of the bus voltages. Assuming there is only one generator bus which is taken as the slack bus and all other buses are load buses. we get:

$$\begin{bmatrix} \Delta P_2 \\ \vdots \\ \Delta P_n \\ \Delta Q_2 \\ \vdots \\ \Delta Q_n \end{bmatrix} = \begin{bmatrix} \frac{\partial P_2}{\partial e_2} & \cdots & \frac{\partial P_2}{\partial e_n} & \frac{\partial P_2}{\partial f_2} & \cdots & \frac{\partial P_2}{\partial f_n} \\ \vdots & & \vdots & & & \vdots \\ \frac{\partial P_n}{\partial e_2} & & \frac{\partial P_n}{\partial e_n} & \frac{\partial P_n}{\partial f_n} & \cdots & \frac{\partial P_n}{\partial f_n} \\ \frac{\Delta Q_2}{\partial e_2} & & \frac{\Delta Q_2}{\partial e_n} & \frac{\partial Q_2}{\partial f_2} & \cdots & \frac{\partial Q_2}{\partial f_n} \\ \vdots & & \vdots & & & \vdots \\ \frac{\Delta Q_n}{\partial e_2} & & \frac{\Delta Q_n}{\partial e_n} & \frac{\partial Q_n}{\partial f_2} & & \frac{\Delta Q_n}{\partial f_n} \end{bmatrix} \begin{bmatrix} \Delta e_2 \\ \vdots \\ \Delta e_n \\ \Delta f_2 \\ \vdots \\ \Delta f_n \end{bmatrix} \text{------} (20)$$

2(n-1) x 1   2(n-1) x 2 (n-1)   2(n-1) x 1.

Where the coefficient matrix is the Jacolion.

In short form this equation (20) can be written as:

$$\begin{bmatrix} \Delta P \\ \hdashline \Delta Q \end{bmatrix} = \left[\begin{array}{c:c} J_1 & J_2 \\ \hdashline J_3 & J_4 \end{array}\right] \begin{bmatrix} \Delta e \\ \Delta f \end{bmatrix}$$

In case the system contains all types of buses, the set of equations is written as:

$$\begin{bmatrix} \Delta P \\ \hline \Delta Q \\ \hline |\Delta V_p|^2 \end{bmatrix} = \left[\begin{array}{c:c} J_1 & J_2 \\ \hline J_3 & J_4 \\ \hline J_5 & J_6 \end{array}\right] \begin{bmatrix} \Delta e \\ \hline \Delta f \end{bmatrix}$$

The elements of the Jecolion matrix matrix can be derived from the three load flow equations (27) - (19).

The off - diagonal elements of J_1 are

$$\frac{\partial P_p}{\partial e_p} = e_p G_{pq} - f_p B_{pq}, \quad q \neq p. \qquad \text{———} \quad (21).$$

and the diagonal elements of J_1 are

$$\frac{\partial P_p}{\partial e_{p_q}} = 2e_p G_{pq} + f_p B_{pq} - f_p B_{pp} + \sum_{\substack{q=1 \\ q \neq p}}^{n} (e_q G_{pq} + f_q B_{pq})$$

$$= 2e_p G_{pp} + \sum_{\substack{q=1 \\ q \neq p}}^{n} (e_q G_{pq} + f_q B_{pq}) \qquad \text{———} \quad (22).$$

The off-diagonal of J_2 are

$$\frac{\partial P_p}{\partial f_q} = e_p B_{pq} + f_p G_{pq}, \quad q \neq p \qquad \text{———} \quad (23)$$

and the diagonal elements are

$$\frac{\partial P_p}{\partial f_q} = 2 f_p G_{pp} + \sum_{\substack{q=1 \\ q \neq p}}^{n} (f_q G_{pq} - e_q B_{pq}) \qquad \text{———} \quad (24)$$

The off-diagonal elements of J_3 are

$$\frac{\partial Q_p}{\partial e_q} = e_p B_{pq} + f_p G_{pq}, \quad q = p \quad \text{------------} \quad (25)$$

and the diagonal elements are

$$\frac{\partial Q_p}{\partial e_p} = 2e_p - \sum_{\substack{q=1 \\ q \neq p}}^{n} (f_q G_{pq} - e_q B_{pq}) \quad \text{------------} \quad (26)$$

The off-diagonal and diagonal elements of J_4 respectively are

$$\frac{\partial Q_p}{\partial f_q} = - e_p G_{pq} + f_p B_{pq}, \quad q \neq p \quad \text{------------} \quad (27)$$

$$\frac{\partial Q_p}{\partial f_p} = 2 f_p B_{pp} + \sum_{\substack{q=1 \\ q \neq p}}^{n} (e_q G_{pq} + f_q B_{pq}) \quad \text{--------} \quad (28)$$

The off-diagonal and diagonal elements of J_5 are

$$\frac{\partial /V_p/^2}{\partial e_q} = 0, \quad q \neq p \quad \text{--------} \quad (29)$$

and $$\frac{\partial /V_p/^2}{\partial e_p} = 2 e_p \quad \text{--------} \quad (30)$$

The off- diagonal and diagonal elements of J_6 are

$$\frac{\partial /V_p/^2}{\partial f_q} = 0, \quad q \neq p \quad \text{--------} \quad (31)$$

and $$\frac{\partial /V_p/^2}{\partial f_p} = 2 f_p \quad \text{--------} \quad (32)$$

Next we calculate the residual column vector consisting of ΔP, ΔQ and $/\Delta V/^2$. Let P_{sp}, Q_{sp} and $/V_{sp}/$ be the specified quantities at the bus p. Assuming a suitable value of solution (flat voltage profile in our case) the value of P, Q, /V/ at the various buses are calculated. Then

$$\Delta P_p = P_{sp} - P_p^o$$

$$\Delta Q_p = Q_{sp} - Q_p^o$$

$$/\Delta V/^2 = /V_{sp}/^2 - /V_p^o\ )^2 \qquad \text{--------------------} \qquad (33)$$

Where the superscript zero means the value calculated corresponding to initial guess, that is zeroth iteration.

Having calculated the Jacolian matrix and the residual column vector corresponding to the intial guess (initial solution) the desired increment voltage vector $\begin{bmatrix} \Delta e \\ \Delta f \end{bmatrix}$ can be calculated by using any standard technique (preferably Gauss elimination with sparsity techniques). The next better solution will be

$$e^1_p = e^o_p + \Delta e^o_p$$

$$f^1_p = f^o_p + \Delta f^o_p$$

These values of voltages will be used in the next iteration. The process will be repeated and in general the new better estimates for bus voltages will be

$$e^{k+1}_p = e^k_p + \Delta e^k_p$$

$$f^{k+1}_p = f^k_p + \Delta f^k_p$$

The process is repeated till the magnitude of the largest element in the residual column vector is less than the respecified value.

The flow chart for load flow solution using Newton-Raphson method is given in appendix C.

The procedure of solution is outlined below.

1. Assume a suitable solution for all buses except the slack bus. Let V_p = 1 + jo.o for p = 1, 2 -- n, p = s, V_s = a + jo.o.

2. Set convergence criterion = E, that is if the largest of alsoute of the residues exceeds E the process is repeated, otherwise it is terminated.

3. Set iteration count K = o

4. Set bus count P = 1

5. Check if p is a slack bus. If yes, go to step 10 -

6. Calculate the real and reactive powers P_p and Q_p respecticely using equations (17) and (18) respectively.

7. Evaluate $\Delta P_p^k = P_{sp} - P_p^k$ -

8. Check if the bus in question is a generator bus. If yes, compare the Q_p^k with the limits. If it exceeds the limit, fix the reactive power generation to the corresponding limit and treat the bus as a load bus for that iteration and go to next step. If the lower limit is riolated set $Q_{psp} = Q_{pmin}$. If the limit is not riolated evaluate the following residue

$$/\Delta V_p/^2 = /V_p/^2{}_{sp} - /V_p^k/^2$$ and go to step 10.

