1. INTRODUCTION

1.1 Introduction

Distribution systems hold a very significant position in the power system since it is the main point of link between bulk power and consumers. Effective planning of radial distribution network is required to meet the present growing domestic, industrial and commercial load day by day. Distribution networks have gained an overwhelming research interest in the academics as well as in the industries community nearly from last three decades. The examples of prominent distribution networks that effect domestic/residential users and industrial personals are water distribution networks, electricity distribution networks, data/voice communication networks, and road traffic networks etc. Electricity is an essential commodity and its absence for short-while creates annoyance and discomfort in everybody’s life. In fact, it puts most of the modern household and office appliances to a total stop. Electrical power distribution is either three or four wires. In these four wires,3 wire are for phases and 1 wire for Neutral. The Voltage between phase to phase is called Line Voltage and the voltage between phase and neutral is called Phase Voltage. This forth wire may or may not be distributed and in the same way this neutral may or may not be earthed. The neutral may be directly connected to earth or connected through a resistor or a reactor. This system is called directly earthed or earthed system. In a network, the earthing system plays a very important role. When an insulation fault occurs or a phase is accidentally earthed, the values taken by the fault currents, the touch voltages and over voltages get closely linked to the type of neutral earthing connection. A directly earthed neutral strongly limits over voltages but it causes very high fault currents, same as an unearthed neutral limits fault currents result to very low values but encourages the occurrence of high over voltages. In any installation, service continuity in the event of an insulation fault is also directly related to the earthing system. An unearthed neutral permits service continuity during an insulation fault. Contrary to this, a directly earthed neutral or low impedance-earthed neutral, causes ripping as soon as the first insulation fault occurs **[1].** In order to meet these specifications, a properly designed and operated radial distribution network should possess the following

1. The system should support energy supply at minimum operation and maintenance cost and should satisfy the social and engineering aspects.
2. It must satisfy the continuous changing of the load demand for active and reactive power.
3. Unlike other forms of energy, electricity is not easily stored and thus, adequate "spinning" reserve of active and reactive power should be maintained and controlled in an appropriate manner.
4. The power supply must meet the following specific standards to maintain the quality of service offered

a. Regulated voltage
b. Well maintained constant frequency
c. Level of reliability/security that guarantees consumers satisfaction.

1.2 Literature Review

Firstly we understand the concepts of Load flow studies regarding various methods under transmission. The distribution networks because of the some of the following special features fall in the category of ill-condition. Radial or weakly meshed networks, High R/X ratios, Multi phase, unbalanced operation, Unbalanced distributed load Distributed generation. Due to the above factors the Newton Raphson and other transmission system algorithms are failed with distribution network.

Secondly we studied and understand about the concept of DISTRIBUTION SYSTEMS from V.K.Mehta textbook.

We followed the various IEEE papers and International journals. We analyzed the concept of the load flow analysis of Radial Distribution System from the International Journal for Electrical Engineering Education by **Prasad K [3].** We studied the concept of Particle Swarm Optimization from "A New Optimizer Using Particle Swarm Theory" proposed by Russel Ebehart **[8].** We revised some other IEEE papers, those are put in references.

1.3 Organization of Thesis

This document is organized as follows.

The **Chapter 1** of this document involves brief introduction about the Project. Introductory section is reported in section 1.1, a literature survey which is developed is reported under section 1.2 and an organizational frame work was written in well established manner under section 1.3.

The **Chapter 2** of this document involves brief view about Distribution system. Typical overview of power network is reported in section 2.1. The elements of distribution system are reported under section 2.2. The requirements of the distribution system are reported in section 2.3. A classification of distribution systems plays a major role and is placed under section 2.4.

The **Chapter 3** of the document deals with load flow analysis of Radial distribution system. A small introduction and mathematical model of Radial distribution network is reported in sections 3.1, 3.2 respectively. Mathematical formulation for electrical equivalent of typical branch 1 with the help of its phasor is represented under section 3.3.

The **Chapter 4** introduces Particle Swarm Optimization. A brief introduction is placed in section 4.1. The PSO concept is reported in section 4.2. Training a multilayer perception deals about GBEST model and LBEST version is reported in section 4.3. Section 4.4 deals with flocks, swarms and particles. Section 4.5 deals with Comparison to back propagation of error.

The **Chapter 5** deals with Result Analysis and Conclusion.

2. DISTRIBUTION SYSTEM

2.1 Typical Power Network

An understanding of basic design principles is essential in the operation of electric power systems. This chapter briefly describes and defines electric power generation, transmission, and distribution systems (primary and secondary). A discussion of emergency and standby power systems is also presented. Figure 2.1 shows a one-line diagram of a typical electrical power generation, transmission, and distribution system.**[2]**

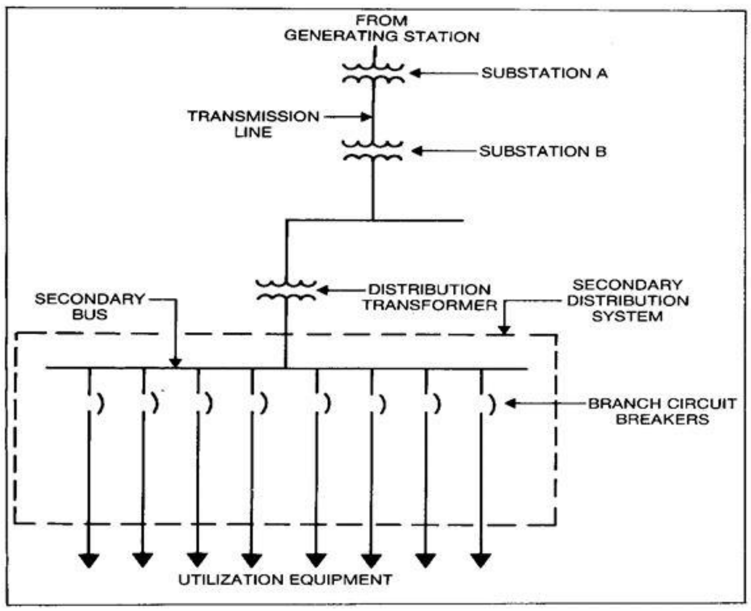

Figure.2.1: Typical Electric Power Generation, Transmission and Distribution system

The transmission systems are basically a bulk power transfer links between the power generating stations and the distribution sub-stations from which the power is carried to customer delivery points. The transmission system includes step-up and step-down transformers at the generating and distribution stations, respectively. The transmission system is usually part of the electric utility's network. Power transmission systems may include sub transmission stages to supply intermediate voltage levels. Sub-transmission stages are used to enable a more practical or economical transition between transmission and distribution systems. It operates at the highest voltage levels (typically, 230 kV and above). The generator voltages are usually in the range of 11 kV to 35 kV. There are also a few transmission networks operating in the extremely high voltage class (345 kV to 765 kV). As compared to transmission system sub-transmission system transmits energy at a lower voltage level to the distribution substations. Generally, sub-transmission systems supply power directly to the industrial customers. The distribution system is the final link in the transfer of electrical energy to the individual customers. Between 30 to 40% of total investment in the electrical sector goes to distribution systems, but nevertheless, they haven't received the technological improvement in the same manner as the generation and transmission systems. The distribution network differs from its two of siblings in topological structure as well as its associated voltage levels. The distribution networks are generally of radial or tree structure and hence referred as Radial Distribution Networks (RDNs). Its primary voltage level is typically between 4.0 to 35 kV, while the secondary distribution feeders supply residential and commercial customers at 120/240/440 volts. In general, the distribution system is the electrical system between the substation fed by the transmission system and the consumers' premises. It generally consists of feeders, laterals (circuit-breakers) and the service mains. **[2]**

