APPLICATION OF RADIAL DISTRIBUTION NETWORK IN DISTRIBUTION MANAGEMENT SYSTEM (DMS)

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Further, I certify that the work is based on the investigation made, data collected and analyzed by him and it has not been submitted in any other University or Institution for award of any degree. In my opinion it is fully adequate, in scope and utility, as a dissertation towards partial fulfillment for the award of degree of MBA.

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Nomenclature

NN : Total number of the nodes,(i=1........NN)

LB : Total number of the branches (LB=NN-1),(jj=1.......LB)

PL(i) : Real power load of i^{th} node

QL(i) : Reactive power load of i^{th} node

V(i) :Voltage of i^{th} node

R(jj) : Resistance of the branch jj

X(jj) : Reactance of the branch jj

Z(jj) : Impedance of the branch jj

I(jj) : current flowing through branch jj

P(m2) : Total real power load fed through node m2

Q(m2) : Total reactive power load fed through node m2

LP(jj) : Real power loss of the branch jj

LQ(jj) : Reactive power loss of branch jj

s(jj) : Sending end node of branch jj

r(jj) : Receiving end node of branch jj

δ(m1) : voltage angle of the node m1

δ(m2) : voltage angle of the node m2

RDS : Radial Distribution System

ABSTRACT

A DMS is a computer system used by a distribution utility to receive data from devices in the field that are equipped with supervisory control and data acquisition (SCADA) technology to provide operators with a real time picture of the status of the distribution system. To meet the present growing domestic, industrial and commercial load day by day, effective management of distribution system is required for which we use of radial distribution network. Using radial distribution network in DMS we are actually regulate the voltages produce by different distribution generator to the feeders.

CHAPTER 1

INTRODUCTION

1.1 Overview

To meet the present growing domestic, industrial and commercial load day by day, effective planning of radial distribution network is required. To ensure the effective planning with load transferring the load- flow study of radial distribution network becomes utmost important. Introduction of distribution system will be carried out at first followed by load-flow.

1.2 Introduction To Electrical Power System

Electrical energy is produced through an energy conversion process. The electric power system is a network of interconnected components which generate electricity by converting different forms of energy, (potential energy, kinetic energy, or chemical energy) are the most common forms of energy converted) to electrical energy; and transmit the electrical energy to load centres to be used by the consumer. The production and transmission of electricity is relatively efficient and inexpensive, although unlike other forms of energy, electricity is not easily stored and thus must generally be used as it is being produced .The electric power system consists of three main subsystems. the generation subsystem , the generating station by converting a primary source of energy to electrical energy. The voltage output of the generators is then stepped - up to appropriate transmission levels using a step-up transformer. The transmission sub-system then transmits the power close to the load centres. The voltage is then stepped- down to appropriate levels. The distribution subsystem then transmits the power close to the customer where the voltage is stepped-down to appropriate levels for use by a residential, industrial, or commercial customer. In this chapter, a brief description of the common methods of converting energy to electric power, and each power subsystem will be discussed.

1.2.1 Generation Systems

Generation Plants produce electrical energy from another form of energy such as fossil fuel , nuclear fuels, or hydropower. Generation Substations connect generation plants to Transmission lines through a step-up transformer that increases voltage to transmission levels. Generation plants consist of one or more generating units that convert mechanical energy into electricity by turning a prime mover coupled to an electric generator .Most prime movers are driven by steam produced in a boiler fired by coal, oil, natural gas, or nuclear fuel. Others may be driven by non thermal sources such as hydroelectric dams and wind farms. Generators produce line-to-line voltages between 11 kV and 30 kV.The ability of generation plants to supply all of the power demanded by customers is referred to as system adequacy. Three conditions must be met to ensure system adequacy. First, available generation capacity must be greater than demanded load plus system losses. Second, the system must be able to transport demanded power to customers without overloading equipment. Third, customers must be served within an acceptable voltage range. System adequacy assessment is probabilistic in nature. Each generator has a probability of being available, a probability of being available with a reduced capacity, and a probability of being unavailable. This allows the probability of all generator state combinations to be computed. To perform an adequacy assessment, each generation state combination is compared to hourly system loads for an entire year. If available generation cannot supply demanded load or constraints are violated, the system is inadequate and load must be curtailed. Generation adequacy assessments produce the following information for each load bus:

(1) The combinations of generation and loading that require load curtailment, and

(2) The probability of being in each of these inadequate state combinations.