9. Evaluate $\Delta Q_p^k = Q_{sp} - Q_p^k$

10. Advance the bus count by 1, that is p = p + 1 and check if all the buses been accounted. If not, go to step 5.

11. Determine the largest of the alsolute of the residue.

12. If the largest of the alsolute value of the residue is less than E, go to step 17.

13. Evaluate elements for the Jacobian

14. Calculate voltage increments Δe_p^k and Δf_p^k

15. Calculate new bus voltages $e_p^{k+1} = e_p^k + \Delta e_p^k$ and $f_p^{k+1} = f_p^k + \Delta f_p^k$.

Evaluate $\cos\delta_p$ and $\sin\delta_p$ of all voltages.

16. Advance iteration count K = k + 1 and go to step 4.

17. Evaluate bus and line powers and print the results.

2.1.4.4.5 Comparison of solution methods.

Since the Guauss - Seidel is undoubtedly superio to Guauss method, the comparison is restricted only between Guauss - Seidel method and Newton-Raphson method and that too when Y bus matrix is used for problem formulation. From the view of computer memory requirements, polar coordinates are preferred for solution based on Newton-Raphson method and rectangular coordinates for Guauss - Seidel method.

The time taken to perform one iteration of the computation is relatively smaller in case of Guauss - Seidel method as compared to Newton-Raphson but the number of iterations required by Guauss-Seidel method for a particular system are greater as compared to Newton-Raphson method and they increase with the increase in the size of the system. In case of Newton-Raphson method the number of iterations is more or less independent of the size of the system and vary between 3 and 5 iterations. The convergence characteristics of Newton-Raphson method are not affected by the selection of a slack bus whereas that of Guauss - Seidel is sometimes very seriously affected and the selection of a particular bus may result in poor convergence.

The main advantage of programming and most efficient use of core memory. Nevertheless, for large power systems. Newton-Raphson is found to be more convergence characteristics. Even though Newton-Raphson method can solve most of the practical problems, it may fail in respect of some ill-conditioned problems where other advanced mathematical programming techniques like the non-linear programming techniques can be used. To have an approximate idea of the computation time taken by Newton-Raphson method, IBM 360/FB44 system takes less than 10 seconds to obtain a load flow solution of 14 bus system starting with a flat voltage solution of (1 + jo.o). This includes the formulation of nodal admittance matrix and its storage time.

2.1.4.4.6 Approximation to Newton-Raphson method

It is well known that a small change in phase angle changes the flow of active power and does not affect much the flow of reactive power. Similarly, a small change in nodal voltage affects the flow of reactive power whereas the active power practically does not change. Keeping these facts in mind and using the polar coordinates, the set of linear load flow equations can be written in matrix form as follows:

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 & 0 \\ 0 & J_4 \end{bmatrix} \begin{bmatrix} \Delta \delta \\ /\Delta V/ \end{bmatrix} \quad \text{-----------------} \quad (34)$$

Here J_1 corresponds to the elements $\frac{\partial P}{\partial \delta}$ which exist.

J_2 corresponds to the elements $\frac{\partial P}{\partial /V/}$ which do not exist, therefore, are zero.

J_3 corresponds to the elements $\frac{\partial Q}{\partial \delta}$ which do not exist and, therefore zero.

J_4 corresponds to the elements $\frac{\partial Q}{\partial /V/}$ which exist.

This certainly simplifies the calculation and results in smaller computation time.

2.1.5 Line flow equations.

After the iterative solution of bus voltages is completed, line flows can be calculated. The current at bus p in the line connecting bus p to q

is $$i_{pq} = (V_p - V_q)y_{pq} + V_p \frac{y'_{pq}}{2}$$

Where y_{pq} is the line admittance

y'_{pq} is the total line charging admittance.

$V_p \frac{y'_{pq}}{2}$ is the current contribution at bus p due to line charging.

The power flow, real and reactive, is

$$P_{pq} - jQ_{pq} = V_p^* \quad i_{qp}$$

or

$$P_{pq} - j\,Q_{pq} = V_p^* \,(V_p - V_q)y_{pq} + V_p^* \,V_p \frac{y_{pq}^{I}}{2}$$

Where P_{pq} is the real power flow from bus p to q and Q_{pq} is the reactive power flow from bus p to q.

Similarly at bus q, the power flow from bus q to p is:

$$P_{pq} - jQ_{pq} = V_{qp}^* \quad (V_q^*(V_q - V_p)y_{pq} + V_{pq}^* + V_q^* V_q \frac{y_{pq}^{I}}{2}$$

The power loss in line p - q is the algebraic sum of the power flows $(P_{pq} - jQ_{pq})$ and $(P_{qp} - jQ_{qp})$.

2.1.6 Representation of transformers in load flow studies.

The tapped transformer operating at off-nominal tap positions provide means of exchanging reactive power between networks operating at different voltages, and between generators and the network system to which they are connected, it is therefore required to reflect this into power balance equations.

2.1.6.1 Fixed tap setting transformers.

A transformer with off - nominal turns ratios can be represented by its impedance, or admittance, connected in series with an ideal auto-transformer. An equivatent cricuit representation to be used in load in load flow studies is shown in the figure 2.1.6.

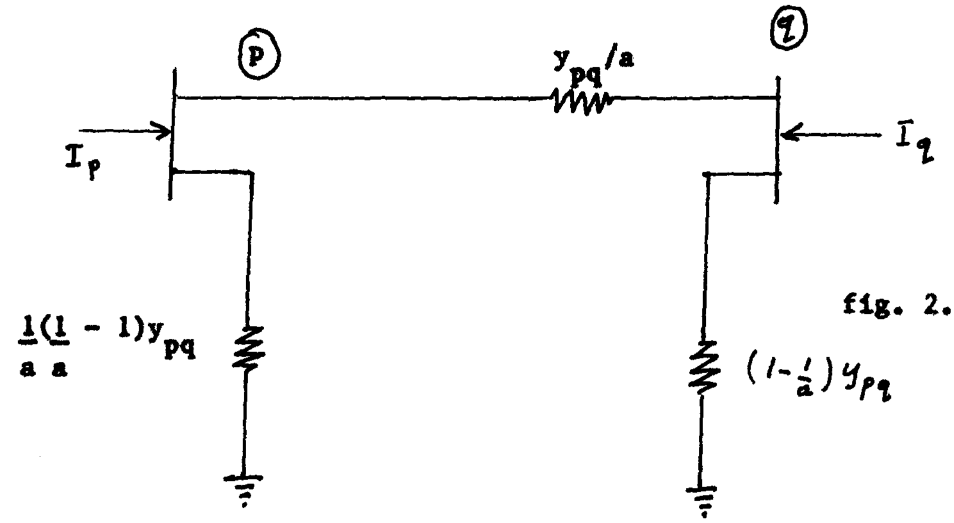


fig. 2.1.6 equivalent π cricuit.

Where a is the turns ratio.