2.2 Elements of the Distribution System

In general, the distribution system is derived from electrical system which is Substation ally fed by the consumers' premises and the transmission system. It generally consists of feeders, laterals (circuit-breakers) and the service mains. Figure1.2 shows the single line diagram of a typical low tension distribution system. **[2]**

2.2.1 Distributed Feeders

A feeder is a conductor, which connects the sub-station (or localized generating station) to the area where power is to be distributed. Generally, no tapping are taken from the feeder so that the current in it remains the same throughout. The main consideration in the design of a feeder is the current carrying capacity.

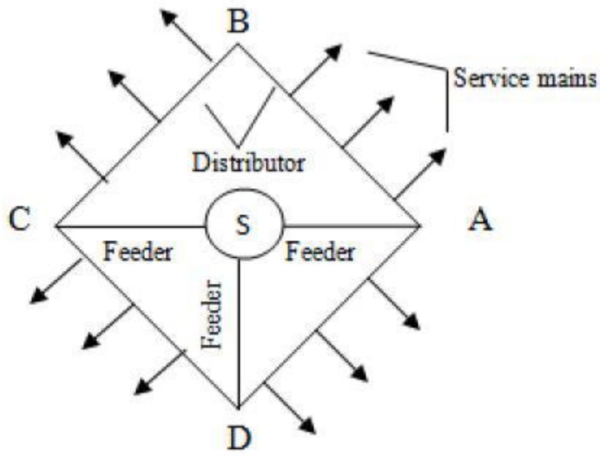

Figure 2.2: Elements of Distribution System

2.2.2 Distributor

A distributor is a conductor from which tapping are taken for supply to the consumers. In Figure1.2, AB, BC, CD, and DA are the distributors. The current through a distributor is not constant because tapping are taken at various places along its length. While designing a distributor, voltage drop along its length is the main consideration since the statutory limit of voltage variations is 10% of rated value at the consumer's terminals.

2.2.3 Service mains

A Service Mains is generally a small cable which connects the distributor to the consumer's terminals.

2.3 Requirements of a Distribution System

It is mandatory to maintain the supply of electrical power within the requirements of many types of consumers. Following are the necessary requirements of a good distribution system: **[2]**

(a) Availability of power demand

Power should be made available to the consumers in large amount as per their requirement. This is very important requirement of a distribution system.

(b) Reliability

As we can see that present day industry is now totally dependent on electrical power for its operation. So, there is an urgent need of a reliable service. If by chance, there is a power failure, it should be for the minimum possible time at every cost. Improvement in reliability can be made up to a considerable extent by

a) Reliable automatic control system.

b) Providing additional reserve facilities.

(c) Proper voltage

Furthermost requirement of a distribution system is that the voltage variations at the consumer terminals should be as low as possible. The main cause of changes in voltage variation is variation of load on distribution side which has to be reduced. Thus, a distribution system is said to be only good, if it ensures that the voltage variations are within permissible limits at consumer terminals.

(d) Loading

The transmission line should never be over loaded and under loaded.

(e) Efficiency

The efficiency of transmission lines should be maximum say about 90%.

2.4 Classification of Distribution System

A distribution system may be classified on the basis of: **[2]**

i) Nature of current: According to nature of current, distribution system can be classified as

a) AC distribution system.

b) DC distribution system.

ii) Type of construction: According to type of construction, distribution system is classified as

a) Overhead system

b) Underground system

iii) Scheme of operation: According to scheme of operation, distribution system may be classified as:

a) Radial delivery network

b) Ring main system

c) Interconnected system

With the growing market in the present time, power flow analysis has been one of the most fundamental and an essential tool for power system operation and planning. In RDN, each of its branch or link has a unique path for power flow from the substation (source of energy) i.e. source node to end (leafs) nodes.

2.4.1 AC distribution

Now-a-days electrical energy is generated, transmitted and distributed in the form of alternating current. One important reason for the widespread use of alternating current in preference to direct current is the fact that alternating voltage can be conveniently changed in magnitude by means of a transformer. Transformer has made it possible to transmit a.c. power at high voltage and utilize it at a safe potential. High transmission and distribution voltages have greatly reduced the current in the conductors and the resulting line losses.

There is no definite line between transmission and distribution according to voltage or bulk capacity. However, in general, the a.c. distribution system is the electrical system between the step down substation fed by the transmission system and the consumers' meters. The a.c. distribution system is classified into **(*i*)** primary distribution system and **(*ii*)** secondary distribution system.

(*i*) Primary distribution system

It is that part of a.c. distribution system which operates at voltages somewhat higher than general utilisation and handles large blocks of electrical energy than the average low-voltage consumer uses. The voltage used for primary distribution depends upon the amount of power to be conveyed and the distance of the substation required to be fed. The most commonly used primary distribution voltages are 11 kV, 6·6 kV and 3·3 kV. Due to economic considerations, primary distribution is carried out by 3-phase, 3-wire system.

(*ii*) Secondary distribution system

It is that part of a.c. distribution system which includes the range of voltages at which the ultimate consumer utilizes the electrical energy delivered to him. The secondary distribution employs 400/230 V, 3-phase, 4-wire system. The primary distribution circuit delivers power to various substations called distribution substations.

The substations are situated near the consumers' localities and contain step down transformers. At each distribution substation, the voltage is stepped down to 400 V and power is delivered by

3-phase, 4-wire A.C. system. The voltage between any two phases is 400 V and between any phase and neutral is 230 V. The single phase domestic loads are connected between any one phase and the neutral, whereas 3-phase 400 V motor loads are connected across 3- phase lines directly.

2.4.2 D.C. Distribution

It is a common knowledge that electric power is almost exclusively generated, transmitted and distributed as a.c. However, for certain applications, D.C. supply is absolutely necessary. For instance, D.C. supply is required for the operation of variable speed machinery (*i.e*., D.C. motors), for electrochemical work and for congested areas where storage battery reserves are necessary. For this purpose, a.c. power is converted into D.C. power at the substation by using converting machinery *e.g.*, mercury arc rectifiers, rotary converters and motor-generator sets. The D.C. supply from the substation may be obtained in the form of **(*i*)** 2-wire or (***ii***) 3-wire for distribution.

(*i*) 2-wire D.C. system

As the name implies, this system of distribution consists of two wires.