1.2.2 Transmission Systems

Electric power transmission is the bulk transfer of electrical power, a process in the delivery of electricity to consumers. A power transmission network typically connects power to multiple substations near a populated area. The wiring from substations to customers is referred to as Electricity distribution, following the historic business model separating the wholesale electricity transmission business from distributors who deliver the electricity to the homes. Electric power transmission allows distant energy sources (such as hydroelectric power plants) to be connected to consumers in population centres, and may allow exploitation of low-grade fuel resources such as coal that would otherwise be too costly to transport to generating facilities. Usually transmission lines use three phase alternating current (AC). Single phase AC current is sometimes used in a railway electrification system. High-voltage direct current systems are used for long distance transmission, or some undersea cables, or for connecting two different ac networks. Transmission Systems transport electricity over long distances from generation substations to transmission or distribution substations. Typical US voltage levels include 69 kV, 115 kV, 138 kV, 161 kV, 230 kV, 345 kV, 500 kV, 765 kV, and 1100 kV. Transmission Switching Stations serve as nodes in the transmission system that allow transmission line connections to be reconfigured. Transmission Substations are ransmission switching stations with transformers that step down voltage to sub transmission levels. Subtransmission Systems transport electricity from transmission substations to distribution substations. Typical US voltage levels include34.5 kV, 46 kV, 69 kV, 115 kV, 138 kV, 161 kV, and 230 kV.