The parameters of the equivalent circuit are as follows.
When the off nominal turns ratio is representated at bus p for a transformer connecting p and q, the self - admittance at bus is:

$$Y_{pq} = y_{p1} + y_{p2} \text{ ——— } + \frac{y_{pq}}{a^2} + y_{pn}$$

The mutual admittance from p to q is:

$$Y_{pq} = - \frac{y_{pq}}{a}$$

The self - admittance at bus q is:

$$Y_{qq} = y_{q1} + y_{q2} + \text{ —— } + y_{qp} + \text{ —— } y_{qn}$$

The mutual - admittance from q to p is:

$$Y_{qp} = - \frac{y_{qp}}{a}$$

2.1.6.2 <u>Phase shifting transformers.</u>

A phase shifting transformer can be represented in load flow studies by its impedance or admittance, connected in series with an ideal auto-transformer having a complex turns ratio as shown in figure 2.1.7. Then the terminal voltages are related by $E_p = a_s + jbs$ where E_p and E_s are the primary and secondary voltages respectively, and $a_s + jbs$ is a complex turns ratio.

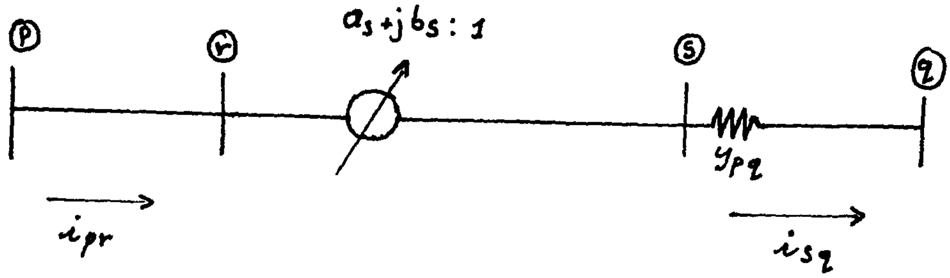


fig. 2.1.7 Phase shifting transformer representation.

The different admittances are as follows:

The self-admittance at bus is given by:

$$Y_{pp} = y_{p1} + y_{p2} --- + \frac{y_{pq}}{a_s^2+b_s^2} --- + y_{pn}$$

The mutual admittance is:

$$Y_{qp} = - \frac{Y_{pq}}{as + jbs}$$

Similarly the self-admittance at bus q is:

$$Y_{qq} = y_{q1} + y_{q2} --- + y_{qp} --- + y_{qn}$$

Anol the mutual admittance is:

$$Y_{pq} = - \frac{y_{pq}}{a_s - jb_s}$$

2.1.6.3 <u>Tap changing under load transformers.</u>

In the representation ~~to~~of tap changing under load (TCUL) transformers, it is necessary to change the turns ratio to obtain the desired magnitude of voltage at a specified bus. This can be accomplished by changing the turns ratio by a small in crement Δa once in any iteration when the voltage magnitude of bus q is such that

$$/\ /V_q^k/ - /V_q/\text{scheduled}/ > E.$$

The standard change in tap setting of TCUL transformers is $\pm$ 5/8 percent per step. The self-admittance Y_{pp} and the mutual admittance Y_{pq} = Y_{qp} must be recalculated for every change in the tap setting of the transformer connecting buses p and q. The equivalent circuit with the shunt and series admittances is shown in the figure 2.1.8.

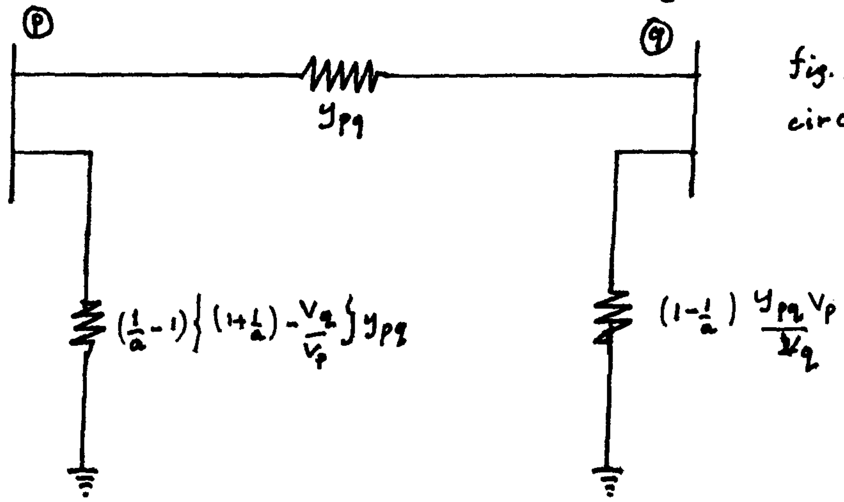


fig. 2.1.8 Equivalent π circuit of TCUL transformer.

Where V_p and Vq are the voltages at bus p and q respectively.

2.1.7 Digital computer studies of load flow.

Power companies use very claborate programs for making load flow studies. A typical program is capable of handling systems of more than 200 buses, 3000 lines and 500 transformers. Programs can be expanded to even greater size provided the available computer facilities are sufficiently large.

Data supplied to the computer must include numerical values such as impedances of the different lines and an indication of whether a bus is a swing bus, or regulated bus where the voltage magnitude is held constant by generation of reactive power Q, or a bus with fixed P and Q. Limits of P and Q generation usually must be specified as well as the limits of line kilo-voltamperes. Unless otherwise specified, programs usually assume a base of 100 MVA.

Total line charging in megavars specified for each line accounts for shunt capacitance and equals $\sqrt{3}$ times the rated line voltage in kilovolts times I_{chg}, divided by 10^3. This equals $wCn\ /V/^2$ where /V/ is the rated line-to-line voltage in kilovolts, and Cn is the line-to-neutral capacitance in forads for the entire length of the line. The program creates a nominal - representation of the line by dividing equally between the two ends of the line the capacitance computed from the given value of charging megavers. For a long line, the computer could be programmed to computer the equivalent for capacitance distributed evenly along the line.

2.1.8 Information obtained in a load-flow study.

The information which is obtained from digital solutions of load flow is an indication of the great contribution digital computers have made to the power system engineer's ability of obtain operating information about the system not yet built and to analyse the effects of changes existing systems. the following discussion is not meant to list all the information obtainable but should provide some insight into the great importance of digital computers in power system engineering.

The print out of results provided by the computer consists of a number tabulations. Usually the most important information to be considered first is the table which lists each bus number and name, bus - voltage magnitude in per unit and phase angle, generation and load at each bus in megawatts and megavars, line charging, and megavars of static capacitors or reactors on the bus. Accompanying the bus information is the flow of megawatts and megavars from that bus over each transmission line connected to the bus. The totals of system generation and loads are listed in megawatts and megavers.

In the operation of power systems any appreciable drop in voltage on the primary of a transformer caused by a change of load may make it desirable to change the tap setting on transformers provided with adjustable taps in order to maintain proper voltage at the load. Where a tap-changing transformer has been specified to keep the voltage at a bus within designated tolerance limits, the voltage is examined before convergence is complete. If the voltage is not within the limits specified, the program causes the computer to perform a new set of iterations with a one-step change in the appropriate tap setting. The process is repeated as many times as necessary to cause the solution to conform to the desired conditions. The tap setting is listed in the tabulated results.

A system may be divided into areas, or one study may include the systems of several companies each designated as a different area. The computer will examine the flow between areas, and deviations from the prescrited flow will be overcome by causing the appropriate change in generation of a selected generator in each area. In actual system operation interchange of power between areas is monitored to determine whether a given area is producing that amount of power which will result in the desired interchange.

Among other information that may be obtained is a listing of all buses where the voltage magnitude is above or below some limits that must be specified. A list of line loadings in megavoltampers can be obtained. The printout will also list the total megaivatt ($/I/^2R$) and megavar ($/I/^2X$) losses in the system and both P and Q mismatch at each bus. Mismatch is an indication of the preciseness of the solution and is the difference between P (and also usually Q) entering and leaving each bus.