One is the outgoing or positive wire and the other is the return or negative wire. This system is never used for transmission purposes due to low efficiency but may be employed for distribution of D.C. power.

(*ii*) 3-wire D.C. system

It consists of two outers and a middle or neutral wire which is earthed at the substation. The principal advantage of this system is that it makes available two voltages at the consumer terminals *viz*., 1V between any outer and the neutral and 2V between the outers. Loads requiring high voltage (*e.g*., motors) are connected across the outers, whereas lamp sand heating circuits requiring less voltage are connected between either outer and the neutral.

2.4.3 Overhead versus Underground System

The distribution system can be overhead or underground.**[2]** Overhead lines are generally mounted on wooden, concrete or steel poles which are arranged to carry distribution transformers in addition to the conductors. The underground system uses conduits, cables and manholes under the surface of streets and sidewalks. The choice between overhead and underground system depends upon a number of widely differing factors. Therefore, it is desirable to make a comparison between the two.

(*i*) Public safety

The underground system is safer than overhead system because all distribution wiring is placed underground and there are little chances of any hazard.

(*ii*) Initial cost

The underground system is more expensive due to the high cost of trenching, conduits, cables, manholes and other special equipment. The initial cost of an underground system may be five to ten times than that of an overhead system.

(*iii*) Flexibility

The overhead system is much more flexible than the underground system. In the latter case, manholes, duct lines etc., are permanently placed once installed and the load expansion can only be met by laying new lines. However, on an overhead system, poles, wires, transformers etc., can be easily shifted to meet the changes in load conditions.

(*iv*) Faults

The chances of faults in underground system are very rare as the cables are laid underground and are generally provided with better insulation.

(*v*) Appearance

The general appearance of an underground system is better as all the distribution lines are invisible. This factor is exerting considerable public pressure on electric supply companies to switch over to underground system.

(*vi*) Fault location and repairs

In general, there are little chances of faults in an underground system. However, if a fault does occur, it is difficult to locate and repair on this system. On an overhead system, the conductors are visible and easily accessible so that fault locations and repairs can be easily made.

(*vii*) Current carrying capacity and voltage drop

An overhead distribution conductor has a considerably higher current carrying capacity than an underground cable conductor of the same material and cross-section. On the other hand, underground cable conductor has much lower inductive reactance than that of an overhead conductor because of closer spacing of conductors.

(*viii*) Useful life

The useful life of underground system is much longer than that of an overhead system. An overhead system may have a useful life of 25 years, whereas an underground system may have a useful life of more than 50 years.

(*ix*) Maintenance cost

The maintenance cost of underground system is very low as compared with that of overhead system because of less chance of faults and service interruptions from wind, ice and lightning as well as from traffic hazards.

(*x*) Interference with communication circuits

An overhead system causes electromagnetic interference with the telephone lines. The power line currents are superimposed on speech currents, resulting in the potential of the communication channel being raised to an undesirable level. However, there is no such interference with the underground system.

2.4.4 Connection Schemes of Distribution System

All distribution of electrical energy is done by constant voltage system. In practice, the following distribution circuits are generally used:

(*i*) Radial System

In this system, separate feeders radiate from a single substation and feed the distributors at one end only. The radial system is employed only when power is generated at low voltage and the substation is located at the centre of the load.

This is the simplest distribution circuit and has the lowest initial cost. However, it suffers from the following drawbacks:

(*a*) The end of the distributor nearest to the feeding point will be heavily loaded.

(***b***) The consumers are dependent on a single feeder and single distributor. Therefore, any fault on the feeder or distributor cuts off supply to the consumers who are on the side of the fault away from the substation.

(***c***) The consumers at the distant end of the distributor would be subjected to serious voltage fluctuations when the load on the distributor changes. Due to these limitations, this system is used for short distances only.

(*ii*) Ring main system

In this system, the primaries of distribution transformers form a loop. The loop circuit starts from the substation bus-bars, makes a loop through the area to be served, and returns to the substation. The ring main system has the following advantages:

(***a***) There are less voltage fluctuations at consumer's terminals.

(***b***) The system is very reliable as each distributor is fed *via* two feeders. In the event of fault on any section of the feeder, the continuity of supply is maintained.

(*iii*) Interconnected system

When the feeder ring is energised by two or more than two generating stations or substations, it is called inter-connected system. The interconnected system has the following advantages:

(***a***) It increases the service reliability.

(***b***) Any area fed from one generating station during peak load hours can be fed from the other generating station. This reduces reserve power capacity and increases efficiency of the system.

3. LOAD FLOW ANALYSIS OF RADIAL DISTRIBUTION NETWORK

3.1 Introduction

A planned and effective distribution network is the key to cope up with the ever increasing demand for domestic, industrial and commercial load. The load-flow study of radial distribution network is of prime importance for effective planning of load transfer majority of LFA algorithms reported so far; researchers have used forward and reverse sweep mechanism predominantly. As leaf (terminal) node identification is a vital component to run LFA algorithm, while estimating the network branch currents during the reverse sweep, so work reported in this chapter mainly proposes a new LFA algorithm which utilize the efficient scheme for leaf node identification proposed by Chaturvedhi and Prasad **[3].**

3.2 Mathematical Model of Radial Distribution Network

In RDNs, the large *R*/*X* ratio causes problems in convergence of conventional load flow algorithms. For a balanced RDN, the network can be represented by an equivalent single-line diagram. The line shunt capacitances at distribution voltage level are very small and thus can be neglected. The simplified mathematical model of a section of a RDN is shown in Fig.2.1.

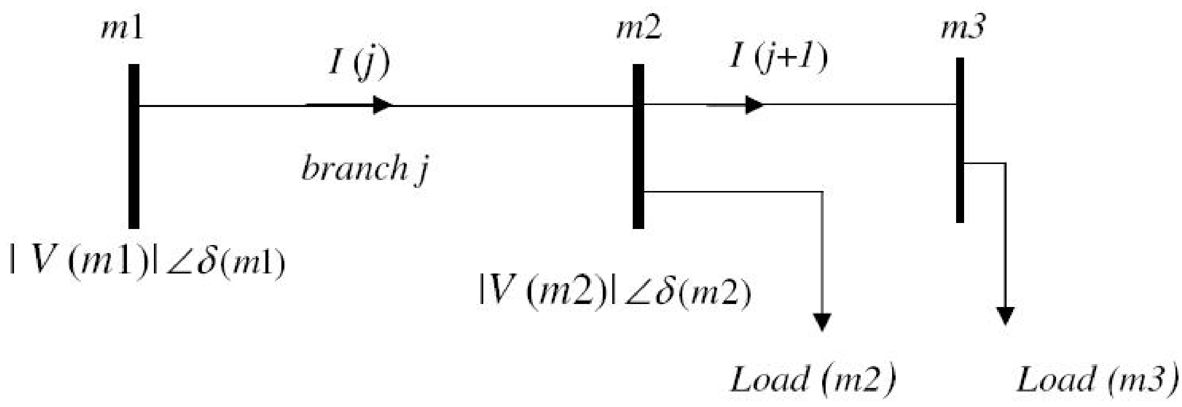

Figure 3.1: Electrical equivalent diagram of RDN for load flow study

The complex power fed to node 'i' can be represented as

$$S_i = V_i (LI)_i^* = P_i + jQ_i \qquad \ldots\ldots (3.1)$$

$$(LI)_i = \left(\frac{S_i}{V_i}\right)^* = \frac{PL_i - jQL_i}{V_i^*} \qquad \text{...... (3.2)}$$

