

TITLE PAGE

# **COMPUTATION OF POWER FLOW**

A Case Study of Minna Metropolis

*By*

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FEDERAL UNIVERSITY OF TECHNOLOGY MINNA,  
NIGERIA

DECEMBER, 2000

## DECLARATION

I Abdullahi Sani Simpa, hereby declare that this project is an original concept and work of mine which was carried out by me under the supervision of my supervisor in person of Engr. A. O. Aduloju

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# CERTIFICATION

This is to certify that this project titled "Computation of power flow" within Minna Metropolis was carried out by Abdullahi Sani Simpa under the supervision of Engr. A.O. Aduloju and submitted to the department of Electrical and Computer Engineering Federal University of Technology Minna in partial fulfillment of the requirements for the award of Bachelor of Engineering (B.ENG) degree in Electrical and Computer Engineering.


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.....  
*Project Supervisor*

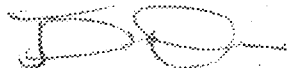
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*Head of Department*

  
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*Sign and date*

14/1/01



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*External Examiner*

17/1/2001  
.....  
*Sign and Date*

## DEDICATION

This project work is dedicated to my mother Mallama Rekiya S. Daniya.

## ACKNOWLEDGEMENT

To God Almighty for granting me the grace, strength and wisdom to pursue this programme. I want to appreciate the contributions of my project supervisor Engr. A. O. Aduloju for his effort and guidance in the course of this study. I also want to acknowledge the contribution of the H.O.D. and other lecturers of the department.

My sincere gratitude goes to my parents Mr. & Mrs. S. Daniya; my brothers and sisters for their lone and unrelenting support.

Finally, I wish to express my gratitude to the following people Mr. & Mrs. Ajinowoh; Engr. Musani for their understanding and support and also Hajiya Aisha Sadiq for unalloyed support and encouragement.

May God reward all of them bountifully (Amen).

## ABSTRACT

This report presents the computation of power flow for NEPA 11kv distribution network within Minna metropolis.

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

Finally, the computation of this power flow is applied to NEPA 11kv distribution network within Minna metropolis, where the different quantities associated with the buses, that is, the bus voltages, the real and reactive power flow have been calculated using computer program.

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# CHAPTER ONE

## GENERAL INTRODUCTION

### 1.1 INTRODUCTION

Power distribution system required continuous and comprehensive analysis in order to evaluate the system performance and to determine the effectiveness of alternative plans for system expansion. This study plays an important role in producing a high standard of power system reliability, security, quality and in ensuring the maximum utilization of power.

Minna metropolis consists of the following areas Mobil, Chanchaga, Saiko, Angodagi, Bosso, Limawa, Tunga, Maitumbi, Sabongari, Kpakungu, and Shiroro. Before Minna was linked to the national grid in 1976, there was a power station that was called isolated power station, which was installed in 1960. The power station has three units, each of which generated about 1.3MW of power and due to low demand of power then, only one of the unit was use before in 1976 when Niger state was created and Minna was made the capital there was increased in load demand which raise from 1.3MW to 10MW due to increase in demand of power by people working in government ministry and parastatals. This led to the installation of more distribution transformer.

Presently, the daily power demand in the metropolis is about 24MW. Minna is served by a 132/33/11KV Sub-transmission station situated at Kpakungu village on the outskirts of the township. The Sub-transmission station is supplied by two lines at 132KV each from Shiroro power station. That is SHIRORO LINE ONE and SHIRORO LINE TWO. The two lines feeds the two power transformer of 30MVA (132/33KV) rating each, that is TR1 and TR2. The 33kv output of each of the transformer is passed on respectively on the two step-down transformers, TR3 and TR4 of 15MVA (33/11KV) rating each. 11KV output is feed on the respective bus bars for supply on four feeders.

The four feeders presently used in the metropolis are Chanchaga feeder, parliamentary feeder, Shiroro feeder and piggery feeder. Chanchaga and parliamentary feeders are supplied by transformer (TR3), while Shiroro and piggery feeders are supplied by transformer (TR4).

### 1.2 AIMS AND OBJECTIVES

The main aims and objectives of this project work is to develop a computer simulation program in Pascal language to evaluate the performance of the network by calculating the power flow, both real and reactive power associated with the buses as well as the bus voltages.

The study therefore would ease the problem associated with the present manual calculation which is time consuming and prone to error as well.



## 1.3 METHODOLOGY

In the analysis of power system instead of using actual values of quantities, it is usual to express them as fraction of reference quantities, such as rated or full load values. These fractions are called per unit value (denoted by P.U.) and the per unit value of any quantity is defined as the ratio of the actual value (in any unit) to the base or reference value in the same unit.

The advantages of per unit representation are:

- (i) Per unit data representation yields valuable relative magnitude information.
- (ii) Circuit analysis of system containing transformers of various transformation ratio is greatly simplified.
- (iii) Circuit parameters tends to fall in relatively narrow numerical ranges making erroneous data easy to spot.

## 1.4 LITERATURE REVIEW

### THEORY OF POWER DISTRIBUTION, LOAD FLOW AND FORECASTING

#### 1.4.1 THEORY OF POWER DISTRIBUTION

According to Anthony J. Pansini (1971), stated that distribution is the delivery of electric energy from the bulk supply substation to the consumers energy meter. He further observed that distribution circuit normally uses primary or main feeders and lateral distributors. A main feeder originate at the substation and passes through the major load centres. The individual load points are connected to the main feeder by lateral distributor with distribution transformer at their ends. The distribution system use in the metropolis is the radial circuit configuration (radial system) which has a single circuit main feeder. Distribution network differs from transmission network in several ways, apart from voltage magnitude. The number of branches and sources is much high in distribution network and general topology is different.

A typical distribution systems consist of a step down (example 132/11kv) on load tap-changing transformer at a bulk supply point feeding a number of cables which can vary in length from a few hundred metres to several kilometers. A series of step-down three phase transformers for instance 11/0.415kv are spaced along the route and from these one supplied to consumers three phase, four wire network from which the single phase is apped for utilisation.

## TYPES OF DISTRIBUTION NETWORK

(i) **Primary Distribution:** which carries the load at higher than utilisation voltage from the substation (or other source) to the point where the voltage is stepped down to the value at which the energy is utilised by the consumer.

(ii) **Secondary Distribution:** which includes that part of the system operating at utilisation voltage, up to the meter at the consumer premises.

### PRIMARY DISTRIBUTION SYSTEM

Primary distribution systems include three basic types:

(i) **Radial systems:** Distribution is at the utilisation voltage. A single primary service and distribution transformer supply all the feeders. There is no duplication of equipment.

The radial type system is the simplest of all circuit arrangement. It comprises separate feeders or circuits "radiating" out of the substation or source, each feeder usually serving a given area. The feeder may be considered as consisting of a main or trunk portion from which there radiate spurs or laterals to which distribution transformers are connected as shown figure 1.4.

The spur or lateral are usually connected to the primary feeder through fuses, so that a fault on the lateral will not cause an interruption to the entire feeder.

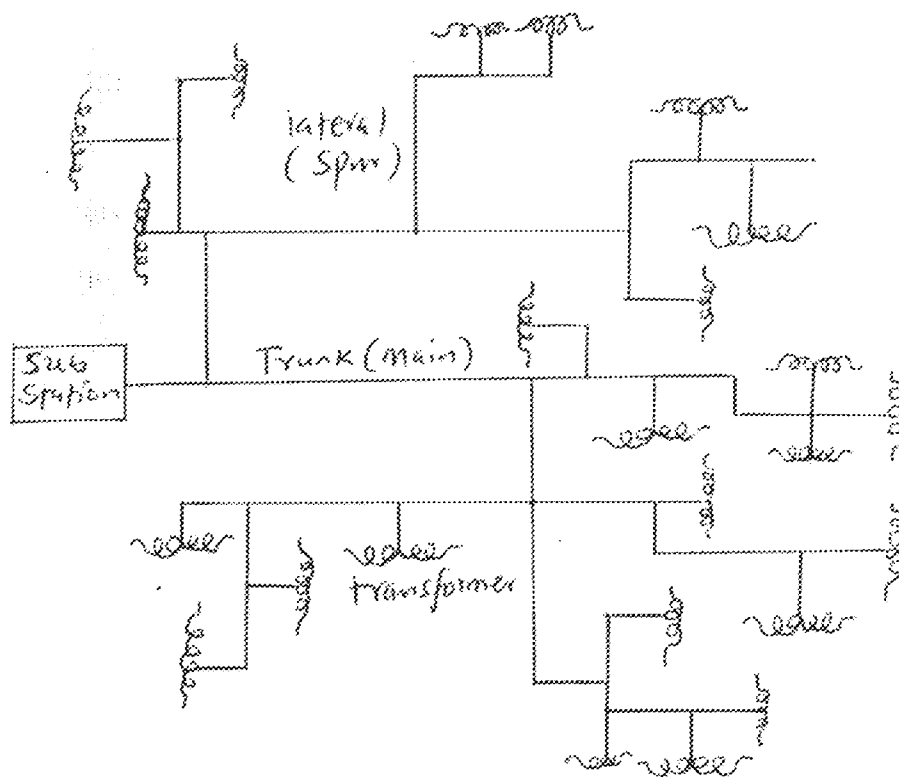


Fig. 1.4 Primary feeder schematic diagram showing trunk or main feeds and lateral or spurs

(ii) **Loop Systems:** Another means of restricting the duration of interruption employs feeders, not clear which essentially provide a two-way primary feed for critical consumers. Here, should the supply from one direction fail, the entire load of the feeder may be carried from the other end, but sufficient spare capacity must be provided in the feeder. This type of system may be operated with the loop normally open or with the loop normally closed.