2.2 THEORY OF LOAD FORECASTING

2.2.1 Introduction.

It is evident that load forecasting is a crutial activity in electricity supply. Forecasts are based on the previous year's loading for the period in question updated by factors such general load increases, major new loads, and weather trends. Both power demand and energy forecasts are used, the latter often being the more readily obtained. From energy forecasts demand values may be determined. Energy trends tend to be less erratic than peak power demands and are considered better growth indicators; however load forecasts are also erratic in nature.

As weather has much greater influence on residential than on industrial demands, it may be preferable to assemble the load forecast in constituent parts to obtain the total. In many cases, the seasonal variations in peak demand are caused by weather-sensitive appliances such as heaters, air conditioners etc ---. A knowledge of the increasing use of such appliances is therefore essential. The many physical factors affecting loads, example weather, national economic health, popular T.V programs, public holidays etc-- make forecasting a complex process demanding experience and analytical ability.

2.2.2 Types of forecasting.

Two common time scale of importance to load forecasting exist. These are

(i) long-term forecasting, with time horizons on the order of 15 to 20 years and

(ii). Short-term forecasting of an integrated active load demand of an urban power system is often required for economic generation scheduling and security checking. It also helps the power plant operator in allocating the generator spinning reserve to meet the peak load demand for the area - Long-term forecasting is an essential necessity for any country in view of the long gestation period for the power projects. Demand for such electricity is forecasting by agencies such as NEPA (National Power electric Authority). The techniques used by these agencies are mainly based on the assumption of taking on average year and then projecting the growth every year based on a certain pattern of assumption.

2.2.3 Factors influencing load forecast.

The load growth of a geographical area served by a utility company is the most important factor influencing the expansion of the distribution system. The figure 2.2.1 indicates some of the factors which influence the load forecast.

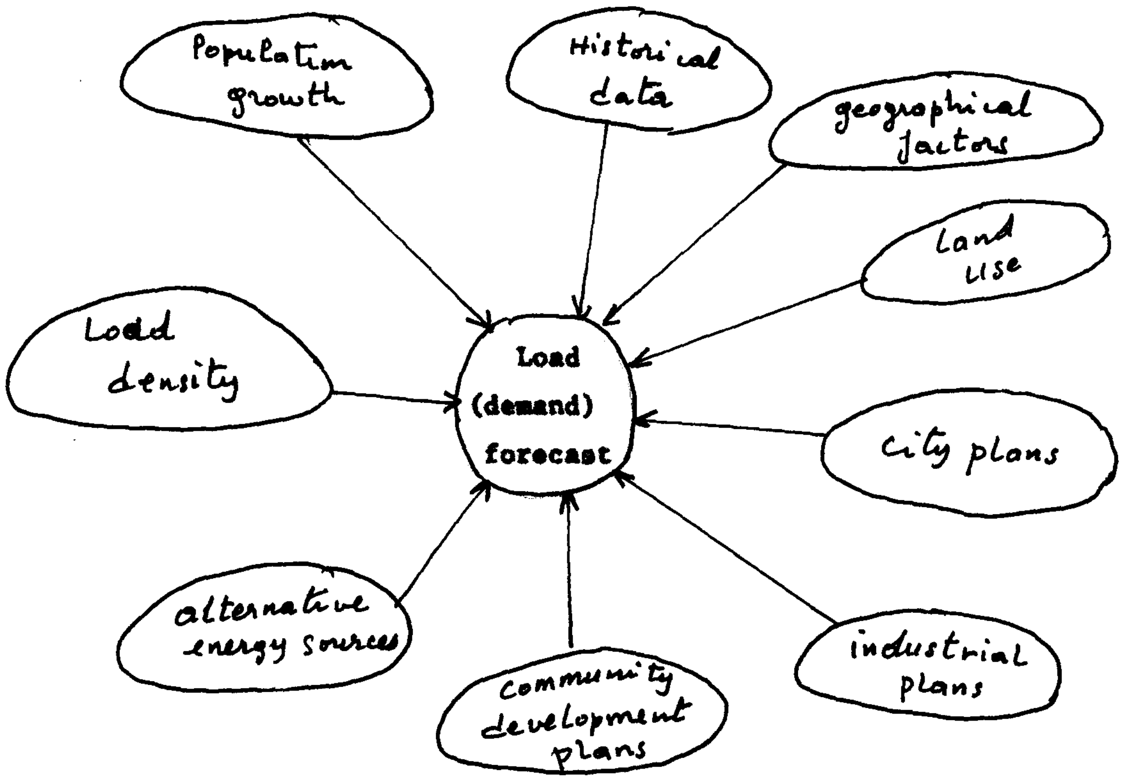


fig. 2.2.1 Factors influencing load forecast.

As one would expect, load growth is very much dependent on the community and its development. Thus the level of the overall economic eactivity, the relative levels of the activity, the relative levels of the activity in the different sectors of the economy, the technologies which are adopted for production of goods and services etc --, are all, factors that influence the load forcasting. Economic indicators demographic data, and official land use plans all serve as raw input to the forecasting procedure.

2.2.4 Load growth equation

The load growth of the geographical area served by a utility company is the most important factor influencing the expansion of the distribution system. Therefore, load forecasting of load increases is essential to the planning procedure. Fitting trends after transformation of data is a common practice in technical forecasting. An arithmetic staight line that will not fit the original data may fit for example, the logarithms of the data as typified by the exponential trend,

$$y_t = ab^x \qquad (2.2.1)$$

This expression is sometimes called a growth equation, since it is after used to explain the phenomenon of growth through time. For example, if the load growth rate is known, the load at the end of n th year is given by

$$P_n = P_o (1 + g)^n \qquad (2.2.2)$$

Where p_n = load at the end of the n th year

p_o = initial load

g = annual growth rate

n = number of yeras.

Now, if it is so that $P_n = y_t$, $P_o = a$, $1 + g = b$ and $n = x$, then equation 2.2.2 is identical to the exponential trend equation 2.2.1.

2.2.5 Forecast methods.

The forecast method are diverse and based on extrapolation, that is the ability to look into the future proceeding from the past and today's information. Many works relating to the energy problems reveal the possibility of wide-scale employment of the probality theory methods and mathematical statistics for solving the planning problems.

A number of most popular methods in load forecasting include

(i). forecast by produce growth factors

(ii). normative method

(iii). correlation method

(iv). forecasting with the use of time series.

2.2.5.1 Forecast by produce growth factors.

This is made by progjecting the growth trend in the past into the future. For instance, if the growth factor K_{T-1} of the power consumption for the past years is known, the forecast for the Tth year is:

$$C_T = (1 + K_{T-1}) \; C_{T-1} \qquad \text{------------------} \quad (2.2.3)$$

and $K_{T-1} = \dfrac{C_{T-1}}{C_{T-2}}$

Where C_{T-1}, C_{T-2} are the consumption for the (T-1)th and (T-2)th years.

This method is simple but inaccurate because the data in the past (growth factor K_{T-1}) are applied to the future without any refinement. On some occassions, this technique offers tolerable occuracy, however the advent of computers make it obsolete.

2.2.5.2 Normative method.

The power demand is also forcast by the so-called normative method which normalizes specific power consumption per unit produce of various enterprises and branches. Now the forecast is:

$$C_T = \sum_i C_{T,i} \, F_i \qquad \text{--------------------} \quad (2.2.4)$$

Where i = number of branch or enterprise

$C_{T,i}$ = forecast specific power consumption

Fi = forecast output.