$$= \frac{\sqrt{PL_i^2 + QL_i^2}}{|V_i|} \frac{\angle \tan^{-1}(-QL_i / PL_i)}{\angle -\theta_{V_i}} \qquad \text{...... (3.3)}$$

$$= |LI_i| \angle \theta$$

$$= |LI_i| \cos\theta_i + j |LI_1| \sin\theta_i \qquad \text{...... (3.4)}$$

Where

$$|LI_i| = \frac{\left[PL_i^2 + QL_i^2\right]^{1/2}}{|V_i|}$$

$$\theta_i = \theta_{V_i} - \tan^{-1}\left(\frac{QL_i}{PL_i}\right)$$

Branch Current calculation

$$I_{br_j} = \sum_{i=1}^{n} |LI_i| \cos\theta_i + j\sum_{i=1}^{n} |LI_i| \sin\theta_i$$

$$= \mathrm{Re}\left(I_{br_j}\right) + \mathrm{Im}\left(I_{br_j}\right)$$

$$I_{br_j} = |I_{br_j}| \angle I_{br_j}$$

where

$$|I_{br_j}| = \left[\left(\mathrm{Re}\left(I_{br_j}\right)\right)^2 + \left(\mathrm{Im}\left(I_{br_j}\right)\right)^2 ..\right]^{1/2} \qquad \text{...... (3.5)}$$

And

$$\angle I_{br_j} = \tan^{-1}\left(\frac{\mathrm{Im}\left(I_{br_j}\right)}{\mathrm{Re}\left(I_{br_j}\right)}\right) \qquad \text{...... (3.6)}$$

Voltage Calculations

$$V_r = V_s - I_{br} Z_{br}$$

$$|V_r|\angle\theta V_r = |V_s|\angle\theta V_s - |I_{br}|\angle\theta I_{br} . |Z_{br}|\angle\theta Z_{br}$$
$$= |V_s|\angle\theta V_s - |I_{br}||Z_{br}|\angle\phi \qquad \text{...... (3.7)}$$

On equating real and imaginary part equation (3.7) can be split as

$$|V_r|\cos\theta V_r = |V_s|\cos\theta V_s - |I_{br}||Z_{br}|\cos\phi$$
$$|V_r|\sin\theta V_r = |V_s|\sin\theta V_s - |I_{br}||Z_{br}|\sin\phi \qquad \text{.....(3.8)}$$

Where

$$\phi = \theta I_{br} + \theta Z_{br} = \tan^{-1}\frac{\mathrm{Im}(I_{br})}{\mathrm{Re}(I_{br})} + \tan^{-1}\left(\frac{X_{br}}{R_{br}}\right) \qquad \text{...... (3.9)}$$

On squaring and adding equations (3.8) results in

$$|V_r|^2 = |V_s|^2 + |I_{br}|^2|Z_{br}|^2 - 2|V_s||I_{br}||Z_{br|}|\{\cos\theta V_s \cos\phi + \sin\theta V_s \sin\phi\}$$
$$= |V_s|^2 + |I_{br}|^2|Z_{br}|^2 - 2|V_s||I_{br}||Z_{br}|\cos(\theta V_s - \phi) \qquad \text{...... (3.10)}$$

On dividing equations of (3.8) respectively, following expression results

$$\theta V_r = \tan^{-1}\left[\frac{|V_s|\sin\theta V_s - |I_{br}||Z_{br}|\sin\phi}{|V_s|\cos\theta V_s - |I_{br}||Z_{br}|\cos\phi}\right] \qquad \text{...... (3.11)}$$

Thus, once branch currents are computed, the node voltages are estimated using the above equations. Hence, the complexity of the solutions lies in the computation of branch currents. This paper presents a relatively simple and efficient procedure to identify the leaf code of a RDN and subsequently estimate the branch currents and node voltages. In a typical load flow study, without any prior knowledge, the following iterative procedure is followed.

Step 1: Read the system data and initially set all the node voltages to 1.0 p. u. (per unit) and branch currents to 0.

Step 2: Compute the currents for all the branches of the RDN.

Step 3: Update the node voltages using the computed branch currents.

Step 4: If the absolute value of the difference between the previous (iteration) and present (iteration) voltage at any node is more than some preset value (0.0001), then go to **Step 2** else **stop**.

The nomenclature of variables used in equations 1-16 are as follows.

S_i : Complex power fed at node i

P_i : Real Power fed at node i

Q_i : Reactive Power fed at node i

NB: Total number of nodes (i = 1, 2, -------- NB)

LN: Total number of branches (LN =NB-1)

PL_i : Real power load at i^{th} node

QL_i : Reactive power load at i^{th} node

$|V_i|$: Voltage magnitude of i^{th} node

θ_{V_i} : Voltage angle of i^{th} node

$|LI_i|$: Load current magnitude at i^{th} node

θ_i : Load current angle at i^{th} node

$|I_{br_j}|$: Current magnitude in branch j

$\angle I_{br_j}$: Current angle in branch j

V_s : Sending node voltage

V_r : Receiving node voltage

3.3 Mathematical Formulation:

Assumptions:

- Radial distribution networks are balanced and can be represented by their equivalent single line diagram.
- Half line charging susceptances of distribution lines are negligible and these distribution lines are represented as short lines.
- Shunt capacitor banks are treated as loads.

Consider a branch between buses 1 and 2 as shown in **fig 3.1.**

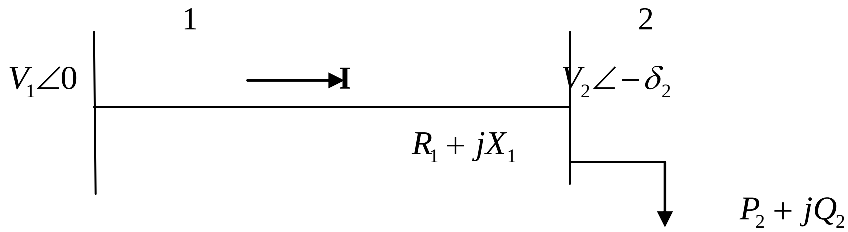

Fig 3.2 Electrical equivalent of a typical branch 1

In fig 3.2, V1 and V2 are the voltage magnitudes and phase angles of two buses 1 and 2. Let the current flowing through branch 1 is I. The substation voltage is assumed to be 1+j0 p.u. Let power factor angle of load P2+jQ2 be θ_2. Let R1 and X1 be the resistance and reactance of the branch 1 respectively. The phasor diagram of Fig 3.2 is shown in Fig 3.3