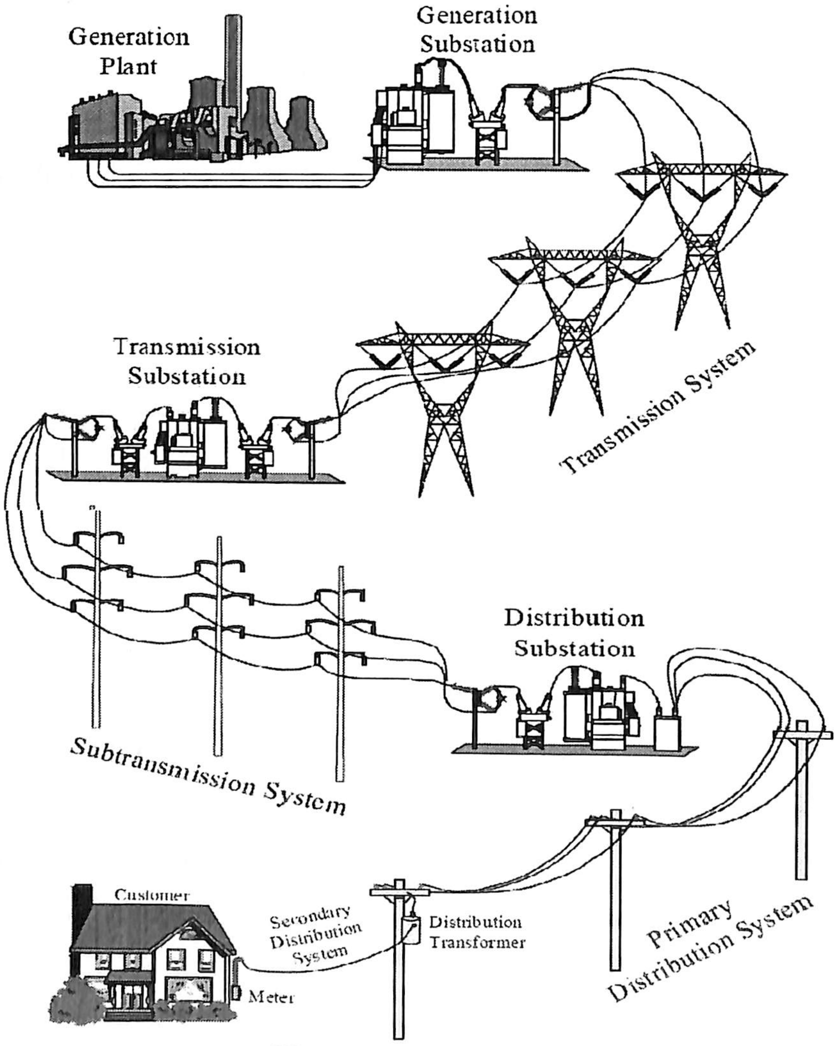


Fig. 1.1 Different Parts of Power Systems

1.2.3 Distribution System

Electrical power is transmitted by high voltage transmission lines from sending end substation to receiving end substation. At the receiving end substation, the voltage is stepped down to lower value (say 66kV or 33kV or 11kV). The secondary transmission system transfers power from this receiving end substation to secondary sub-station. A secondary substation consists of two or more power transformers together with voltage regulating equipments, buses and switchgear. At the secondary substation voltage is stepped down to 11kV. The portion of the power network between a secondary substation and consumers is known as distribution system. The distribution system can be classified into primary and secondary system. Some large consumers are given high voltage supply from the receiving end substations or secondary substation. The area served by a secondary substation can be subdivided into a number of sub- areas. Each sub area has its primary and secondary distribution system. The primary distribution system consists of main feeders and laterals. The main feeder runs from the low voltage bus of the secondary substation and acts as the main source of supply to sub- feeders, laterals or direct connected distribution transformers. The lateral is supplied by the main feeder and extends through the load area with connection to distribution transformers. The distribution transformers are located at convenient places in the load area. They may be located in specially constructed enclosures or may be pole mounted . The distribution transformers for a large multi storied building may be located within the building itself. At the distribution transformer, the voltage is stepped down to 400V and power is fed into the secondary distribution systems. The secondary distribution system consists of distributors which are laid along the road sides. The service connections to consumers are tapped off from the distributors. The main feeders, laterals and distributors may consist of overhead lines or cables or both. The distributors are 3- phase, 4 wire circuits, the neutral wire being necessary to supply the single phase loads. Most of the residential and commercial consumers are given single phase supply. Some large residential and commercial consumer uses 3-phase power supply. The service connections of consumer are known as service mains. The consumer receives power from the distribution system.

1.2.3.1 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 toppings 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.

1.2.3.2 Distributor*:* A distributor is a conductor from which tapping are taken for supply to the consumers. In Figure 2.1, 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.

1.2.3.3 Service mains*:* A service mains is generally a small cable which connects the distributor to the consumer's terminals.

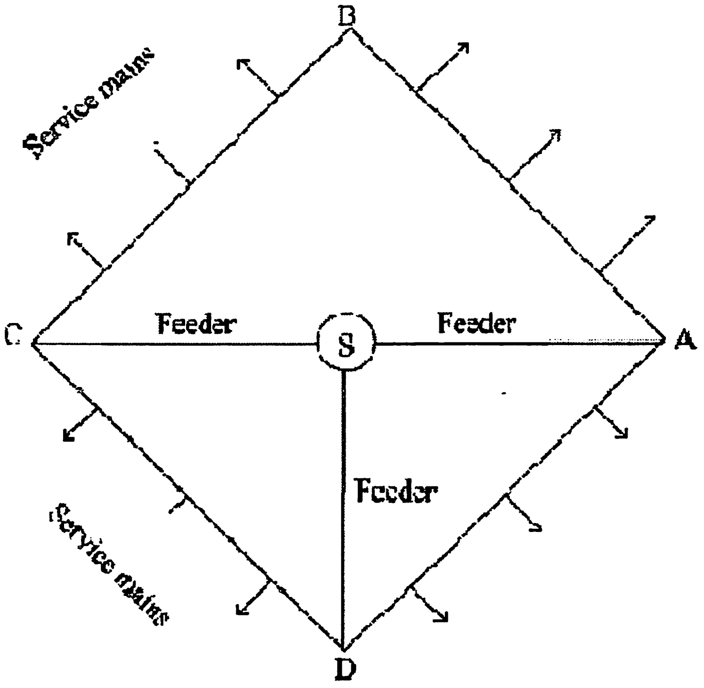


Figure 1.2 The single line diagram of a typical low tension distribution system.