This method is widespread for forecasting power demand for 5 - 20 years over separate areas. It is also applicable to shorted period but, likewise the first method, involves gross errors. Besides the use of this technique is limited because the power systems are not furnished with information on the expansion of the energy consuming branches of industry.

2.2.5.3 Correlation method.

This is a mathematical modelling method. It relates the statistical data of power consumption with main factors affecting the power demand. Extrapolating such relations for the future gives the forecasting. The correlations may exist between the power consumption and gross product, labour productivily, power availability per man etc - - - The relation between the power generation and the gross product is more rigid for forecasting 5 to 10 years into the future. The correlation are also used for short-term forecasting though the number of the main variables increases with reduction of the forecasting period.

2.2.5.4 Forecasting with the use of time series.

This is also a mathematical modelling. This method is based on the extrapolation of correlation method. The time series is striturally represented as two components taking the form.

$$Y(t) = \varphi(t) + V(t) \quad \text{———} \quad (2.2.5)$$

Here $\varphi(t)$ descrites the determinate component of the series and is called a trend; the component V(t) gives the random deviations from the trend which are probalistic or indeterminate.

The trend reflects the average steady laws of the value Y variation as a function of time, such as the consumers comprising the system and the basic particular of their operation, average weather indicators and the like. Howver the unsteadiness of many factors affecting the power consumption causes the random deviations from the trend, example at the ambient temperature fluctuations-

If a mathematical model can be selected Y(t), it is readily applicable for forecasting by extrapolation for a period of (t + t). The forecast for the moment $(t + \Delta t)$ will be:

$$Y_f(t + \Delta t) = \varphi_f(t + \Delta t) + V_f(t + \Delta t) \quad \text{———} \quad (2.2.6)$$

Where $\varphi_f(t + \Delta t)$ is the value obtained by extrapolating the series $\varphi(t)$ by the moment $(t + \Delta t)$ and $V_f(t + \Delta t)$ by extrapolation of V(t).

CHAPTER THREE.

APPLICATION OF LOAD FLOW CALCULATION TO NEPA 11kv DISTRIBUTION NETWORK FOR MINNA METROPOLIS.

3.1 Introduction

In the present chapter, the load flow analysis is applied to the NEPA 11kv distribution network within Minna metropolis.

Four different feeders supply Minna metropolis in electricity. The 11kv network distribution comprises six buses.

3.2 The NEPA 11kv distribution network.

Two 33kv lines come from Shiroro hydroductric power station. At the Shiroro substation situated near Shiroro Hotel, two 15MVA step-down transformers are used to step-down the 33kv to 11kv. At this stage, there is a bus where four 11kv feeders take their power to supply Minna metropolis. These four feeders are commonly named:

(i). the parliamentary feeder,

(ii). the piggery feeder,

(iii). the Shiroro feeder,

(iv). the Chanchage feeder.

The Chanchaga feeder supplies the area comprising custom house, Niger State Secretariat complex and Chanchaga quaters. The Shiroro feeder is the one supplying the Shiroro quaters, bay clinic quaters and Maitumbi area. The piggery feeder supplies Minna down town, Bosso town and Maikunkule area. And finally the parliamentary feeder is concerned with the area of Kpa bungu and its surroundings.

It is also important to mention that, at the different load centers, 11kv/415v step - down transformers are used to supply customers.

3.3 Data preparation.

For the computer program that is to be used for simulation, data have to be prepared. These data comprise the resistances, the admittances and susceptances of the different lines connecting the different buses together. These are obtained by first measuring the lengths of the various lines. Then the following formulae are used to calculate the values of the different parameters, that is, the resistances, the reactances and the susceptances.

(i). Calculation of the resistance of a conductor (line).

The active resistance per kilometer r_o is given by:

r_o (Ω) /km = $\frac{\rho}{F}$ where ρ is the resistivity of the conductor used, F is the cross-sectional area.

The total resistance of the particular line is obtained by multiplying r_o by the total length of the line in km.

(ii). The reactance x_o

$$x_o\ (\Omega)/\text{km} = 0.1445 \log_{10} \frac{D_{GMD}}{R} + 0.0157$$ where

R is the radius of confuctor, D_{GMD} = 1.26D for horizontally arranged conductors.

The total reactance of the line is obtained by multplying x_o by the total length of the line in km.

(iii). The susceptance b_o is given by:

$$b_o\ (\underline{1})/\text{km} = \frac{7.58}{\log_{10} \frac{D_{GMD}}{R}} \times 10^{-6}$$

For the present project work, practical values of r_o = 0.155 Ω/ϕ /km, x_o = 0.41Ω/ϕ/km and b_o = 7.59 μmhΩ/ϕ/km are used. And the following table is obtained.

Bus n°	name	Bus n°	name	Length (km)	Resistance (Ω)	Reactance (Ω)	Susceptance (µmho)
1	Shiroro Substation	2	Shiroro Hotel	1.071	0.166	0.439	8.129
1	Shiroro Substation	3	Power Statio	4.428	0.686	1.815	33.608
1	Shiroro Substation	4	Chanchaga Water works	9.428	1.461	3.865	71.558
1	Shiroro Substation	5	IBB House	8.428	1.306	3.455	63.968
1	Shiroro Substation	6	NAA 11KV panel	27.714	4.30	11.362	210.350
2	Shiroro Hotel	3	Power Station	4.785	0.741	1.961	36.318
2	Shiroro Hotel	4	Chanchaga Water Works	9.214	1.417	3.748	69.387
2	Shiroro Hotel	5	IBB House	7.071	1.096	2.900	53.668
3	Power Station	4	Chanchaga Water works	9.214	1.428	3.778	69.934
3	Power Station	5	IBB House	5.071	0.786	2.079	38.488
3	Power Station	6	NAA 11KV panel	22.714	3.520	9.312	172.400
5	IBB House	6	NAA 11KV panel	23.857	3.700	9.781	181.075

<u>Table 3.1:</u> Line data.

3.4 Use of per unit system.

In this project work a base of 100 MVA is used. The base KV is 11KV. From these two values a base impedance is calculated and is given by:

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

$$= 1.21$$

This will enable us to express the impedance (hence the admittances) of the different lines in per unit values.

The bus data, that is, the voltage, the active and reactive power associated with each bus are given in the table 3.2. These values are in per unit.

			Load		Generation	
Bus	name	volts	MW	MVAR	MW	MVAR
1	Shiroro Substation	1.06 + jo.o	0	0	0	0
2	Shiroro Hotel	1.0 + jo.o	0.01275	0.0078	0	0
3	Power Station	1.0 + jo.o	0.0034	0.00208	0	0
4	Chanchaga water works	1.0 + jo.o	0.0085	0.0052	0	0
5	IBB House	1.0 + jo.o	0.0085	0.0052	0	0
6	NAA 11KV panel	1.0 + jo.o	0	0	0	0

Table 3.2: bus data

3.5 The simılation program.

For the simulation of the present work, a PASCAL program is used. The program is given in appendix D. The Guauss-Seidel method is used.

CHAPTER FOUR

RESULTS AND DISCUSSION

The result from the simulation program are printed out in appendix E. The bus voltages associated with each bus are first printed out. This is followed by the print out of the real and reactive powers flowing between the various buses. As we have a total number of six buses, six different values of voltages are printed out.

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

For example bus 1 is connected to all other five buses. To the computer prints the real and reactive power flowing from bus 1 to each of the other five buses. It is to be noted that bus 1 is the slack bus. The total bus power is obtained by summing the flows on the lines terminating at the bus. So a summary of the bus powers is given below.