(a) **Open Loop:** In the open loop system, the several sections of the feeder are connected together through disconnecting devices, with the loads connected to the several sections, and both ends of the feeder connected to the supply. At a predetermined point in the feeder, the disconnecting device is deliberately left open. Fundamentally, this constitutes two feeders whose ends are separated by a disconnecting device, which may be a fuse, switch, or circuit breaker.

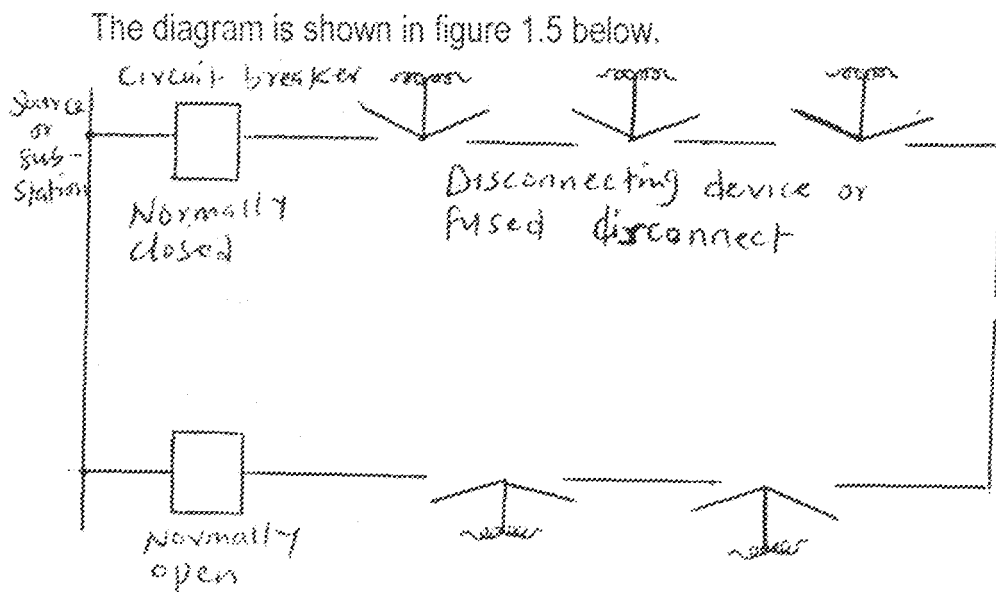


Fig. 1.5 open-loop circuit schematic diagram.

In the event of a fault, the section of the primary on which the fault occurs can be disconnected at both its ends and services re-established to the unfaulted portions by closing the loop at the point where it is normally left open, and re-closing the breaker at the substation (or supply source) on the other, unfaulted portion of the feeder. Such loops are not normally closed, since a fault would cause the breakers (or fuses) at both ends to open, leaving the entire feeder de-energised and no knowledge of where the fault has occurred. The disconnecting device between section are manually operated and may be relatively inexpensive fuses, cutouts, or switches.

(b) **Closed Loop:** This is used when a higher degree of reliability is desired, the feeder may be operated as a closed loop. Here, the disconnecting devices are usually the

more expensive circuit breakers. The breakers are actuated by relays, which operate to open only the circuit breakers on each end of the faulted section, leaving the remaining portion of the entire feeder energised. In many instances, proper relay operation can only be achieved by means of pilot wires which run from circuit breaker to circuit breaker and are costly to install and maintain, in some instances these pilot wires may be rented telephone circuits. As shown in figure 1.6

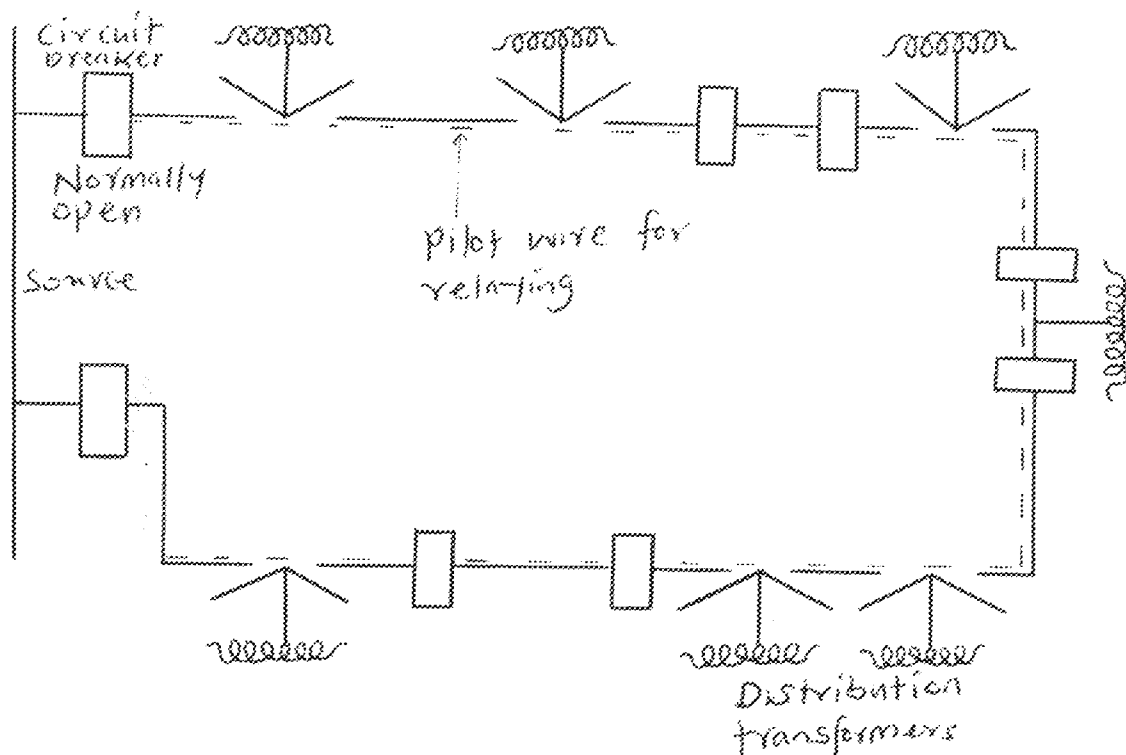


Fig. 1.6 closed loop circuit.

To hold down costs, circuit breaker may be installed only between certain section of the loop, and ordinary, less expensive disconnecting device installed between the intermediate sections. A fault will then de-energised several sections of the loop; when the fault is located, the disconnecting devices on both ends of the faulted section may be opened and the unfaulted section re-energised by closing the proper circuit breaker.

(iii) **Primary Network System:** This system is formed by tying together primary mains ordinarily found in radial systems to form a mesh or grid. The grid is supplied by a number of power transformers supplied in turn from sub-transmission and transmission lines at higher voltages. A circuit breaker between the transformer and grid, controlled by reverse – current and automatic re-closing relays, protect the primary network from feeding fault current through the transformer when faults occur on the supply sub-transmission or transmission lines. Faults on sections of the primaries constituting the grid are isolated by circuit breaker and fuses.

## SECONDARY DISTRIBUTION

Secondary distribution systems operate at relatively low utilisation voltages and like primary systems, involve considerations of service reliability and voltage regulation. The secondary system may be of four general types:

(i) **Individual Transformer – Single Service:** Individual transformer service is applicable to certain loads that are more or less isolated, such as in rural area where consumers are far apart and long secondary mains are impracticable, or where a particular consumer has an extraordinarily large or unusual load even though situated among a number of ordinary consumers.

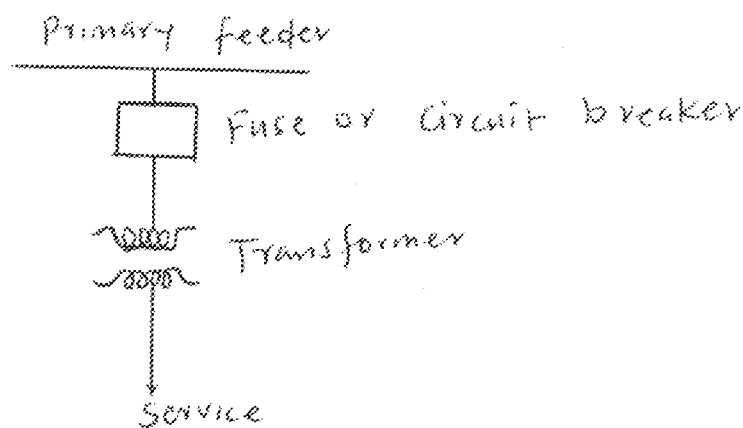


Fig. 1.8 single – service secondary supply

In this type of system, the cost of the several transformer and the sum of power losses in the units may be greater (for comparative purposes) than those for one transformer supplying a group of consumers from its associated secondary main. The diversity among consumers' loads and demands permit a transformer of smaller capacity than the capacity of the sums of the individual transformer to be installed. On the other hand, the cost and losses in the secondary main are obviated, as is also the voltage drop in the main. Where low voltage may be undesirable for a particular consumer, it may be well to apply this type of service to the consumer.