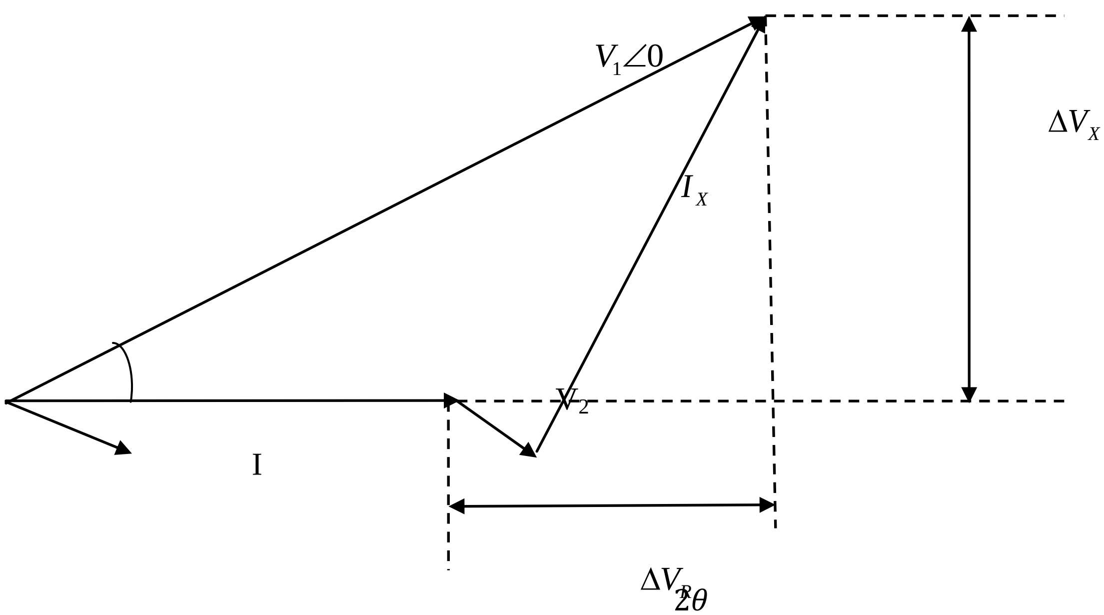

Fig 3.3 Phasor Diagram of branch 1 connected between buses 1 and 2

From Fig 3.3, the equations are

$$|V_1|^2 = (|V_2| + \Delta V_R)^2 + (\Delta V_X)^2 \quad \text{...}(3.12)$$

$$|V_1|^2 = (|V_1| + (IR_1\cos\theta_2 + IX_1\sin\theta_2))^2 + (IX_1\cos\theta_2 - IR_2\sin\theta_2)^2 \quad \text{...}(3.13)$$

To eliminate 'I' in Equation (3.15)

$$I\cos\theta_2 = \frac{P_2}{|V_2|}$$

$$I\sin\theta_2 = \frac{Q_2}{|V_2|}$$

Where

P_2= total active power load of all buses beyond bus 2 including local load and active power losses beyond bus 2.

Q_2=total reactive power load of all buses beyond bus 2 including local load and reactive power losses beyond bus 2.

The equation (3.13) becomes

$$|V_1|^2 = \left[|V_2| + \frac{(P_2R_1 + Q_2X_1)}{|V_2|}\right]^2 + \left[\frac{(P_2X_1 - Q_2R_1)}{|V_2|}\right]^2$$

On solving we get

$$|V_2|^4 + 2|V_2|^2\ (P_2R_1 + Q_2X_1) + (P_2^2 + Q_2^2)(R_1^2 + X_1^2) - |V_1|^2|V_2|^2 = 0$$

$$|V_2|^4 + 2|V_2|^2\left(P_2R_1 + Q_2X_1 - \frac{|V_1|^2}{2}\right) + (P_2^2 + Q_2^2)(R_1^2 + X_1^2) = 0$$

$$|V_2|^4 - b|V_2|^2 + c = 0 \qquad \ldots\ldots(3.14)$$

Where

$$b = |V_1|^2 - 2P_2R_1 - 2Q_2X_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.15)$$

$$c = (P_2^2 + Q_2^2)(R_1^2 + X_1^2) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.16)$$

Where

|V|=substation voltage (taken as 1.0 p.u)

R_1=resistance of branch 1

X_1=reactance of branch 1

The possible solutions for the voltage, V_2 from equation (3.14) are first solution is positive and second is negative i.e.

$$\pm\left[\frac{1}{2}\left[b-\{b^2-4c\}^{1/2}\right]\right]^{1/2}$$

And the third solution and forth solution are

$$\pm\left[\frac{1}{2}\left[b+\{b^2-4c\}^{1/2}\right]\right]^{1/2}$$

It is found for realistic systems, when P_2, Q_2, R_1, X_1 and V are expressed in p.u. 'b' is always positive because the term $(2P_2R_1+2Q_2X_1)$ is extremely small as compared to $|V_1|^2$. In addition the term '4c' is negligible compared to b2. Therefore, $\{b^2\text{-}4c\}^{1\backslash 2}$ is nearly equal to 'b' and hence the first two solutions of $|V_2|$ are nearly equal to zero and fourth solution is negative and hence not feasible. The third solution of $|V_2|$ is positive and hence it is only the possible feasible solution. Therefore, the feasible solution of equation (3.14) is

$$|V_2|=\left[\frac{1}{2}\left[b+\{b^2-4c\}^{1/2}\right]\right]^{1/2} \qquad \text{…… (3.17)}$$

In general, the solution for $|V_{i+1}|$ is

$$|V_{i+1}|=\left[\frac{1}{2}\left[b_i+\{b_i^2-4c_i\}^{1/2}\right]\right]^{1/2} \qquad \text{…… (3.18)}$$

Where

$$b_i = |V_i|^2 - 2P_{i+1}R_k - 2Q_{i+1}X_k$$
$$c_i = \left(P_{i+1}^2 + Q_{i+1}^2)(R_k^2 + X_k^2)\right)$$

Where

i= 1, 2 ….n bus

k=1, 2, 3 ….n bus-1

n bus = total number of buses

The real and reactive power loss of branch 'k' is given by

$$P_{loss}[k] = \frac{R_k\left(P_{i+1}^2 + Q_{i+1}^2\right)}{|V_{i+1}|^2} \qquad \text{...... (3.19)}$$

$$Q_{loss}[k] = \frac{X_k\left(P_{i+1}^2 + Q_{i+1}^2\right)}{|V_{i+1}|^2} \qquad \text{...... (3.20)}$$

The total active and reactive power losses (TPL, TQL) are given by

$$TPL = \sum_{k=1}^{nbus-1} P_{loss}[k] \text{.................................... (3.21)}$$

$$TQL = \sum_{k=1}^{nbus-1} Q_{loss}[k] \text{.................................... (3.22)}$$