	Load	
Bus no	active power (Kw)	reactive power (KVAR)
1	30.74	22.42
2	22.1	16.18
3	2.08	1.52
4	11.8	8.6
5	10.6	7.75
6	1.41	1.03

It is to be noted, however, that the results printed out by computer are in per unit values. A base MVA of 100 is used. So the actual value is obtained by multiplying the p.u value by the base value, that is, 10^8, to get the real value in watts. So the values of power given above are the real values.

Looking at these results we can see that the largest real and reactive powers are at bus one. And the smallest real and reactive powers are bus 6. From the print out 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 generation system. The one in the system, that is, bus no. 3 is not more generating. So all the buses are load buses.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

A review of the objectives of this work is briefly highlighted in this section. The work has taken a general look on load flow analysis and load forecasting and the various methods of solution used in both cases.

However, the main area of contribution of this project work is the development of the simulation program. The program is written in PASCAL using Gauss-Seidel method of solution. With this program, the user will be able to calculate the bus voltages, the real and reactive powers associated with each bus in apower distribution network. therefore the simulation program is the major contribution of this present project work.

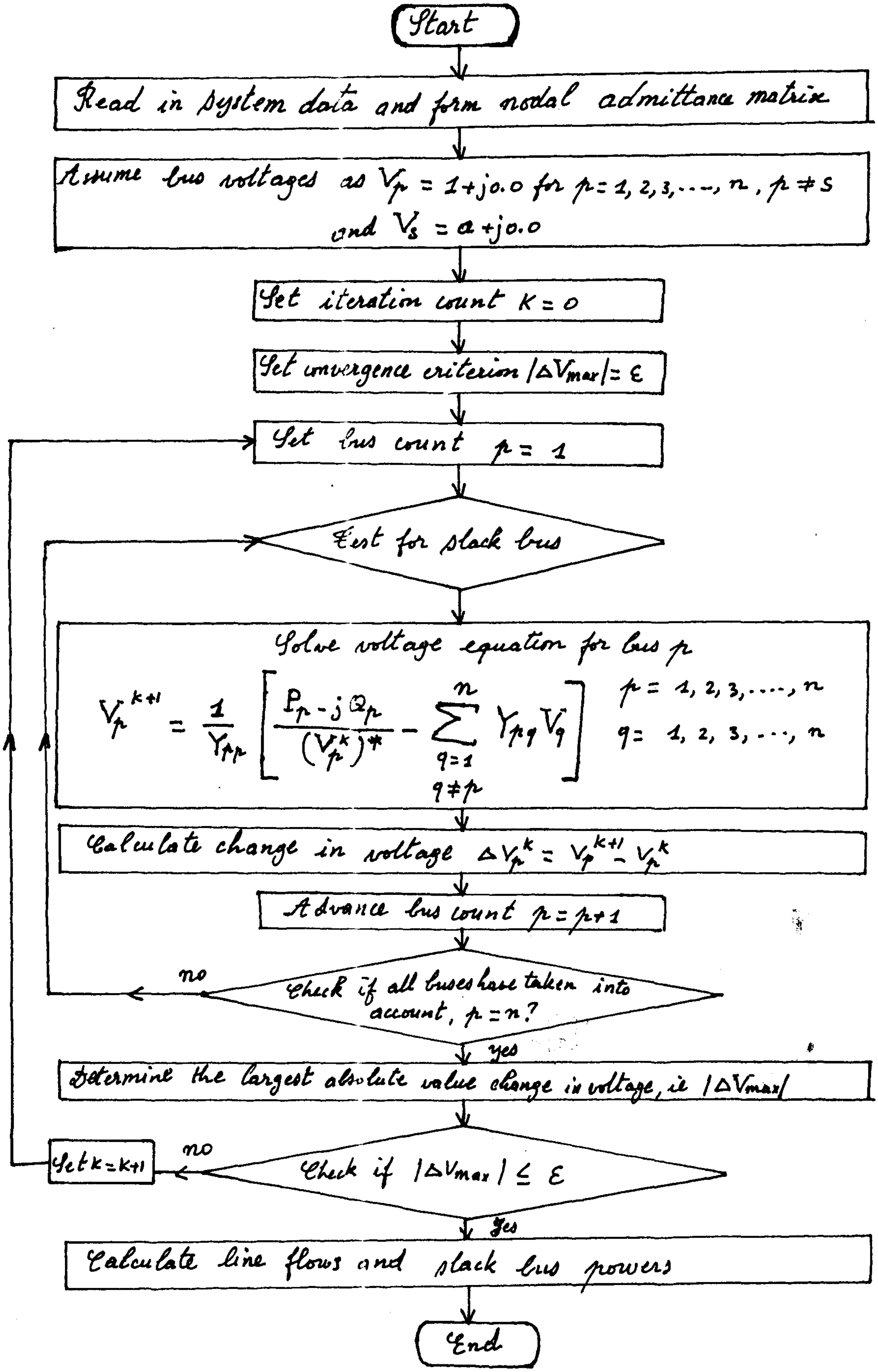
5.2 RECOMMENDATIONS

A practical project of this type needs a lot of finance, which of course is the brain behind this simulation program. The school of Engineering in general and the department in particular should normally help the students to carry out such projects by providing them adequate financial assistance, as it is done in some of the higher institutions of learning in the country. This proposition should be taken into account for the next coming years.

Finally I suggest that, some companies, like the National Electric Power Authority (NEPA) in the present case, should be associated in carrying out such projects.