(ii) **Common secondary main:** This is the most common type of secondary system. It takes advantage of diversity between consumers' loads and demands, as indicated below. In many instances, the secondary main installed are more or less continuous, but cut into sections insulated from each other as conditions require. As loads change or increase, the portion of these division points may be readily changed, sometimes loading of the need to install additional transformer capacity. Also, additional separate sections can be created and a new transformer installed to serve a load or voltage conditions require.

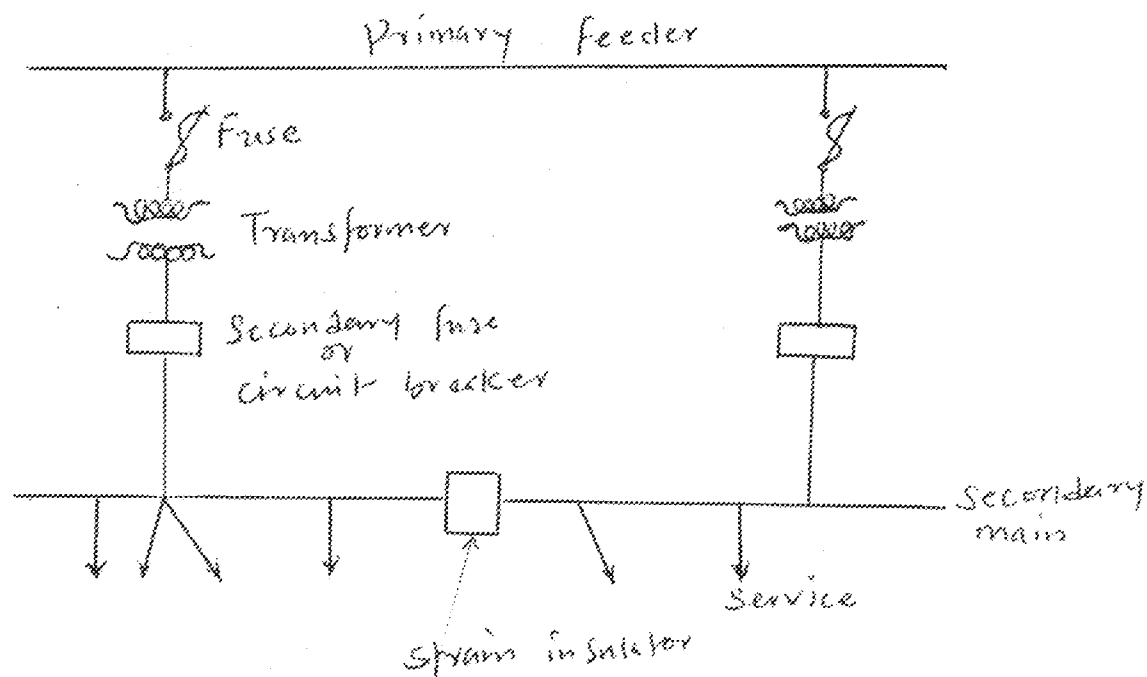


Fig 1.9 common - secondary - main supply

(iii) **Banked Secondaries:** The secondary system employing banked secondaries is not very commonly used, although such installations exist and are usually limited to overhead systems. This type of system may be viewed as a single feeder low voltage network and the secondary may be a long section or grid to which the transformers are connected.

Fuses or circuit breakers are used to protect the transformer from any fault, as indicated in the figure name. Banked secondaries, while providing for failure of transformers, do not provide against faults on the primary main or feeder. Further, a hazard on any transformer disconnected for any reason may result from a back feed if the secondary energises the primary (which may have been considered safe).

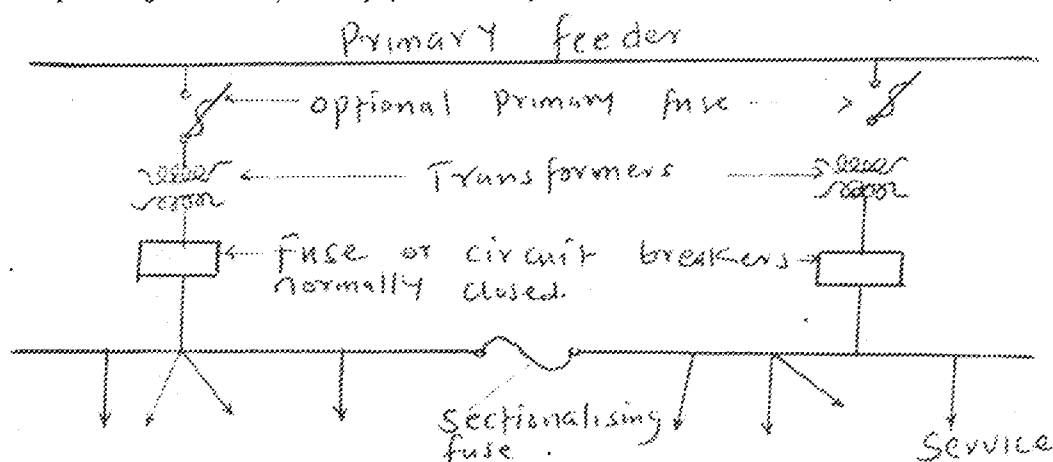


Fig 1.10 Banked secondary supply.

(iv) **Secondary Networks:** This network is created by connecting together the secondary main fed from transformer supplied by two or more primary feeders. The secondary network at present provides the highest degree of service reliability and serves areas of high load density, where revenue justifies them and where this kind of

reliability is imperative. In some instances, a single consumer may be supplied from this type of system by what is known as spot network. Automatically operated circuit breakers in the secondary connection between the transformer and the secondary mains, known as network protectors are used to disconnect the transformer from fault and they are also back up with fuse should the protector fail to operate, the fuse will blow and disconnect the transformer from the secondary mains.

### **TYPES OF CONSTRUCTION (OVERHEAD AND UNDER GROUND)**

Although the original distribution system pioneered by Thomas Edison was a direct current low-voltage system installed underground, the widespread expansion of electric system was based principally on the adoption of alternating current (through the application of transformers) and the very economic overhead type of construction.

While the main limitation to the adoption of underground system is economic, there are other reasons that argue against its selection. The necessity for ducts, for manholes, and for cable that require expensive insulation all tends to make investment costs several times as great as for overhead systems of comparable characteristics.

Where loads becomes so great, however, that the number of pole lines and the congestion of conductors on such lines become impractical from safety, operational and appearance viewpoints, there is no alternative but to place the lines underground. In such areas, traffic conditions are usually so severe that difficulty is experienced in building and maintaining overhead systems; moreover, the heavy traffic itself presents additional hazards from vehicles striking the poles.

While an underground system is not exposed to damage and interruptions from storms, traffic. On the other hand, when trouble does occur, it is very much more difficult and time-consuming to locate and repair than in the overhead systems. For this reason, additional provisions and expenditures are made for maintaining service reliability; these include duplicate facilities, throw over schemes, network. Also, the lesser ability for heat radiation in an underground system does not permit the loading and overloading of conductors and equipment possible with overhead systems. With plastics taking over the functions of insulation and sheathing in underground cables, and the ability of these materials to be buried directly in the ground, the economic advantage of overhead systems, though still favourable, is markedly reduced. The recent greater emphasis on environment (appearance) also has contributed to a greater pressure for underground installations. Overhead systems will, however, prevail to a very great extent for some time, and will be in almost exclusive use in rural areas. (Anthony J. Pansini, 1971).

## 1.4.2 LOAD FLOW

A.S. Pabla (1981), observed that in order to evaluate the performance of a power distribution network and to examine the effectiveness of proposed alterations to a system in the planning stage, it is essential that a load flow analysis of a network is carried out. The load flow studies are normally carried out to determine:

- (a) The flow of active and reactive power in a network branches.
- (b) No circuits are overloaded, and the busbar voltages are within acceptable limits.
- (c) Effect of additional or alterations on a system
- (d) Effect of loss of circuits under emergency conditions
- (e) Optimum system loading conditions
- (f) Optimum system losses.

The load flow in distribution network is carried out in essentially two forms. In the case of simple radial networks, the load flow is largely self-evident. However, in interconnected networks having a number of series or parallel paths, the problem is more complex.

The use of the digital computer is now almost universally accepted in studying load flow

### POWER SYSTEM EQUATION

**Formulation of the Problem:** The network matrix equation provides an extremely suitable mathematical model of an electrical network. With the help of this equation it is possible to describe the characteristics of the network as well as the interconnection of these elements. The selection of independent variables determines the elements of the network matrix. The independent variable can be voltage or current and corresponding the elements of the network matrix are impedance or admittance. The form of network matrices used in the equation depends on the frame of reference, namely, bus, loop or branch. In the bus (or nodal) frame of reference, the variables are nodal voltages and currents. In the loop frame of reference the variables are loop voltages and loop currents.

Since the loop frame of reference does not yield sets of voltages or currents it is rarely used in the study of load flow problems. The complexity of data preparation further restricts its use.