1.3 History of Distribution System

In the early days of electricity distribution, direct current DC generators were connected to loads at the same voltage. The generation, transmission and loads had to be of the same voltage because there was no way of changing DC voltage levels, other than inefficient motor-generator sets. Low DC voltages were used (on the order of 100 volts) since that was a practical voltage for incandescent lamps, which were then the primary electrical load. The low voltage also required less insulation to be safely distributed within buildings. The losses in a cable are proportional to the square of the current, the length of the cable, and the resistivity of the material, and are inversely proportional to cross -sectional area. Early transmission networks were already using copper, which is one of the best economically feasible conductors for this application. To reduce the current and copper required for a given quantity of power transmitted would require a higher transmission voltage, but no convenient efficient method existed to change the voltage level of DC power circuits. To keep losses to an economically practical level the Edison DC system needed thick cables and localgnerators.

1.4 Modern Distribution System

The modern distribution system begins as the primary circuit leaves the sub-station and ends as the secondary service enters the customer's meter socket. A variety of methods, materials, and equipment are used among the various utility companies, but the end result is similar. First, the energy leaves the sub-station in a primary circuit , usually with all three phases. The most common type of primary is known as a **Wye configuration** (so named because of the shape of a "Y".) The Wye configuration includes 3 phases (represented by the three outer parts of the "Y") and a neutral (represented by the centre of the "Y".) The neutral is grounded both at the substation and at every power pole. The other type of primary configuration is known as **delta**. This method is older and less common. Delta is so named because of the shape of the Greek letter delta, a triangle. Delta has only 3 phases and no neutral. In delta there is only a single voltage, between two phases (phase to phase), while in Wye there are two voltages, between two phases and between a phase and neutral (phase to neutral). Wye primary is safer because if one phase becomes grounded, that is, makes connection to the ground through a person, tree, or other object, it should trip out the circuit breaker tripping similar to a household fused cut-out system. In delta, if a phase makes connection to ground it will continue to function normally. It takes two or three phases to make connection to ground before the fused cut-outs will open the circuit. The voltage for this configuration is usually 4800 volts.

1.5 Requirement of Distribution system

A considerable amount of effort is necessary to maintain an electric power supply within the requirements of various types of consumers. Some of the requirements of a good distribution systems are: proper voltage, availability of power on demand, and reliability

1.5.1 Proper Voltage

One important requirement of a distribution system is that voltage variations at consumers' terminals should be as low as possible. The changes in voltage are generally caused due to the variation of load on the system. Low voltage causes loss of revenue, inefficient lighting and possible burning out of motors. High voltage causes lamps to burn out permanently and may cause failure of other appliances . Therefore, a good distribution system should ensure that the voltage variations at consumers' terminals are within permissible limits. The statutory limit of voltage variations is +10% of the rated value at the consumers' terminals. Thus, if the declared voltage is 230 V, then the highest voltage of the consumer should not exceed 244 V while the lowest voltage of the consumer should not be less than 216 V.

1.5.2 Availability of Power Demand

Power must be available to the consumers in any amount that they may require from time to time. For example, motors may be started or shut down, lights may be turned on or off , without advance warning to the electric supply company. As electrical energy cannot be stored, therefore, the distribution system must be capable of supplying load demands of the consumers. This necessitates that operating staff must continuously study load patterns to predict in advance those major load changes that follow the known schedules.

1.5.3 Reliability

Modern industry is almost dependent on electric power for its operation. Homes and office buildings are lighted, heated, cooled and ventilated by electric power. This calls for reliable service. Unfortunately electric power, like everything else that is man-made, can never be absolutely reliable. However, the reliability can be improved to a considerable extent by (a) inter-connected system, (b) reliable automatic control system and (c) providing additional reserve facilities.

1.6 Classification of Distribution System

A distribution system may be classified according to:

1.6.1 Nature of current

According to nature of current, distribution system may be classified as (a) d.c. distribution system and (b) a.c. distribution system. Now-a-days a.c. system is universally adopted for distribution of electric power as it is simpler and more economical than direct current method.

1.6.2 Type of construction

According to type of construction, distribution system may be

Classified as (a) overhead system and (b) underground system. The overhead system is generally employed for distribution as it is 5 to 10 times cheaper than the equivalent underground system. In general, the underground system is used at places where overhead construction is impracticable or prohibited by the local laws.

1.6.3 Scheme of connection

According to scheme of connection, the distribution system may be classified as (a) radial system (b) ring main system and (c) inter-connected system. Each scheme has its own advantages and disadvantages.