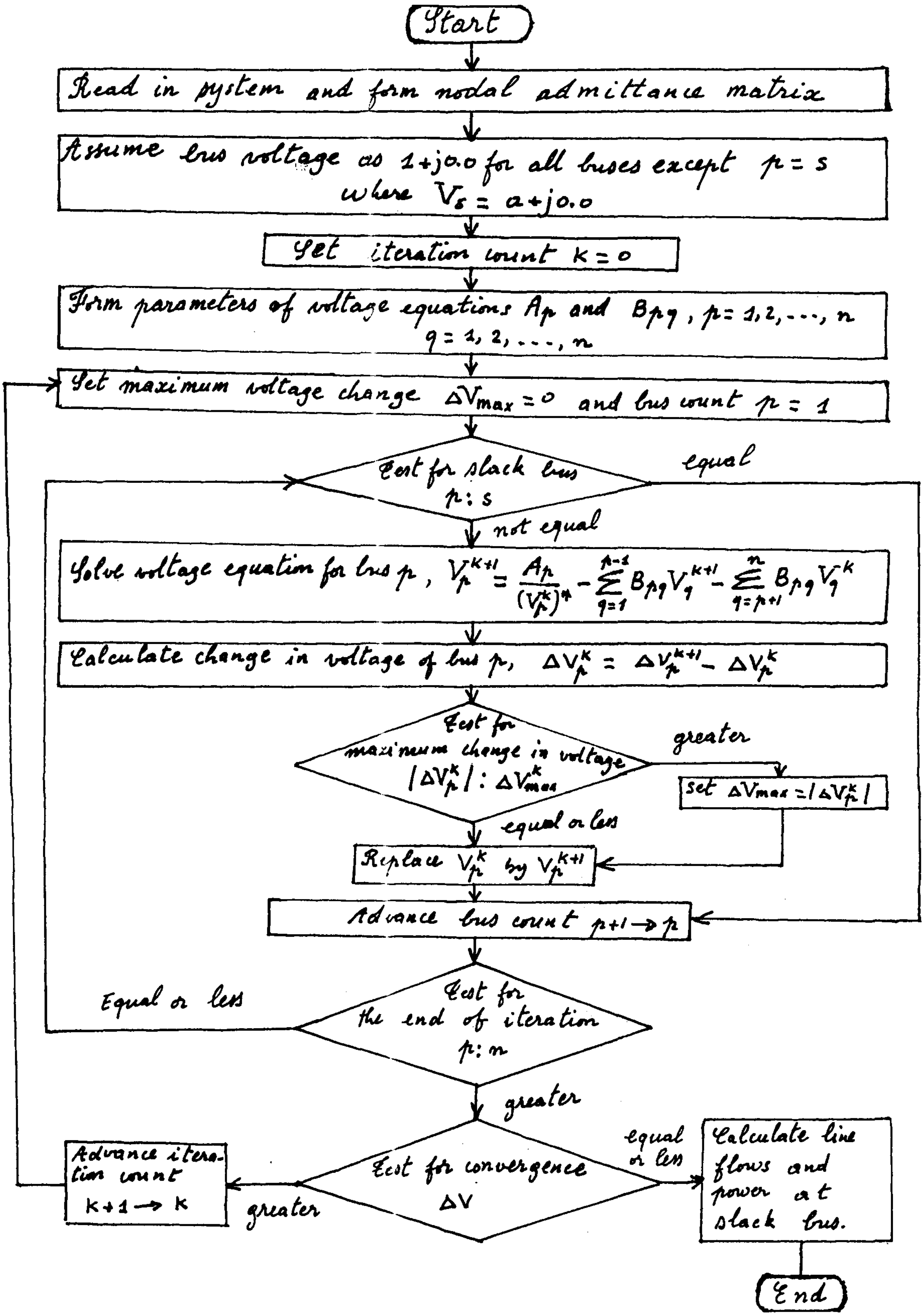
Appendix A

Flowchart using Gauss method of solution



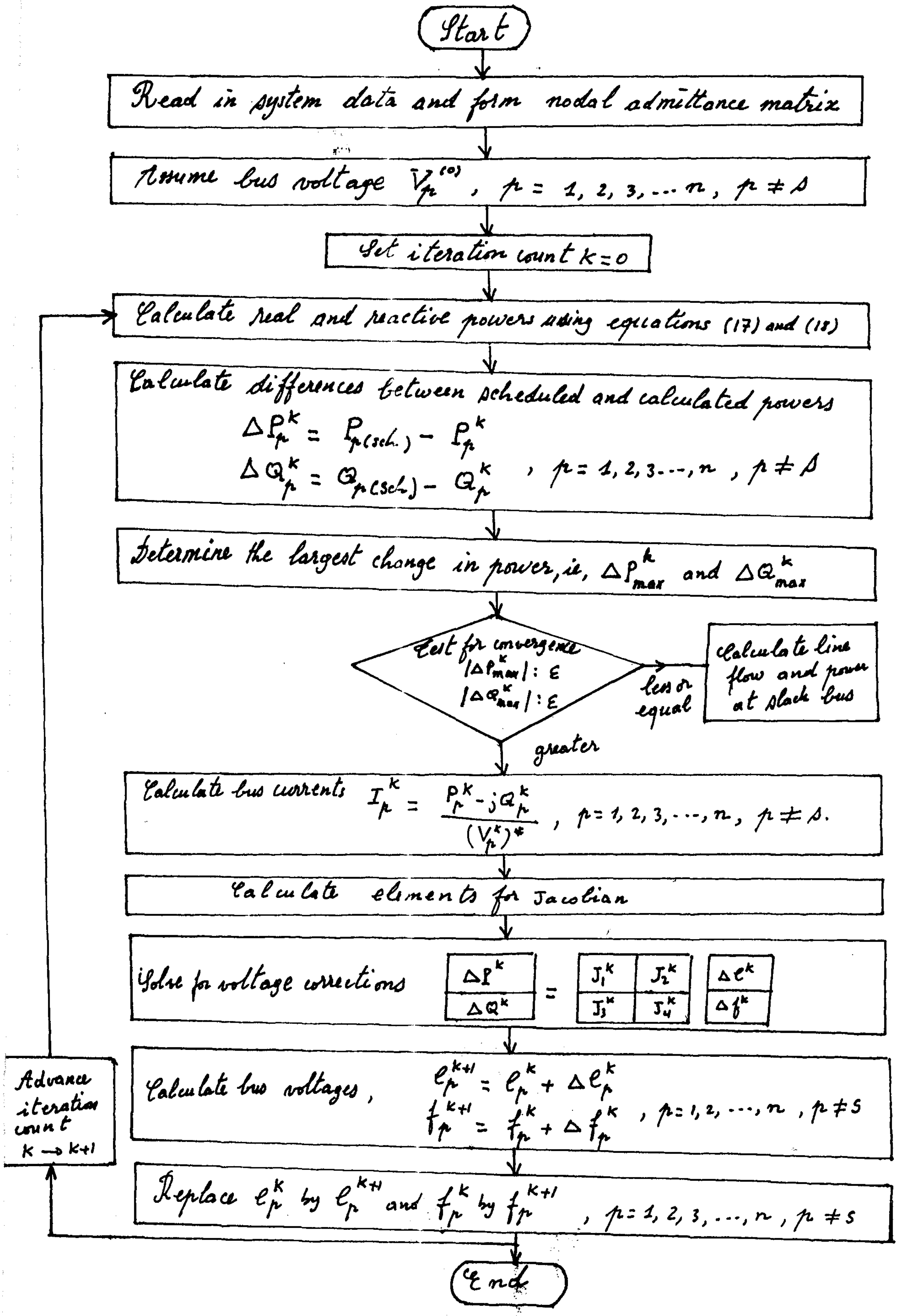
Appendix B

Flowchart using Gauss-Seidel method of solution



Appendix C

Flowchart using Newton-Raphson method of solution



```
Program load flow(input,output);

{ Program to compute Load flow for 11 KV NEPA Distribution
  Network within Minna Metropolis.

  Developed by :-   Salifou  Sandagou  (90/1565)
                    Department of Electrical/Computer Engineering
                    Federal University of Techonology
                    Minna.

  Date :   January, 1997
  }

uses

   crt,dos;

CONST
    itermax = 150;
    n       = 6;

TYPE
    array2 = array[1..6,1..6] of real;
    array1 = array[1..6] of real;

VAR
    Y, YS, YP, Pac, Prc   : array2;
    V, Vinstar, A, Vold   : array1;
    tol, sum1, sum2, sum  : real;
    p, q, iter,row,col    : integer;

    converged             : boolean;

Procedure read data;
BEGIN
Y[1,1]:=3.60; Y[1,2]:=2.13;Y[1,3]:=0.51;Y[1,4]:=0.24;Y[1,5]:=0.62;
Y[1,6]:=0.30;
Y[2,1]:=2.13;Y[2,2]:=3.18;Y[2,3]:=0.47;Y[2,4]:=0.25;Y[2,5]:=0.32;
Y[2,6]:=0.00;
Y[3,1]:=0.51;Y[3,2]:=0.47;Y[3,3]:=1.79;Y[3,4]:=0.24;Y[3,5]:=0.45;
Y[3,6]:=0.09;
Y[4,1]:=0.24;Y[4,2]:=0.25;Y[4,3]:=0.24;Y[4,4]:=0.73;Y[4,5]:=0.00;
Y[4,6]:=0.00;
Y[5,1]:=0.62;Y[5,2]:=0.32;Y[5,3]:=0.45;Y[5,4]:=0.00;Y[5,5]:=1.40;
Y[5,6]:=0.09;
Y[6,1]:=0.30;Y[6,2]:=0.00;Y[6,3]:=0.09;Y[6,4]:=0.00;Y[6,5]:=0.09;
Y[6,6]:=0.28;


YS[1,2]:=2.13;YS[1,3]:=0.51;YS[1,4]:=0.24;YS[1,5]:=0.62;YS[1,6]:=0.30;
YS[2,1]:=2.13;YS[2,3]:=0.47;YS[2,4]:=0.25;YS[2,5]:=0.32;YS[2,6]:=0.00;
YS[3,1]:=0.51;YS[3,2]:=0.47;YS[3,4]:=0.24;YS[3,5]:=0.45;YS[3,6]:=0.09;
YS[4,1]:=0.24;YS[4,2]:=0.25;YS[4,3]:=0.24;YS[4,5]:=0.00;YS[4,6]:=0.00;
YS[5,1]:=0.62;YS[5,2]:=0.32;YS[5,3]:=0.45;YS[5,4]:=0.00;YS[5,6]:=0.09;
YS[6,1]:=0.30;YS[6,2]:=0.00;YS[6,3]:=0.09;YS[6,4]:=0.00;YS[6,5]:=0.09;


YP[1,2]:=0.024;YP[1,3]:=0.015;YP[1,4]:=0.035;YP[1,5]:=0.040;YP[1,6]:=0.022;
YP[2,1]:=0.024;YP[2,3]:=0.016;YP[2,4]:=0.032;YP[2,5]:=0.016;YP[2,6]:=0.00;
YP[3,1]:=0.015;YP[3,2]:=0.016;YP[3,4]:=0.02;YP[3,5]:=0.045;YP[3,6]:=0.035;
YP[4,1]:=0.035;YP[4,2]:=0.032;YP[4,3]:=0.020;YP[4,5]:=0.00;YP[4,6]:=0.00;
YP[5,1]:=0.04;YP[5,2]:=0.016;YP[5,3]:=0.045;YP[5,4]:=0.00;YP[5,6]:=0.108;
YP[6,1]:=0.022;YP[6,2]:=0.00;YP[6,3]:=0.035;YP[6,4]:=0.00;YP[6,5]:=0.108;
```

```
A[1]:=0.00; A[2]:=0.015;  A[3]:=0.004; A[4]:=0.01;A[5]:=0.01; A[6]:=0.00;

Vinstar[1]:=1.05; Vinstar[2]:=1.0; Vinstar[3]:=1.0;
Vinstar[4]:=1.0; Vinstar[5]:=1.0;  Vinstar[6]:=1.0;

tol:=0.001

end;



Procedure compute V;
Begin

iter:=0;
REPEAT
  iter:= iter+1;
  FOR p:= 1 TO n DO
    Vold[p]:=V[p];

  FOR p:= 1 TO n DO
  BEGIN
    sum:=0.0;
      FOR q:=1 TO n DO
        IF p<>q THEN
            sum:=sum+Y[p,q]*V[q];


            V[p]:=((A[p]/Vinstar[p])-sum)/Y[p,p];

            converged:=abs(V[p]-Vold[p]) < tol;

  END;


    p:=0;
    REPEAT
    p:=p+1;
    converged:=abs(V[p]-Vold[p]) < tol;
    UNTIL (p=n) OR NOT converged;



  UNTIL converged OR (iter = itermax);
  writeln;
  IF NOT converged THEN
     write('no');
     writeln('convergence to specified tolerance after',iter,'iterations');

END;

Procedure compute power;
Begin
   FOR p:=1 TO n DO
     FOR q:=1 TO n DO
     if p<>q then