### NETWORK PERFORMANCE EQUATIONS

The equation describing the performance of the network of a power system using the bus frame of reference in impedance form is

$$V_{bus} = Z_{bus} I_{bus} = [Y_{bus}]^{-1} I_{bus} \dots\dots\dots (1.1)$$

or in admittance form is



$$I_{\text{Bus}} = Y_{\text{bus}} \bar{E}_{\text{bus}} \quad (1.2)$$

Where  $\bar{E}_{\text{bus}}$  = vector of node voltages measured with respect to the reference node

$I_{\text{Bus}}$  = vector of impressed node currents

$Z_{\text{bus}}$  = bus impedance matrix

$Y_{\text{bus}}$  = bus admittance matrix

The bus impedance and admittance matrices can be formed for the network including the ground bus. The elements of the matrices, then, will include the effects of shunt elements to ground such as line charging and shunt elements of transformer equivalents. When the ground bus is included and selected as the reference node, the bus voltages in the network performance equations (1.1) and (1.2) are measured with respect to ground

If the ground bus is not included in the network, the elements of the bus impedance and admittance matrices will not include the effects of shunt elements and one of the buses of the network must be selected as the reference node. In this case, the effects of shunt elements are treated as current sources at the buses of the network and the bus voltages in the performance equations (1.1) and (1.2) are measured with respect to the selected reference bus.

Using the loop frame of reference, the network performance equation in the impedance form is

$$\bar{E}_{\text{Loop}} = Z_{\text{loop}} I_{\text{loop}}$$

Or in admittance form is

$$I_{\text{loop}} = Y_{\text{loop}} \bar{E}_{\text{loop}}$$

When the loop impedance and admittance matrices are formed for the network not including shunt elements, the dimension of the matrices is  $L \times L$ , where  $L$  is the number of links or basic loops calculated from

$$L = e - n + 1$$

$e$  is the number of elements, including the shunt connections, and  $n$  is the number of nodes. In this case, the effects of shunt elements are treated as current sources at the buses of the network.

If the shunt elements  $e_s$  are included in forming the loop matrices, the number of elements of the network is increased by  $e_s$ . The total number of elements is, then,  $e + e_s$  and the number of nodes is increased to  $n + 1$ . Consequently, the number of loops and the dimension of the loop matrices are increased by  $e_s - 1$

The different forms of network equations are summarised in Table 1.4

Parameter form

Frame of \_\_\_\_\_

Reference \_\_\_\_\_

(impedance) (Z)

Admittance (Y)

Bus	$\vec{E}_{bus} = Z_{bus} I_{loop}$	$I_{bus} = Y_{bus} \vec{E}_{bus}$
-----	------------------------------------	-----------------------------------

Loop	$\vec{E}_{Loop} = Z_{bus} I_{loop}$	$I_{bus} = Y_{bus} \vec{E}_{bus}$
------	-------------------------------------	-----------------------------------

Bus loading equation

The real and reactive power at any bus P is

$$P_p - jQ_p = E^* p I_p$$

And the current is

$$I_p = \frac{P_p - jQ_p}{E^* p}$$

Where  $I_p$  is positive when flowing into the system. In the formulation of the network equation, if the elements to ground are included in the parameter matrix, then equation (1.3) is the total current at bus p is

$$I_p = \frac{P_p - jQ_p}{E^* p} - Y_p E_p$$

Where  $Y_p$  is the total shunt admittance at the bus and  $Y_p E_p$  is the shunt current flowing from bus P to ground.

**Line flow equation**

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

$$i_{pq} = \frac{(E_p - E_q) Y_{pq} + E_p Y'_{1pq}}{2}$$

- Where  $Y_{pq}$  = line admittance
- $Y'_{1pq}$  = total line charging admittance
- $E_p Y'_{1pq}$  current contribution at bus p due to line charging

The power flow, real and reactive is

$$P_{pq} - jQ_{pq} = E_p^* I_{pq}$$

or

$$P_{pq} - jQ_{pq} = E_p^* (E_p - E_q) Y_{pq} + E_p^* E_p \frac{Y'_{pq}}{2} \dots\dots\dots(1.4)$$

Where at bus p the real power flow from bus P to q is  $P_{pq}$  and the reactive power is  $Q_{pq}$ . Similarly, at bus of the power flow q to P is

$$P_{qp} - jQ_{qp} = E_p^* (E_q - E_p) Y_{pq} + E_p^* E_q \frac{Y'_{pq}}{2} \dots\dots\dots(1.4)$$

The power loss in line p-q is the algebraic sum of the power flows determined from equations (1.4) and (1.5). [(G.W Stagg and A. H. E1 – Abiad, (1968)).

### Solution Techniques.

The techniques used for solving load-flow problems are:

- (i) Gauss iterative method
- (ii) Gauss – seidel iterative method
- (iii) Newton – Raphson iterative method ( also referred to as the ward -Hale method).

### GAUSS ITERATIVE METHOD

The solution is initiated by assuming voltages for all buses except the slack bus where the voltage is specified. Currents are calculated for all buses except the slack bus from the bus loading equation.

$$I_p = \frac{P_p - jQ_p}{E_p^*}$$

The performance of the network is then obtained from the equation:

$$I_{bus} = Y_{bus} E_{bus}$$

This then allows the bus voltages to be calculated from the expression:

$$E_p = \frac{1}{Y_{pp}} [I_p - \sum_{\substack{q=1 \\ p \neq q}}^n Y_{pq} E_q], \quad P = 1, 2, \dots\dots\dots n$$

This new voltage is then substituted back into the expression to calculate bus currents for a subsequent solution of the bus voltages. This is continued until changes in the bus are negligible.

## GAUSS-SEIDEL ITERATIVE METHOD

This method is almost identical to the Gauss iterative method except that in substituting the bus voltages into the expression to obtain the new value of the bus voltage, the most recent value of bus voltage is substituted into the expression. In other words, while the Gauss method only the bus voltages from the previous iterations are used, in the Gauss-Seidel method, for evaluating the  $n$ th bus voltages for the iteration are used for the 1 to  $(n-1)$  bus while the bus voltage for the previous iterations are used for the rest of the bus voltages.

## NEWTON-RAPHSON ITERATIVE METHOD

This method of solving non linear equation was adopted by ward and Hale. It is by far the most sophisticated of the basic methods. Not only it will work in most cases without risk of divergence, but it will also as a rule converge faster than the proceeding methods described.

The method is based on the following theory consider the simultaneous equations:

$$f_1(x_1, x_2, \dots, x_r) = 0$$

$$f_2(x_1, x_2, \dots, x_r) = 0$$

.

.

.

$$f_n(x_1, x_2, \dots, x_r) = 0$$

Let us initially guess that  $x_1^{(0)}, x_2^{(0)}, x_r^{(0)}$  are solutions of these  $n$  equations and the error in each guess is  $\Delta x_1^{(0)}, \Delta x_2^{(0)}, \dots, \Delta x_r^{(0)}$

$$f_1(x_1^{(0)} + \Delta x_1^{(0)}, x_2^{(0)} + \Delta x_2^{(0)}, \dots, x_r^{(0)} + \Delta x_r^{(0)}) = 0$$

$$f_2(x_1^{(0)} + \Delta x_1^{(0)}, x_2^{(0)} + \Delta x_2^{(0)}, \dots, x_r^{(0)} + \Delta x_r^{(0)}) = 0$$

.

.

.

$$f_r(x_1^{(0)} + \Delta x_1^{(0)}, x_2^{(0)} + \Delta x_2^{(0)}, \dots, x_r^{(0)} + \Delta x_r^{(0)}) = 0$$

These equations can then be expanded using the Taylor's series. Neglecting the second order terms, since the errors  $\Delta x_i$  are small, we get

$$f_1(x_1^{(0)}, x_2^{(0)}, \dots) + \Delta x_1^{(0)} \left(\frac{df_1}{dx_1}\right)^{(0)} + \Delta x_2^{(0)} \left(\frac{df_1}{dx_2}\right)^{(0)} + \dots = 0$$

$$f_2(x_1^{(0)}, x_2^{(0)}, \dots) + \Delta x_1^{(0)} \left(\frac{df_2}{dx_1}\right)^{(0)} + \Delta x_2^{(0)} \left(\frac{df_2}{dx_2}\right)^{(0)} + \dots = 0$$

Writing this in a matrix form, we have

$$f^{(0)} + J^{(0)} \Delta X^{(0)} \approx U$$

Where  $J$  is referred to as the Jacobian and is equal to:

$$J^{(0)} = \begin{pmatrix} (df_1/dx_1)^{(0)} & \dots & (df_1/dx_n)^{(0)} \\ (df_2/dx_1)^{(0)} & \dots & (df_2/dx_n)^{(0)} \\ \dots & \dots & \dots \\ (df_n/dx_1)^{(0)} & \dots & (df_n/dx_n)^{(0)} \end{pmatrix}$$

The corrections to the initial guess  $\Delta x^{(0)}$  are equal to

$$\Delta x^{(0)} \approx - [J^{(0)}]^{-1} f^{(0)}$$

In terms of the load flow problem, the power at bus P is

$$S_p = P_p - jQ_p = E_p \cdot I_p = E_p \cdot \sum_{q=1}^n Y_{pq} E_q$$

### 1.4.3 LOAD FORECASTING

Ching – Lien Hung and S. Kahman (1996), observed that it is evident that load forecasting is a very crucial activity in electricity supply. Forecast are bases on the previous year loading for the period in question updated by factors such as general load increase, major new load, and weather trends. Both power demand and energy forecasts are used, the later often being the more readily obtained. Energy trends tends 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 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. A knowledge of the increasing use of such appliances is therefore essential. The many physical factors affecting loads, examples weather, popular T.V programmes, public holiday, make forecasting a complex process demanding experience and analytical ability

### TYPES OF FORECASTING

- (i) Long term forecasting, with time horizon on the order of 15 to 20 years.
- (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 plant operator in allocating the generator spinning reserve to meet the peak load demand for the area. Demand for such electricity is forecasting by agencies such as NEPA. The techniques used by these agencies are mainly based on the assumption of taking on average year loading and then projecting the growth every year based on a certain pattern of assumption.