The phase angle (δ_2) of voltage V_2 can be calculated as follows

From equation 3.17,

$$Tan\delta_2 = \frac{\Delta V_X}{|V_2| + \Delta V_R}$$

$$Tan\delta_2 = \frac{IX_1\cos\theta_2 - IR_1\sin\theta_2}{|V_2| + IR_1\cos\theta_2 + IX_1\sin\theta_2} \qquad \text{...... (3.23)}$$

On simplification we will get

$$\delta_2 = \tan^{-1}\left\{\frac{P_2X_1 - Q_2R_1}{P_2R_1 + Q_2X_1 + |V_2|^2}\right\} \qquad \text{...... (3.24)}$$

In general

$$\delta_{i+1} = \tan^{-1}\left\{\frac{\left(P_{i+1}X_k - Q_{i+1}R_k\right)}{\left(P_{i+1}R_k + Q_{i+1}X_k + |V_{i+1}|^2\right)}\right\} \qquad \text{...... (3.25)}$$

Usually, the substation voltage V_1 is known and is taken as 1.0 at an angle 0^0 p.u. initially, $P_{loss}[k]$ and $Q_{loss}[k]$ are set to zero for all k. then the initial estimate of P_{i+1} and Q_{i+1} will be the sum of the loads of all the buses beyond bus 'i' plus the local load of bus 'i' plus the losses beyond 'i'.compute V_{i+1}, $P_{loss}[k]$, $Q_{loss}[k]$, δ_{i+1}.this will complete one

Iteration of the solution. Update the loads P_{i+1} and Q_{i+1} (by including losses) and repeat the same procedure until the voltage mismatches reach a tolerance level of 0.0001 p.u. in successive iterations.

4. PARTICLE SWARM OPTIMIZATION

4.1 Introduction

Particle swarm optimization has roots in two main component methodologies. Perhaps more obvious are its ties to artificial life (A-life) in general, and to bird flocking, fish schooling, and swarming theory in particular. It is also related, however, to evolutionary Computation, and has ties to both genetic algorithms and evolution strategies **[4]**

Particle swarm optimization comprises a very simple concept, and paradigms are implemented in a few lines of computer code. It requires only primitive mathematical operators, and is computationally inexpensive in terms of both memory requirements and speed. Early testing has

found the implementation to be effective with several kinds of problems **[6]**

4.2 Particle Swarm optimization concept

Particle swarm optimization is similar to a genetic algorithm **[5]** in that the system is initialized with a population of random solutions. It is unlike a genetic algorithm, however, in that each potential solution is also assigned a randomized velocity, and the potential solutions, called particles, are then "flown" through hyperspace. Each particle keeps track of its coordinates in hyperspace which are associated with the best solution (fitness) it has achieved so far. (The value of that fitness is also stored.) This value is called *pbest.* Another "best" value is also tracked. The "global" version of the particle swarm optimizer keeps track of the overall best value, and its location, obtained thus far by any particle in the population; this is called *gbest.*

The particle swarm optimization concept consists of, at each time step, changing the velocity (accelerating) each particle toward its *pbest* and *gbest* (global version). Acceleration is weighted by a random term, with separate random numbers being generated for acceleration toward *pbest* and *gbest.*

This document introduces a "local" version of the optimizer in which, in addition to *pbest*, each particle keeps track of the best solution, called *lbest*, attained within a *local* topological neighborhood of particles. Both the global and local versions are described in more detail below. The only variable that must be determined by the user is the maximum velocity to which the particles are limited. **Acceleration** constant is also specified, but in the experience of the authors, is not usually varied among applications.

4.3 Training a Multilayer Perceptron

'The problem of finding a set of weights to minimize residuals in a feed forward neural network is not a trivial one. It is nonlinear and dynamic in that any change of one weight requires adjustment of many others. Gradient descent techniques, e.g., back propagation of error, are usually used to find a matrix of weights that meets error criteria, though there is not widespread satisfaction with the effectiveness of these methods. A number of researchers have attempted to use genetic algorithms (GAS) to find sets of weights, but the problem is riot well suited to crossover. Because a large number of possible solutions exist, two chromosomes with high fitness evaluations are likely to be very different from one another; thus recombination may not result in improvement. This discussion uses a three-layer network designed to solve the XOR problem, as a demonstration of the particle Swarm optimization concept. The network has two inputs, three Hidden processing elements (PES), and one output PE. The output PE return a 1 if both inputs are the same, that IS, input vector (1, l) or (0, 0), and returns 0 if the inputs are different (1, 0) or (0, l). Counting biases to the hidden and output PES, solution of this problem requires estimation of 13 floating-point parameters. Note that, for the current presentation, the number of hidden units is arbitrary. A feed forward network with one or two hidden PE's can solve the XOR problem. Future research can test particle swarm optimization on a variety of architectures; the present document necessarily, and arbitrarily, settled on one.
The particle swarm optimization approach is to "fly" a population of particles through 13-dimensional hyperspace. Each particle is initialized with position and velocity vectors of 13 elements. For neural networks, it seems reasonable to initialize all positional coordinates (corresponding to connection weights) to within a range of (-4.0, +4.0), and velocities should not be so high as to fly particles out of the usable field. It is also necessary to clamp velocities to some maximum to prevent overflow. The test examples use a population of 20 particles. (The authors have used populations of 10-50 particles for

other applications.) The **XOR** data are entered into the net and an error term to be minimized, usually squared error per output PE, is computed for each of the 20 particles. As the system iterates, individual agents are drawn toward a global optimum based on the interaction of their individual searches and the group's public search. Error threshold and maximum iteration termination criteria have been specified: when these are met, or when a key is pressed, iterations cease and the best weight vector found is written to a file.

4.3.1 The GBEST Model

The standard "GBEST" particle swarm algorithm, which is the original form of particle swarm optimization developed, is very simple. The steps are:

1. Initialize an array of particles with random positions and velocities on *D* dimensions,

2. Evaluate the desired minimization function in *D* variables,

3. Compare evaluation with particle's previous best value

(PBEST [ ]): If current value < PBEST [ ] then PBEST [ ] = current value and PBEST x [ ][d] = current position in ***D*** dimensional hyperspace,

4. Compare evaluation with group's previous best (PBEST [GBEST]): If current value < PBEST [GBEST] then GBEST=particle's array index,

5. Change velocity by the following formula:

V [ ][d]=V[][d]+

ACC-CONST*r and ( )*(PBEST x [ ] [d] – Present X [ ] [d]) +

ACC-CONST*r and ( )*(PBEST x [GBEST] [d] -

Present X [ ][d]) and

6. Move to Present X [ ][d] + v[ ][d]: Loop to step 2 and repeat until a criterion is met.

4.3.2 The LBEST Version

Based, among other things, on findings from social simulations, it was decided to design a "local" version (paradigm) of the particle swarm concept. In this paradigm, particles have information only of their own and their nearest array neighbors' bests, rather than that of the entire group. Instead of moving toward the stochastic average of ***pbest*** and ***gbest*** (the best evaluation in the entire group), particles move toward the points defined by *pbest* and *"lbest,"* which is the index of the particle with the best evaluation in the neighborhood. In the neighborhood=2 model, for instance, particle (i) compares it's error value with particle (i-1) and particle (i+l). The ***lbest*** version was tested with neighborhoods consisting of the immediately adjacent neighbors (neighborhood=2), and with the three neighbors on each side (neighborhood=6).