1.7 Essential Parts of Distribution System

Various type of distribution system has identical subsystems and components. These components can be connected and configured in various alternative ways depending upon the area covered, load density, type and importance of consumer , reliability and freedom from interruption desired, cost of land and right of way available.

a. Sub-transmission Circuits.

b. Distribution Substations.

c. Primary Distribution Circuit.

d. Distribution Transformers.

e. Secondary Distribution System.

1.8 A.C. Distribution System

Now a day's 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, the down sub-station is 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.

1.8.1 Primary Distribution System

It is part of a.c. distribution system, which operates a voltages somewhat higher than general utilization and handles large blocks of electrical energy than the average low-voltage consumer uses.

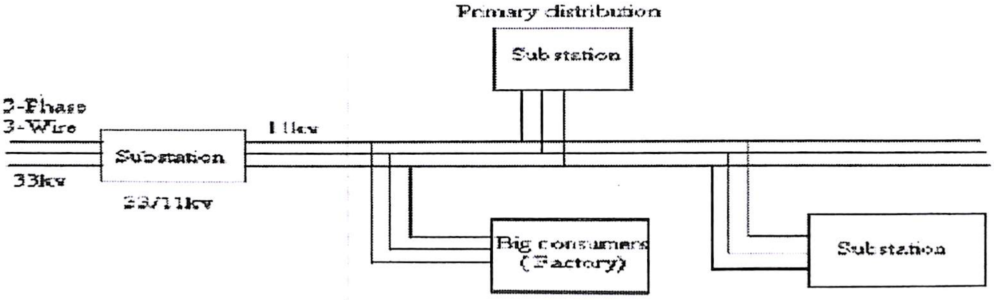


Figure 1.3 **Primary Distribution Systems.**

The voltage used for primary distribution depends upon the amount of power to be conveyed and the distance of the sub-station required to be fed. The most commonly used primary distribution voltages are 22 kV, 6.6 kV and 2.2 kV. Due to economic considerations, primary distribution is carried out by 3-phase , 3-wire system. Figure 1.3 shows a typical primary distribution system. Electric power from the generating station is transmitted at high voltage to the sub-station located in or near the city. At this sub-station, voltage is stepped down to 11kV with the help of step-down transformer. Power is supplied to various sub-stations for distribution or to big consumers at this voltage. This forms the high voltage distribution or primary distribution.

1.8.2 Secondary Distribution System

It is that part of a.c. distribution system that 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. Figure 2.3 shows a typical secondary distribution system.

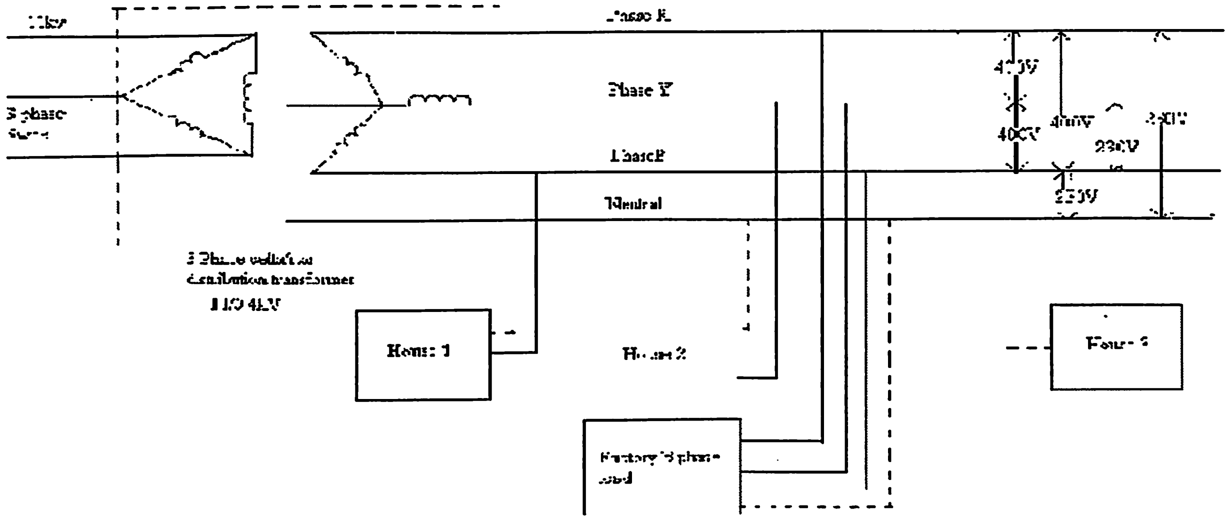


Figure 1.4 Secondary Distribution Systems.