### 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 below shows some of the factors, which influence the load forecast.

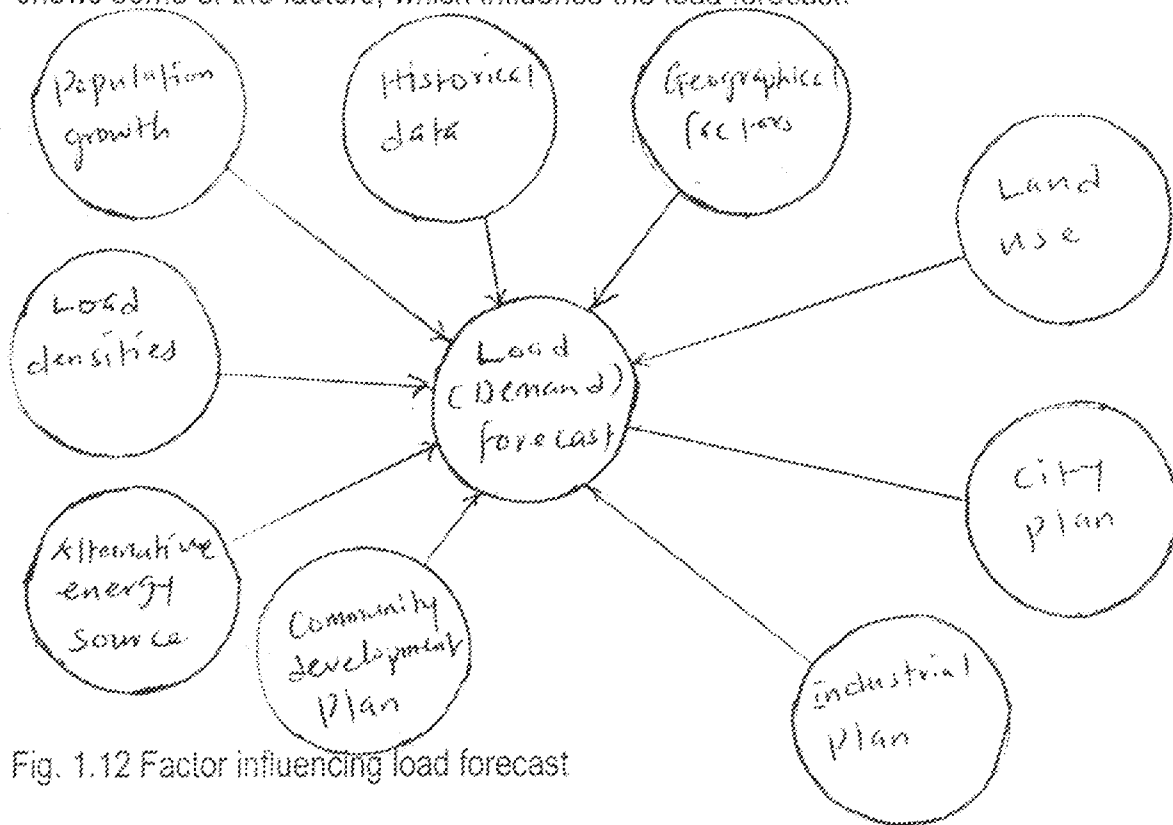


Fig. 1.12 Factor influencing load forecast

### 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 as a common practice in technical forecasting. An arithmetic straight line that will not fit the original data may fit for example, the logarithms of the data as shown by exponential trend,

$$Y(t) = ab^x$$

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

$$P_n = P_0 (1 + g)^n$$

- Where  $P_n$  = Load at the end of the  $n$ th year  
 $P_0$  = Initial load  
 $G$  = Initial growth rate  
 $N$  = number of years

Now, if it is so that  $P_n = Y.t$ ,  $P_0 = a$ ,  $1 = g = b$  and  $n = x$ , then equation is identical to the exponential trend of equation.

## FORECAST METHODS

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

A number of most popular method in load forecasting include

- (i) Forecast by produce growth factor.
- (ii) Normative method
- (iii) Correlation method
- (iv) Forecasting with the use of time series.

## FORECAST BY PRODUCE FACTOR

This is made by projecting the growth trends 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  $T$ th year is  $C_T = (1 + K_{T-1}) C_{T-1}$

$$\text{And } K_{T-1} = \frac{C_{T-1}}{C_{T-2}}$$

Where  $C_{T-1}$  and  $C_{T-2}$  are 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 occasions, these techniques offer tolerable accuracy, however the advent of computers make it obsolete.

## NORMATIVE METHOD

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

$$C_T = \sum_i C_{T,i} | F_i |$$

- Where  $i$  = number of branch or enterprise  
 $C_{T,i}$  = forecast of specific power consumption  
 $F_i$  = forecast output

This method is widespread for forecasting power demand for 5-20 years over separate areas. It is also applicable for short period but likewise the first method, involved gross error. Besides, the use of this technique is limited because the power system is not furnished with information on the expression of the energy consuming branches of industry.

### 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 correlation's may exist between the power consumption and goes product, labour productivity, power reliability per man. The relation between the power generation and the gross product is more rigid for forecasting 5-10 years into the future. The correlations are also used for short term forecasting through the number of the main variable increases with reduction of the forecasting period.

### 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 structurally represented as two components, taking the form:

$$Y(t) = \varphi(t) + V(t)$$

Where  $\varphi(t)$  describes the determinate component of the series and is called a trend; the component  $V(t)$  gives the random deviations for the trend which are probabilistic or indeterminate.

The trend reflect 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 indicates and the like.

However, the unsteadiness of many factors affecting the power consumption causes the random deviation from the trends example at the ambient temperature fluctuations. If a mathematical model can be selected  $Y_i$ ; it is readily applicable for forecasting by extrapolation for a period of  $(t + \Delta t)$ . The forecast for the moment

$(t + \Delta t)$  will be:

Where  $\varphi_i(t + \Delta t)$  is a value obtained by extrapolating the series.

$\varphi(t)$  by the moment  $(t + \Delta t)$  and  $V_i(t + \Delta t)$  by extrapolation of  $V(t)$



## 1.5 PROJECT OUTLINE

Chapter one introduces the project and literature review on power distribution, load flow and forecasting.

Chapter two deals with the application of power flow analysis to NEPA 11KV distribution network.

Chapter three discusses the results obtained from the computer simulation program.

Finally, Chapter four discusses the conclusion reached and recommendations given.

## CHAPTER TWO

### 2.0 APPLICATION OF POWER FLOW ANALYSIS TO NEPA 11KV DISTRIBUTION NETWORK (CASE STUDY OF MINNA METROPOLIS)

In the application of power analysis to NEPA 11kv distribution network within Minna metropolis, it is important to know how electricity is distributed within the metropolis, the total number of feeders used and also the approximate number of transformer used in the metropolis as well as their ratings.

Minna is served by 132/33/11KV sub-transmission substation. The transmission substation is supplied by two lines at 132KV each. The voltage (132KV) is step down by 230MVA to 33KV and ratings to 11KV. It is this 11KV that is fed onto the respective bus bars for supply on the four feeders, which is used within the metropolis. However, the distribution transformers are installed at a specific location within the metropolis ranging from 50KVA to 500KVA ratings. Minna metropolis uses about 281 distribution transformers. These are sixty transformers rated 500KVA with current rating of 096A, sixty-five rated 300KVA (417A), twenty-three rated 200KVA (278A), fifty-eight rated 100KVA (139A) and fifteen transformed with current rating of 69A. All these transformers of various ratings step down 1KV primary distribution voltage to secondary utilization voltage of 240V single phase (Phase to neutral) and 415V three phase (line to line voltage). Also, at the 132KV transmission substation, there are total of eight feeders but Minna metropolis uses only these feeders which are described as follows:

- i) Parliamentary Feeder government - House, Dutse Kura, Limawa, Barkin Sale, Bosso and
- ii) Piggery Feeder areas, such as Mobil, Saiko, General Hospital, Anguwa-Daji and Sabor
- iii) Chanchaga Feeder areas, such as Army Barracks, Tunga, Shango and Chanchaga.
- iv) Shiroro Feeder areas Shiroro Hotel, NITECO, Tunga - Lowcost and Maitumbi.