Note that no trials fixated on local optima- nor have any in hundreds of unreported tests. Cluster analysis of sets of weights from this version showed that blocks of neighbors, consisting of regions from 2 to 8 adjacent individuals, had settled into the same regions of the solution space. It appears that the invulnerability of this version to local optima might result from the fact that a number of "groups" of particles spontaneously separate and explore different regions. It is thus a more flexible approach to information processing than the GBEST model.

Nonetheless, though this version rarely if ever becomes entrapped in a local optimum, it clearly requires more iteration on average to find a criterion error level. This local optimum represents tests of a LBEST version with neighborhood=6, that is, with the three neighbors on each side of the agent taken into account (arrays wrapped, so the final element was considered to be beside the first one). This version is prone to local optima, at least when VMAX is small, though less so than the GBEST version. Otherwise it seems, in most cases, to perform somewhat less well than the standard GBEST algorithm. In sum, the neighborhood=2 model offered some intriguing possibilities, in that is seems immune to local optima. It is a highly decentralized model, which could be run with any number of particles. Expanding the neighborhood speeds up convergence, but introduces the facilities of the GBEST model.

4.4 Flocks, Swarms and Particles

A number of scientists have created computer simulations of various interpretations of the movement of organisms in a bird flock or fish school. Notably, Reynolds **[7]** presented simulations of bird flocking.

It became obvious during the development of the particle swarm concept that the behavior of the population of agents is more like a swarm than a flock. The term **swam** has a basis in the literature. In particular, the authors use the term in accordance with a paper by Millonas **[9],** who developed his models for applications in artificial life, and articulated five basic principles of swarm intelligence. First is the proximity principle: the population should be able to carry out simple space and time computations.

Second is the quality principle: the population should be able to respond to quality factors in the environment. Third is the principle of diverse response: the population should not commit its activities along excessively narrow channels fourth is the principle of stability: the population should not change its mode of behavior every time the environment changes. Fifth is the principle of adaptability. The population must be able to change behavior mode when it’s worth the computational price. Note that principles four and five are the opposite sides of the same coin. The particle swarm optimization concept and paradigm presented in this document seem to adhere to all five principles. Basic to the paradigm are n-dimensional space calculations carried out over a series of time steps. The population is responding to the quality factors *pbest* and ***ghest/lbest.*** The allocation of responses between ***pbest*** and gbest/lbest ensures a diversity of response. The population changes its state (mode of behavior) only when ***gbest/lbest*** changes, thus adhering to the principle of stability. The population is adaptive because it *does* change when ***gbest/lbest*** changes. The term particle was selected as a compromise. While it could be argued that the population members are mass-less and volume-less, and thus could be called “points,” it is felt that that velocities and accelerations are more, appropriately applied to particles, even if each is defined to have arbitrarily small mass and volume. Further, this document discusses particle systems consisting of clouds of primitive particles as models of diffuse objects such as clouds, fire and smoke. Thus the label the authors have chosen to represent the optimization concept is particle Swam.

4.5 Comparison to back propagation of error

The theoretical view of learning as back propagation of error differs from the particle swarm view in two important ways (see Rumel hart, Hinton, and Williams, 1986). First, back propagation implies that the individual is a kind of sealed container with information processing going on inside it. The particle swarm shifts the locus of information processing, and of mind itself, out into interpersonal space, with individuals discovering collaboratively how to process information. In other words, a society is viewed as a parallel distributed processing system comprising individual cognitive networks which adapt collaboratively. Secondly, while

Back propagation of error is a deterministic hill climbing algorithm, the particle swarm exploits the impartiality of randomness in the search of the problem space; individuals in the population are pulled toward optimal positions, but do not climb hills in or between optimal regions.

Importantly, the dynamical nature of the algorithm represents a departure from rational models of cognition. Whereas back propagation of error depicts an individual reasonably changing his or her beliefs in order to make them more consistent with the facts as they are perceived, the particle swarm simulates individuals changing their beliefs in order to be more like their neighbors. Thus it is a social-psychological model of knowledge management.

5. RESULT ANLAYSIS

5.1 Conventional Load Flow Analysis

For IEEE 33 bus, the input data used to calculate load flows is

```
m= [ 1   0    0     0    1
    2  100  60    0    1
    3  90   40    0    1
    4  120  80    0    1
    5  60   30    0    1
    6  60   20    0    1
    7  200  100   0    1
    8  200  100   0    1
    9  60   20    0    1
    10  60  20    0    1
    11  45  30    0    1
    12  60  35    0    1
    13  60  35    0    1
    14  120 80    0    1
    15  60  10    0    1
    16  60  20    0    1
    17  60  20    0    1
    18  90  40    0    1
    19  90  40    0    1
    20  90  40    0    1
    21  90  40    0    1
    22  90  40    0    1
    23  90  50    0    1
    24  420 200   0    1
    25  420 200   0    1
    26  60   25   0    1
    27  60   25   0    1
    28  60   20   0    1
    29  120  70   0    1
    30  200  600  0    1
    31  150  70   0    1
    32  210  100  0    1
    33  60   40   0    1];
l= [     1  1  2  0.0922 0.0470
         2  2  3  0.4930 0.2511
         3  3  4  0.3660 0.1864
         4  4  5  0.3811 0.1941
         4  5  6  0.8190 0.7070
         6  6  7  0.1872 0.6188
```

```
7  7  8  0.7114 0.2351
8  8  9  1.0300 0.7400
9  9  10 1.0440 0.7400
10 10 11 0.1966 0.0650
11 11 12 0.3744 0.1238
12 12 13 1.4680 1.1550
13 13 14 0.5416 0.7129
14 14 15 0.5910 0.5260
15 15 16 0.7463 0.5450
16 16 17 1.2890 1.7210
17 17 18 0.7320 0.5740
18 2  19 0.1640 0.1565
19 19 20 1.5042 1.3554
20 20 21 0.4095 0.4784
21 21 22 0.7089 0.9373
22 3  23 0.4512 0.3083
23 23 24 0.8980 0.7091
24 24 25 0.8960 0.7011
25 6  26 0.2030 0.1034
26 26 27 0.2842 0.1447
27 27 28 1.0590 0.9337
28 28 29 0.8042 0.7006
29 29 30 0.5075 0.2585
30 30 31 0.9744 0.9630
31 31 32 0.3105 0.3619
32 32 33 0.3410 0.5302 ];
```