The primary distribution circuit delivers power to various sub-stations, called distribution substations. The sub-stations are situated near the consumer's localities and contain step-down transformers . At each distribution sub-station, 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 in 400 V and between any phase and neutral is 230. 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.

1.9 Direct Current System

Direct current systems usually consist of two or three wires. Although such distribution systems are no longer employed, except in very special instances, older ones now exist and will continue to exist for some time. Direct current systems are essentially the same as single-phase ac systems of two or three wires; the same discussion for those systems also applies to dc systems.

1.10 Over Head versus Underground System

The distribution system can be overhead or underground. Overhead lines are generally Mounted on wooden, concrete or steel poles which are arranged to carry distribution transformers in addition to the conductors. The choice between overhead and underground system depends upon a number of widely differing factors.

1.10.1 Public Safety

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

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

1.10.1.3 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, transformer etc., can be easily shifted to meet the change in load conditions.

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

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

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

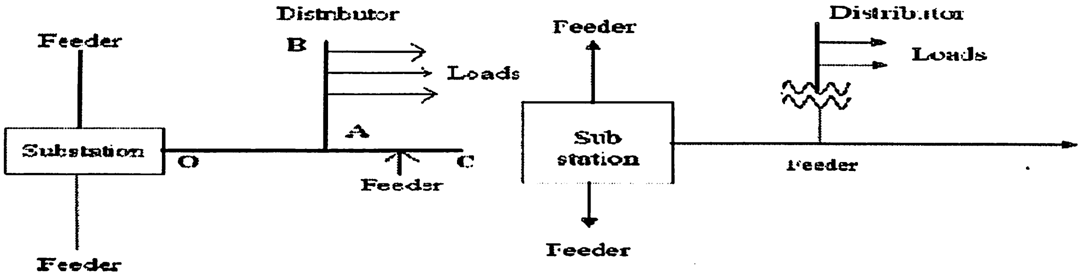
1.10.1.7 Current carrying capacity and voltage drop: An overhead distribution conductor has a Considerably higher current carrying capacity than an underground cable conductor of the same material and cross-section. On the other hand, underground cable conductor has much lower inductive reactance than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

1.10.1.8. 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.

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

1.10.1.10. Interference with communication circuits: An overhead system causes electromagnetic interference with 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.