Among the place, there are 33KV feeders which includes NNPC, water works and a spare for expansion. But for the purpose of this project work, they apply only to 11KV distribution network which is used in the metropolis. The distribution network consists of six buses network connections and the number assigned to each bus. These code numbers specify the location on line and transformer as well as to identify the types

of buses, the location of static capacitors, shunt reactors, and those network elements in which off-nominal turns ratios of transformers are to be represented.

The six buses that constitute the NEPA 11KV distribution network for Minna metropolis are:

- |       |                                       |   |
|-------|---------------------------------------|---|
| (i)   | Shiroro substation bus code number    | 1 |
| (ii)  | Shiroro Hotel bus code number         | 2 |
| (iii) | Former power station bus code number  | 3 |
| (iv)  | Chanchaga Water Works bus code number | 4 |
| (v)   | IBB house bus code number             | 5 |
| (vi)  | NAA 11KV panel bus code number        | 6 |

The connections between these types are shown in figure 2.1

## 2.1 DATA PREPARATION

For the computer program that is to be used for simulation, data have to be prepared. These data comprises the resistance, reactance, impedance, admittance and susceptance of the different line connecting the different buses together. These are obtained by first measuring the length of the line. Thus, the following calculations are carry-out to obtained the values of the different lines parameters, that is, the impedance and line charging admittance all in per unit values.

For the distribution network, the size of the conductor used is 150mm<sup>2</sup> in cross-sectional area. The impedances and admittances of the transmission lines are calculated as follows:

For Aluminum conductor with cross-sectional area = 150mm<sup>2</sup> effective resistance,

$$R = 0.147 \Omega/\text{KM}$$

$$\text{Reactance } , X = 0.124 \Omega / \text{Km}$$

$$\text{Capacitance } , C = 0.405 \mu \text{ f/km}$$

In per unit, the line parameters can be calculated thus:

$$\text{Base Power VA} = S_b = I_b V_b$$

$$\text{Base Current A} = I_b = \frac{S_b}{V_b}$$

$$\text{Base Impedance } \Omega = Z_b = \frac{V_b}{I_b} = \frac{V_b^2}{S_b}$$

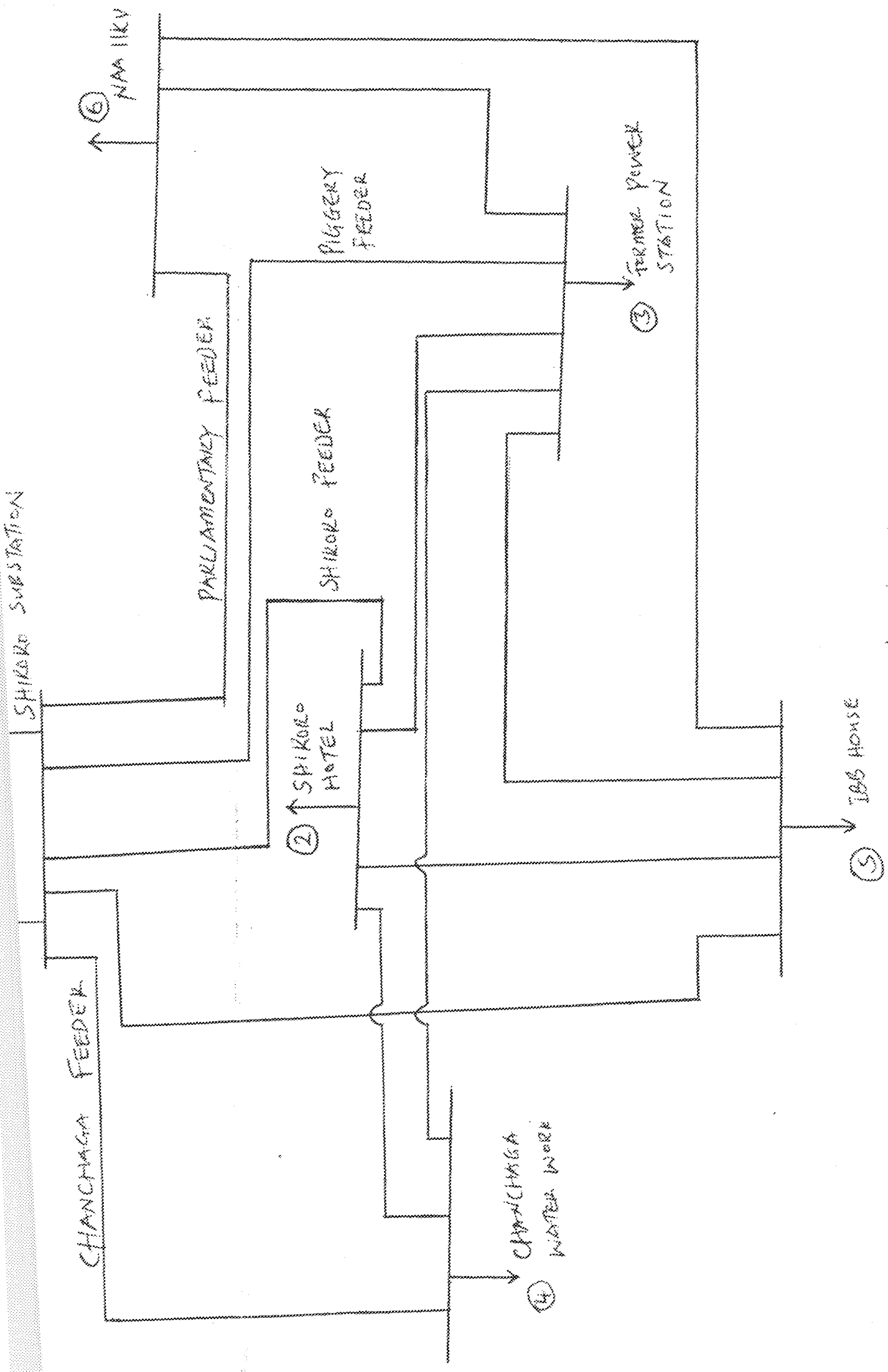


FIG. 2.1 Connections between the buses.

$$\begin{aligned}
 \text{If } C &= 0.405 \mu \text{ f/KM} \\
 Y &= j2\pi fc \\
 &= j2 \times 3.142 \times 50 \times 0.405 \times 10^{-6} \\
 &= j127.235 \times 10^{-6} \Omega/\text{KM}
 \end{aligned}$$

$$\text{Base Power } S_b = 100\text{MVA}$$

$$\text{Base Voltage } V_b = 11\text{KV}$$

$$\text{P.U Impedance } Z_{p.u} = \frac{Z(\Omega)}{Z_b}$$

$$\text{P.u admittance } Y_{P.U} = \frac{1}{Z_{p.u}}$$

$$Z_{p.u} = \frac{Z(\Omega) \cdot S_b}{V_b^2}$$

$$Y_{p.u} = \frac{Y(\Omega) \cdot V_b^2}{S_b}$$

$$\begin{aligned}
 \text{For } Z &= R + jX \\
 &= 0.147 + j0.124 \\
 &= 0.1923 \angle 40.15^\circ
 \end{aligned}$$

$$Z_{p.u} = \frac{0.1923 \cos 40.15^\circ \times 100 \times 10^6 + j0.1923 \sin 40.15^\circ \times 100 \times 10^6}{121 \times 10^6 \quad 121 \times 10^6}$$

$$= 0.1215 + j0.1025 \text{ p.u}$$

$$Y_{p.u} = \frac{j127.235 \times 10^6 \times 121 \times 10^6}{100 \times 10^6}$$

$$= j0.00015 \text{ p.u}$$

The bus power at the bus (except the slack or reference bus) are calculated from the transformer ratings.

For example, for a transformer of 0.5MVA

$$\text{MVA rating} = 0.5\text{MVA}$$

$$\text{Base Power } S_b = 100 \text{ MVA}$$

$$\text{Per unit value} = \frac{0.5}{100} = 0.005 \text{ p.u}$$

$$\text{At power factor of } 0.8 = \cos^{-1}(0.8) = 36.87^\circ$$

$$\text{Real Power, } P = 0.004 \cos 36.87^\circ = 0.004 \text{ p.u}$$

$$\text{Reactive Power, } Q = 0.005 \sin 36.87^\circ = 0.003 \text{ p.u}$$

For 0.4 MVA

$$\text{Per unit value} = \frac{0.4}{100} = 0.004 \text{ p.u}$$

$$\text{Real Power } P = 0.004 \cos 36.87^\circ = 0.0032 \text{ p.u}$$

$$\text{Reactive Power } Q = 0.004 \sin 36.87^\circ = 0.0024 \text{ p.u}$$

For 1MVA

$$\text{Per unit value} = \frac{1}{100} = 0.01 \text{ p.u}$$

$$\text{Real Power } P = 0.01 \cos 36.87^\circ = 0.008 \text{ p.u}$$

$$\text{Reactive Power } Q = 0.01 \sin 36.87^\circ = 0.006 \text{ p.u}$$

For 1.5MVA

$$\text{Per unit value} = \frac{1.5}{100} = 0.015 \text{ p.u}$$

$$\text{Real Power } P = 0.015 \cos 36.87^\circ = 0.012 \text{ p.u}$$

$$\text{Reactive Power } Q = 0.015 \sin 36.87^\circ = 0.009 \text{ p.u}$$

For the present work, series impedance is  $0.1215 + j0.1025 \text{ p.u}$ .