      Begin
        Pac[p,q]:=V[p]*((V[p]-V[q])*YS[p,q]-V[p]*YP[p,q]/2)*0.85;
        Prc[p,q]:=V[p]*((V[p]-V[q])*YS[p,q]-V[p]*YP[p,q]/2)*0.62;
      END;
END;
```

```
(*  Beginning of the main program *)

BEGIN
clrscr;
row:=3;
GOTOXY(20,10);
write('Please wait computation in progress...');

read data;

compute V;

compute power;


(*   Results Section *)
clrscr;
writeln('Bus Voltages  V');
writeln('---------------');
FOR p:=1 TO n DO
   writeln('V',p,' = ',V[p]);
   writeln;
   write('Press [Enter] to coninue...');
   repeat until keypressed;

clrscr;
row:=3;
gotoxy(19,1);writeln('Active Power ','          Reactive Power');
gotoxy(19,2);writeln('------------ ','          --------------');
   FOR p:=1 TO n DO
     FOR q:=1 TO n DO
       IF p<>q THEN
       BEGIN
       gotoxy(10,row);writeln('P',p,q,'  =  ',Pac[p,q], '     ',Prc[p,q]);
       row:=row+1;
       IF row=20  THEN
          BEGIN
            gotoxy(10,row+2); write('Press [Enter] to continue...');
            row:=3; readln;
            repeat until keypressed; clrscr;
       gotoxy(19,1);writeln('Active Power ','          Reactive Power');
       gotoxy(19,2);writeln('------------ ','          --------------');
          END;
      END;
      writeln;
      writeln('Maximum number of iterations allowed is ',itermax);
      writeln;
      writeln('No of iterations after which convergence occured is ',iter);
      writeln;
      write('Press [Enter] key to exit...');
      readln;
      repeat until keypressed;
END.
(*          END OF PROGRAM (LOADFLOW)     *)
```

```
Bus Voltages  V
---------------
V1 = -6.9878838911E-03
V2 =  7.7223185384E-03
V3 = -2.1342399709E-03
V4 =  1.4053054921E-02
V5 =  8.8393275694E-03
V6 =  5.3318117266E-03

Press [Enter] to coninue...
```

		Active Power	Reactive Power
P12	=	1.8560899301E-04	1.3538538313E-04
P13	=	1.4391594947E-05	1.0497398667E-05
P14	=	2.9268100021E-05	2.1348496486E-05
P15	=	5.7455404473E-05	4.1908647968E-05
P16	=	2.1496028275E-05	1.5679455919E-05
P21	=	2.0505886231E-04	1.4957234663E-04
P23	=	3.0002623474E-05	2.1884266534E-05
P24	=	-1.1199717291E-05	-8.1692055537E-06
P25	=	-2.7517572614E-06	-2.0071641200E-06
P26	=	0.0000000000E+00	0.0000000000E+00
P31	=	-4.5195955115E-06	-3.2966461378E-06
P32	=	8.3730124622E-06	6.1073737959E-06
P34	=	7.0089873107E-06	5.1124378031E-06
P35	=	8.8711226265E-06	6.4707012100E-06
P36	=	1.1512221345E-06	8.3971496869E-07
P41	=	5.7383012372E-05	4.1855844319E-05
P42	=	1.6219472945E-05	1.1830674383E-05

Press [Enter] to continue...

		Active Power	Reactive Power
P43	=	4.4306950128E-05	3.2318010682E-05
P45	=	0.0000000000E+00	0.0000000000E+00
P46	=	0.0000000000E+00	0.0000000000E+00
P51	=	6.9908628906E-05	5.0992176379E-05
P52	=	2.5551730502E-06	1.8637732837E-06
P53	=	3.4950162179E-05	2.5493059472E-05
P54	=	0.0000000000E+00	0.0000000000E+00
P56	=	-9.7628850800E-07	-7.1211632348E-07
P61	=	1.4452195000E-05	1.0541601059E-05
P62	=	0.0000000000E+00	0.0000000000E+00
P63	=	2.3102625899E-06	1.6851327126E-06
P64	=	0.0000000000E+00	0.0000000000E+00
P65	=	-2.5762502555E-06	-1.8791472452E-06

Maximum number of iterations allowed is 150

No of iterations after which convergence occured is 4

Press [Enter] key to exit...

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