1.10 Radial Distribution System



(a) DC Distribution System

(b) AC Distribution System

Fig.1.5 Single Line Diagram of Radial Distribution System

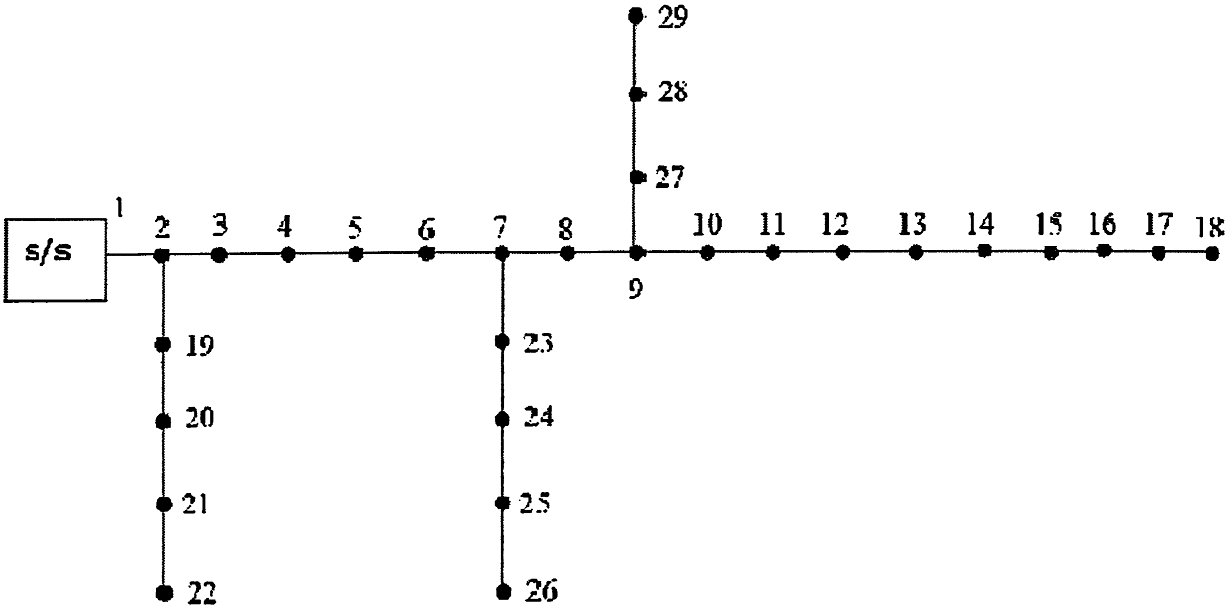


Figure 1.6 29-Node Radial Distribution System.

1.10.2 Objectives of Radial Distribution System:

a. Planning, modernization and automation.

b. To provide service connection to various urban, rural and industrial consumer in the allocated area.

c. Maximum security of supply and minimum duration of interruption.

d. Safety of consumers, utility personnel.

e. To provide electricity of accepted quality in terms of :-

   i. Balanced three phase supply.
   ii. Good power factor.
   iii. Voltage flicker within permissible limits.
   iv. Less voltage dips.
   v. Minimum interruption in power supply

1.10.3 Advantages of Radial Distribution System

- Radial distribution system is easiest and cheapest to build.
- The maintenance is easy.
- It is widely used in sparsely populated areas.

1.10.4 Drawback of Radial Distribution System

- The end of the distributor nearest to the feeding point will be heavily loaded.
- 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 sub-station.
- The consumers at the distant end of the distributor would be subjected to serious voltage fluctuations when the load on the distributor changes.

1.11 Ring Main System

In this system , the primaries of distribution transformers are from a loop. The loop circuit starts from the sub-station bus bars, makes a loop through the area to be served, and returns to the substation. Figure shows the single line diagram of ring main system for a.c. Distribution where substation supplies to the closed feeder LMNOPQRS and Q of the feeder through distribution transformers.

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. For example, suppose that fault occurs at any point F of section SLM of the feeder. Then section SLM of the feeder can be isolated for repairs and at the same time continuity of supply is maintained to all the consumers via the feeder SRQPONM.