Therefore the total series impedance of the particular line is obtained by multiplying  $0.1215 + j0.1025 \text{ p.u}$  by the total length of the line in KM

The line charging admittance is obtained by multiplying  $j0.00015 \text{ p.u}$  by the total length of the line in KM. And the following table 2.1 is obtained.

**TABLE 2.1 LINE DATA SPECIFICATION**

BUS CODE p-q	LENGTH (KM)	IMPEDANCE $Z_{pq}$ (p.u)		LINE CHARGING ADMITTANCE (P.U)
		RESISTANCE	REACTANCE	
1-2	0.25	0.0304	0.0256	0.00004
1-3	2.00	0.2430	0.2050	0.00030
1-4	9.67	1.1749	0.9912	0.00145
1-5	5.60	0.6804	0.5740	0.00084
1-6	20.20	2.4543	2.0705	0.00303
2-3	3.55	0.4313	0.3639	0.00053
2-4	9.48	1.1518	0.9717	0.00142
2-5	5.25	0.6379	0.5381	0.00079
3-4	11.85	1.4398	1.2146	0.00177
3-5	4.25	0.5164	0.4356	0.00064
3-6	17.80	2.1627	1.8245	0.00267
5-6	19.63	2.3850	2.0121	0.00294

**TABLE 2.2 BUS DATA SPECIFICATION**

Bus Code P	Assume Bus Voltage (p.u)	Generation		Load		
		Megawatts	Megavars	Real Power (P.U)	Reactive Power Q (P.U)	
1	1.06 + j0.0	0	0	0		0
2	1.0 + j0.0	0	0	0.0120		0.0090
3	1.0 + j0.0	0	0	0.0032		0.0024
4	1.0 + j0.0	0	0	0.0080		0.0060
5	1.0 + j0.0	0	0	0.0040		0.0030
6	1.0 + j0.0	0	0	0		0

**TABLE 2.3 LINE ADMITTANCES**

BUS CODE p-q	LINE ADMITTANCE Ypq
1-2	19.2464 - j16.2075
1-3	4.8780 - j0.0071
1-4	0.4972 - j0.4195
1-5	0.8586 - j0.7244
1-6	0.2380 - j0.2008
2-3	1.3544 - j1.1427
2-4	0.5072 - j0.4279
2-5	0.9159 - j0.7726
3-4	0.4058 - j0.3423
3-5	1.1314 - j0.9544
3-6	0.2701 - j0.2279
5-6	0.2449 - j0.2066

TABLE 2.4 BUS ADMITTANCE MATRIX

	1	2	3	4	5	6
1	$25.7182 - j17.5593$	$-19.2464 + j16.2075$	$-4.8780 + j0.0071$	$-0.4972 + j0.4195$	$-0.8586 + j0.7244$	$-0.2380 + j0.02008$
2	$19.2464 - j16.2075$	$-22.0239 + j18.5507$	$-1.3544 + j1.1427$	$-0.5072 + j0.4279$	$-0.9159 + j0.7726$	
3	$8.780 - j0.0071$	$-1.3544 + j1.1427$	$-8.0397 + j2.6744$	$-0.4058 + j0.3423$	$-1.1314 + j0.9544$	$-0.2701 + j0.2266$
4	$0.4972 - j0.4195$	$-0.5072 + j0.2279$	$-0.4058 + j0.3423$	$-1.4102 + j1.1895$		
5	$0.8586 - j0.7244$	$-0.9159 + j0.7726$	$-1.1314 + j0.9544$		$-3.1508 + j2.6580$	$-0.2449 + j0.0266$
6	$0.2380 - j0.02008$		$-0.2701 + j0.2279$		$-0.2449 + j0.0266$	$-0.7530 + j0.6353$



## 2.2 The Simulation Program:

Pascal program is used for the simulation of the present work.

Pascal is used because of the simplicity of the program and also very easy to execute on a computer.

The program is given in appendix B . The gauss seidel method of solution is used.

## CHAPTER THREE

### RESULTS AND DISUSSION

The results from the simulation program are printed out in appendix C. The bus voltages associated with each bus are first printed out. This is followed by the print out of the real and reactive power flow between the various buses. Since there is no direct coupling of buses, with six numbers of buses, a total of thirty elements of real and reactive power is obtained.

Also, with 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. The results printed out by computer are in per unit values. A base of 100MVA is used. So the actual value is obtained by multiplying the per unit value by the base MVA, that is  $10^8$ , to get the real value in watts. From the print out we can also see that there is no generation, this is due to the fact that, the system under consideration does not involve power generation. So all the buses are load buses.

# CHAPTER FOUR

## CONCLUSION AND RECOMMENDATION

### 4.1 CONCLUSION

The aims and objectives of this project work is achieved, since the simulation program developed is capable of calculating the bus-bar voltages, line flow both real and reactive power flow.

The program is written in Pascal using the Gauss-seidel method of solution of solving power flow problems. With this program the user will be able to compute the bus-bar voltage and real and reactive power flow in a power network.

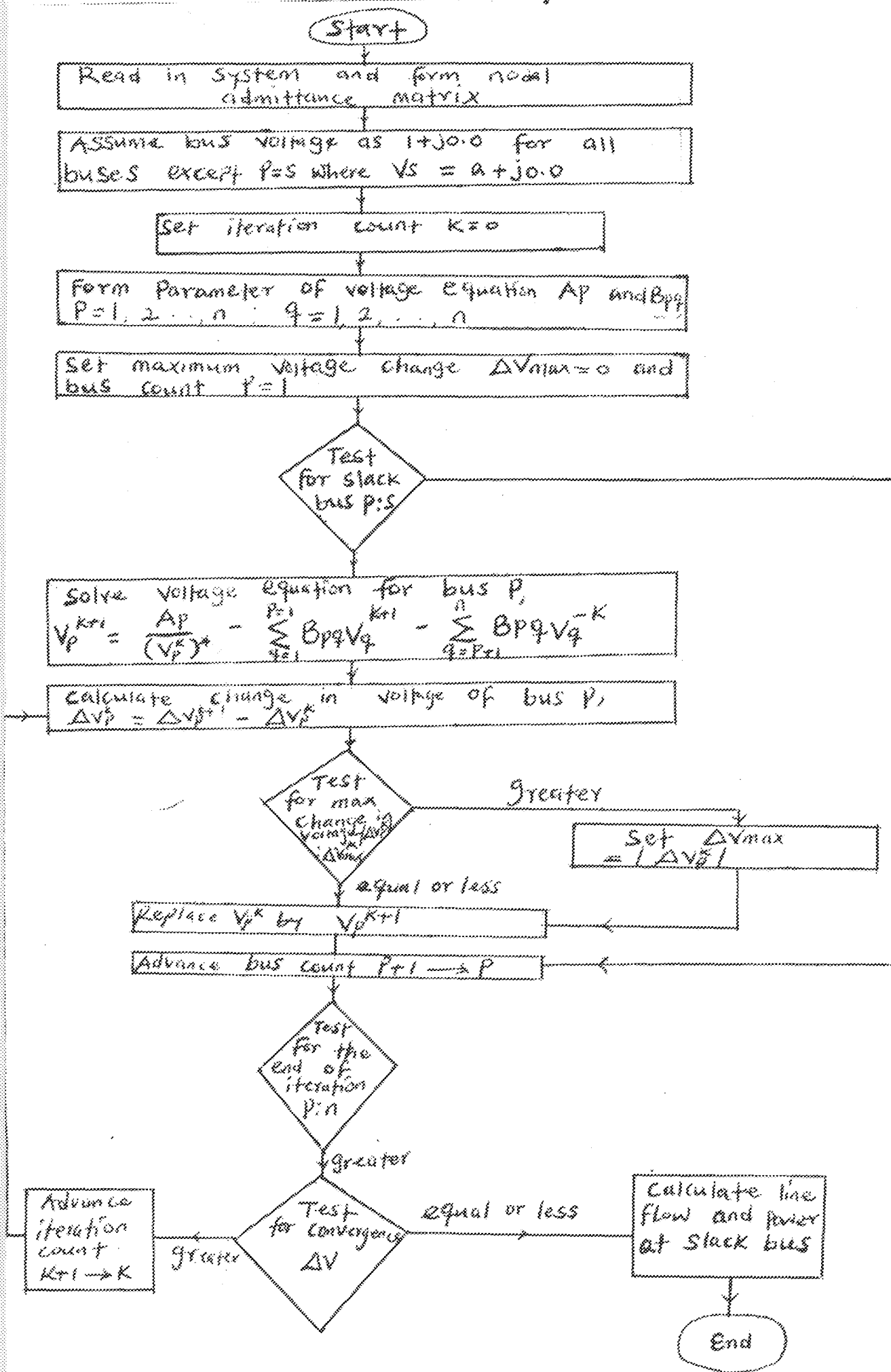
The number of iteration after which convergence occurred is 6, that shows the method of solution is effective for a small network of this kind.

### 4.2 RECOMMENDATIONS

I want to recommend that, utility company like the National Electric Power Authority (NEPA) should encourage students to carry on project work with her, especially a project work of this kind. This will go along way in assisting NEPA to improve on her services to consumers by maintaining the stability of power supply and in this way people will be willing to pay their bills promptly.