The output for conventional load flow is as shown below

Bus no.	**Voltage**	**P loss**	**Q loss**
1	1.0000	0.0104	0.0053
2	0.9999	0.0396	0.0202
3	0.9995	0.0630	0.0321
4	0.9990	0.0142	0.0072
5	0.9987	0.0272	0.0235
6	0.9982	0.0778	0.2570
7	0.9974	0.2963	0.0979
8	0.9960	0.0344	0.0247
9	0.9954	0.0349	0.0247

10	0.9947	0.0048	0.0016
11	0.9946	0.0151	0.0050
12	0.9944	0.0593	0.0467
13	0.9933	0.0945	0.1245
14	0.9923	0.0184	0.0163
15	0.9920	0.0251	0.0183
16	0.9915	0.0434	0.0580
17	0.9906	0.0599	0.0470
18	0.9898	0.0134	0.0128
19	0.9897	0.1235	0.1113
20	0.9881	0.0337	0.0393
21	0.9876	0.0584	0.0772
22	0.9868	0.0406	0.0278
23	0.9863	1.6657	1.3153
24	0.9819	1.6768	1.3121
25	0.9776	0.0074	0.0038
26	0.9774	0.0104	0.0053
27	0.9773	0.0367	0.0324
28	0.9766	0.1348	0.1174
29	0.9754	1.7695	0.9013
30	0.9737	0.2334	0.2306
31	0.9724	0.1470	0.1713
32	0.9718	0.0155	0.0241
33	0.9720		

Table no. 5.1. Conventional load flow analysis

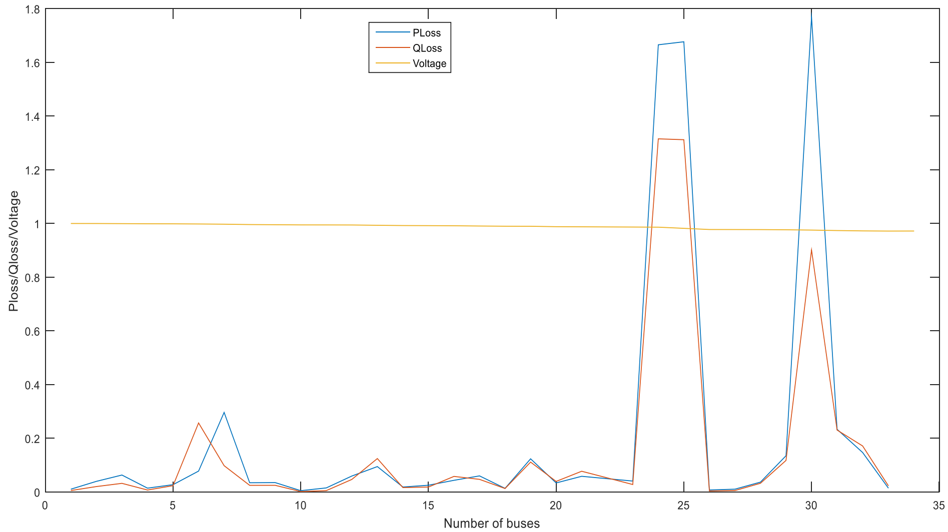

Fig 5.1 Conventional load flow graph having voltage, Ploss and Qloss

5.2 Load Flow Analysis Using Particle Swarm Optimization

For calculating the load flow analysis using PSO, the input data used in this method is same as mentioned in conventional load flow method.

The output for PSO load flow is as shown below

Bus no.	Voltage	P loss	Q loss
1	1.1334	0	0
2	1.1309	0.0433	0.0221
3	0.9918	0.0298	0.0152
4	1.1469	0.0498	0.0254
5	1.0135	0.0297	0.0256
6	1.0604	0.0055	0.0182
7	0.9552	0.3222	0.1065
8	1.0565	0.3813	0.2739
9	1.0136	0.0336	0.0238

10	1.0238	0.0062	0.0021
11	0.9892	0.0092	0.0031
12	1.1375	0.0452	0.0356
13	1.0671	0.0190	0.0250
14	1.0424	0.0935	0.0832
15	1.1225	0.0181	0.0132
16	0.9985	0.0427	0.0571
17	1.1132	0.0195	0.0153
18	1.0255	0.0125	0.0119
19	1.1178	0.0965	0.0870
20	1.0919	0.0275	0.0322
21	1.0265	0.0539	0.0713
22	1.0491	0.0329	0.0225
23	1.0501	0.0713	0.0563
24	1.1026	1.3182	1.0314
25	1.0570	0.3249	0.1655
26	0.9941	0.0100	0.0051
27	1.0148	0.0359	0.0317
28	1.1425	0.0204	0.0177
29	1.0869	0.0685	0.0349
30	1.0251	3.0652	3.0294
31	1.0797	0.0603	0.0703
32	0.9503	0.1688	0.2625
33	1.0253		

Table no. 5.2.load flow analysis using PSO

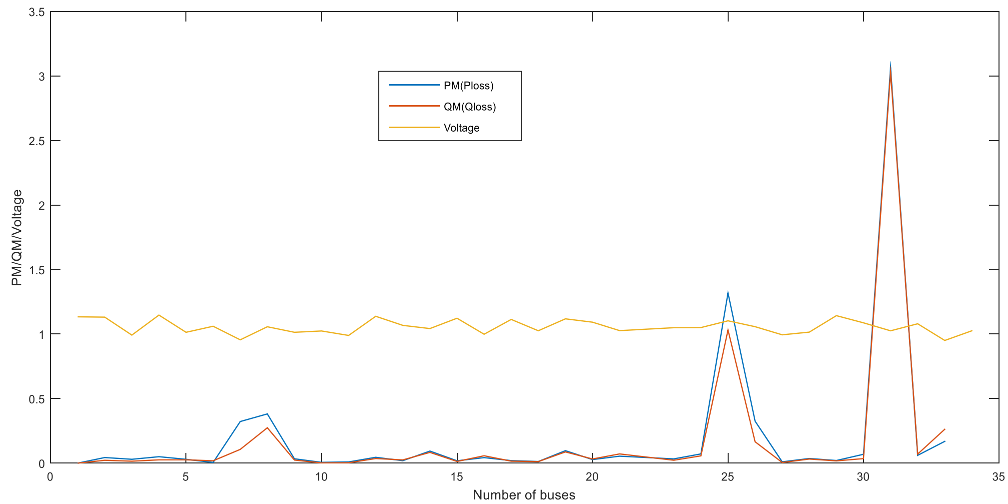

Fig 5.2 Load flow graph using PSO

5.3 Comparison between conventional method and PSO method

Method	TPL	TQL
Conventional Method	6.8850	5.1919
PSO Method	6.5157	5.6748

5.4 Conclusion

In this project, an IEEE 33 bus distribution system for optimal power flow is being discussed and studied. Total Real Power loss, Total Reactive Power loss and voltage Profile for the 33 bus system were studied and compared, from the two methods conventional method and Particle Swarm Optimization (PSO) method. From the results, we can conclude that PSO method is capable of obtaining optimum solution efficiently for Load flow problems. The study was done using MATLAB simulation software and the results showed that PSO method is more reliable and efficient than conventional method.

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