# APPENDIX A

Flow Chart for power flow computation using the Gauss seidel method of solution



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(\*program to compute power flow for 11kv NEPA Distribution Network  
within Minna Metropolis

Developed by: Abdullahi Sani Simpa (95/4371)  
Department of Electrical and  
Computer Engineering  
Federal University of Technology,  
Minna.

Date: December, 2000.\*)

uses crt;  
CONST

itermax = 150;  
n = 6;

TYPE

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

VAR

YA, YAN, YC, Pac, Prc : array2;  
V, RAV, PUV, Val : array1;  
tole, sum, sum1, sum2 : real;  
P, q, iter, row, col : integer;  
converged : boolean;

Procedure read\_data;

BEGIN

YA[1,1]:= 31.1409; YA[1,2]:=25.1616; YA[1,3]:= 4.8780;  
YA[1,4]:=0.6505; YA[1,5]:=1.1234; YA[1,6]:=0.3114;  
YA[2,1]:= 25.1616; YA[2,2]:=28.7955; YA[2,3]:= 1.7721;  
YA[2,4]:=0.6634; YA[2,5]:=1.1982; YA[2,6]:=0.0000;  
YA[3,1]:= 4.8780; YA[3,2]:=1.7721; YA[3,3]:= 8.4729;  
YA[3,4]:=0.5309; YA[3,5]:=1.4802; YA[3,6]:=0.3534;  
YA[4,1]:= 0.6505; YA[4,2]:=0.6634; YA[4,3]:= 1.5309;  
YA[4,4]:=1.8450; YA[4,5]:=0.0000; YA[4,6]:=0.0000;  
YA[5,1]:= 1.1234; YA[5,2]:=1.1982; YA[5,3]:= 1.4802;  
YA[5,4]:=0.0000; YA[5,5]:=4.1222; YA[5,6]:=0.3204;  
YA[6,1]:= 0.3114; YA[6,2]:=0.0000; YA[6,3]:= 0.3534;  
YA[6,4]:=0.0000; YA[6,5]:=0.3204; YA[6,6]:=0.9852;  
YAN[1,2]:= 25.1616; YAN[1,3]:=4.8780; YAN[1,4]:= 0.6505;  
YAN[1,5]:=1.1234; YAN[1,6]:=0.3114;  
YAN[2,1]:= 25.1616; YAN[2,3]:=1.7721; YAN[2,4]:= 0.6634;  
YAN[2,5]:=1.1982; YAN[2,6]:=0.0000;  
YAN[3,1]:= 4.8780; YAN[3,2]:=1.7721; YAN[3,4]:= 0.5309;  
YAN[3,5]:=1.4802; YAN[3,6]:=0.3534;  
YAN[4,1]:= 0.6505; YAN[4,2]:=0.6634; YAN[4,3]:= 0.5309;  
YAN[4,5]:=0.0000; YAN[4,6]:=0.0000;  
YAN[5,1]:= 1.1234; YAN[5,3]:=1.1982; YAN[5,3]:= 1.4802;  
YAN[5,4]:=0.0000; YAN[5,6]:=0.3204;  
YAN[6,1]:= 0.3114; YAN[6,2]:=0.0000; YAN[6,3]:= 0.3534;  
YAN[6,4]:=0.0000; YAN[6,5]:=0.3204;  
YC[1,2]:= 0.00004; YC[1,3]:=0.00030; YC[1,4]:= 0.00145;  
YC[1,5]:=0.00084; YC[1,6]:=0.00303;  
YC[2,1]:= 0.00004; YC[2,3]:=0.00053; YC[2,4]:= 0.00142;  
YC[2,5]:=0.00079; YC[2,6]:=0.00000;  
YC[3,1]:= 0.00030; YC[3,2]:=0.00053; YC[3,4]:= 0.00177;  
YC[3,5]:=0.00064; YC[3,6]:=0.00267;  
YC[4,1]:= 0.00145; YC[4,2]:=0.00142; YC[4,3]:= 0.00177;

```

YC[4,5]:=0.00000; YC[4,6]:=0.00000;
      YC[5,1]:= 0.00084; YC[5,2]:=0.00079; YC[5,3]:= 0.00064;
YC[5,4]:=0.00000; YC[5,6]:=0.00294;
      YC[6,1]:= 0.00303; YC[6,2]:=0.00000; YC[6,3]:= 0.00267;
YC[6,4]:=0.00000; YC[6,5]:=0.00294;
      FUV[1]:= 0.000; FUV[2]:= 0.015; FUV[3]:= 0.004; FUV[4]:= 0.010
;FUV[5]:= 0.010; FUV[6]:= 0.000;
      RAV[1]:= 1.06; RAV[2]:=1.00; RAV[3]:= 1.00; RAV[4]:=1.00;
RAV[5]:=1.000; RAV[6]:= 1.00;
      tole := 0.0001;

```

```
END;
```

```
Procedure compute_V;
BEGIN
```

```

      iter := 0;
      REPEAT
      iter := iter + 1;
      for P := 1 to n do
      Val[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 + YA[p,q] * V[q];
      V[p] := ((FUV[p]/RAV[p]) - sum)/YA[p,p];
      converged := abs(V[p] - Val[p])<tole;

```

```
END;
```

```
      P := 0;
```

```
REPEAT
```

```

      P := P+1;
      converged := abs(V[p] - Val[p])<tole;
      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]) * YAN[p,q] - V[p] * YC[p,q]/2)
* 0.85;
      Pre[p,q] := V[p]*((V[p] - V[q]) * YAN[p,q] - V[p] * YC[p,q]/2)
* 0.62;

```

```
END;
```

```
END;
```

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

```
BEGIN
```

```

      clrscr;
      row := 3;
      gotoxy (20,10);
      write (' please wait computation in progress...');
      delay(10000);
      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 continue .....');
Repeat until keypressed;
clrscr;
row :=3;
gotoxy (19,1); writeln ( ' active power      reactive power');
gotoxy (19,3); writeln ( '-----');
for P:=1 to 6 do begin
for q:=1 to 6 do begin
if p<>q then
Begin
gotoxy (10,row);writeln('p',p, 'q=' ,Pac[p,q],', ', Pre[p,q]);
row := row + 1;
if row = 15 then
end;
end;
if row = 20 then Repeat until keypressed;
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 iteration allowed is ',itermax);
writeln;
writeln ( ' no of iteration after which convergence occurred is ',iter);
writeln;
writeln('press [Enter] key to exit ....');
readln;
Repeat until keypressed;
END.
(* End of load flow program *)

```



Bus voltages V

-----  
v1:=-1.2995191488E-03  
v2:= 1.4287957679E-03  
v3:= 2.0298839589E-04  
v4:= 5.1960537445E-03  
v5:= 2.3259740091E-03  
v6:=-4.1850173436E-04

press (Enter) to continue .....

	active power	reactive power
	-----	-----
plq=	0.0000000000E+00	0.0000000000E+00
plq=	0.0000000000E+00	0.0000000000E+00
plq=	4.0000686646E+00	7.4507084946E-09
plq=	3.6404029708E-23	-7.0997484644E-30
plq=	5.0601196289E-01	0.0000000000E+00

press (Enter) to continue...

	active power	reactive power
	-----	-----
p2q=	1.5046334026E-36	0.0000000000E+00
p2q=	-1.7826339621E+29	-4.5438390511E-28
p2q=	0.0000000000E+00	0.0000000000E+00
p2q=	0.0000000000E+00	0.0000000000E+00
p2q=	1.8014707747E+16	5.1200878906E+02

press (Enter) to continue...

```
active power reactive power
-----
p3q=-1.5832970343E+14 -2.9080570143E-26
p3q= 0.0000000000E+00 0.0000000000E+00
p3q= 5.9030594346E+20 1.3422003200E+08
p3q= 2.2752519145E-24 -1.8611565030E-24
p3q= 2.1478768640E+09 0.0000000000E+00
```

press [Enter] to continue...

```
active power reactive power
-----
p4q= 0.0000000000E+00 0.0000000000E+00
p4q= 6.0186343911E-36 3.5184976069E+13
p4q=-6.6121557726E-39 -1.1911401708E-22
p4q= 0.0000000000E+00 0.0000000000E+00
p4q= 1.5777488938E-30 9.2235303665E+18
```

press [Enter] to continue...

```
active power reactive power
-----
p5q=-4.2317797260E-37 -7.6232971501E-21
p5q= 0.0000000000E+00 0.0000000000E+00
p5q= 0.0000000000E+00 0.0000000000E+00
p5q= 4.1359740602E-25 2.4178931444E+24
p5q= 0.0000000000E+00 0.0000000000E+00
```

press [Enter] to continue...

```
active power reactive power
-----
p6q= 0.0000000000E+00 0.0000000000E+00
p6q= 1.0842207840E-19 6.3383618045E+29
p6q=-1.7333370016E-33 -3.1225025592E-17
p6q= 0.0000000000E+00 0.0000000000E+00
p6q= 0.0000000000E+00 0.0000000000E+00
```

press [Enter] to continue...

```
active power reactive power
-----
```

maximum number of iteration allowed is 150

no of iteration after which convergence occurred is 6

press [Enter] key to exit ....