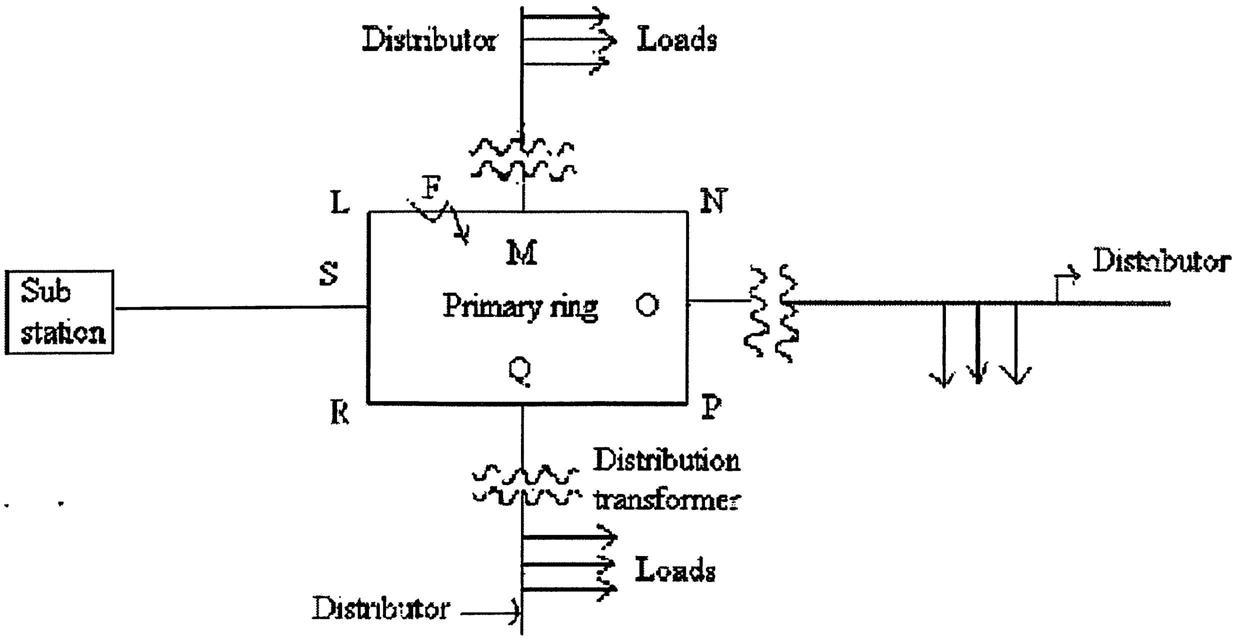


Figure 1.7 Ring Main System.

1.12 Interconnected System

When the feeder ring is energized by two or more than two generating stations or sub stations, it is called interconnected system. Figure 1.8 shows the single line diagram of interconnected system where the closed feeder ring ABCD is supplied by two sub-stations S1 and S2 at points D and C respectively. Distributors are connected to points O, P, Q and R of the feeder ring through distribution transformers.

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.

The figure for the interconnected distribution system is given following as 1.8

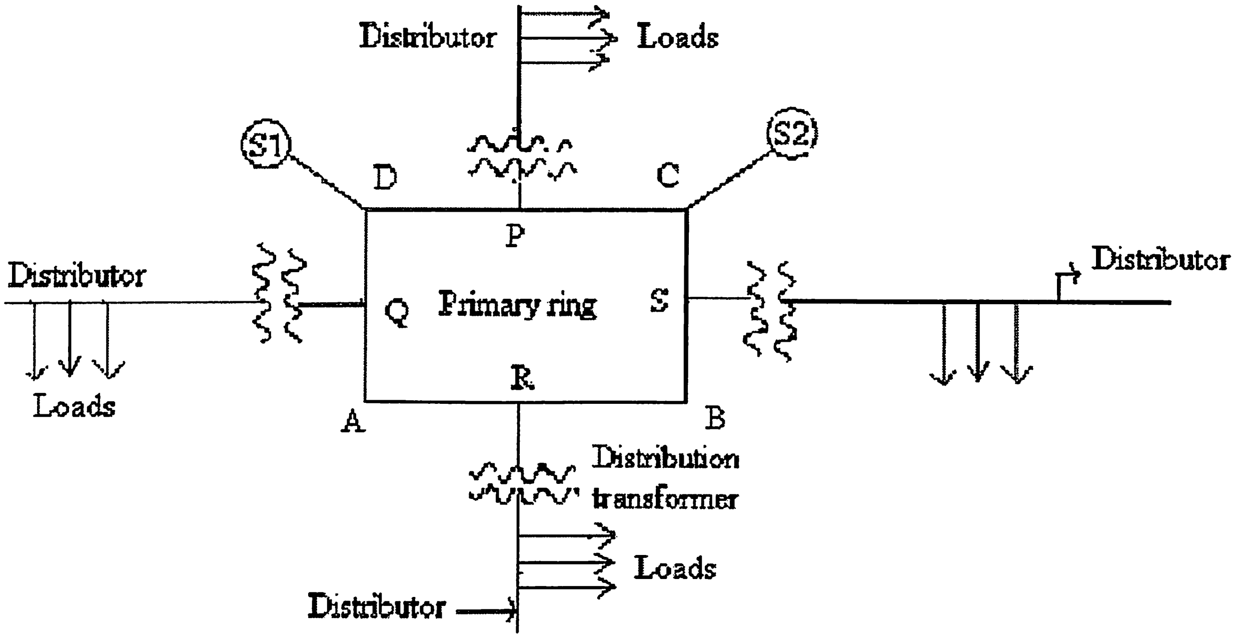


Figure 1.8 Interconnected System.

1.13 Load Flow Analysis

Load flow analysis is concerned with describing the operating state of an entire power system, by which we mean a network of generators, transmission lines, and loads that could represent an area as small as a municipality or as large as several states. Given certain known quantities —typically, the amount of power generated and consumed at different locations— load flow analysis allows one to determine other quantities. The most important of these quantities are the voltages at locations throughout the transmission system, which, for alternating current (AC), consist of both a magnitude and a time element or phase angle. Once the voltages are known, the currents flowing through every transmission link can be easily calculated. Thus the name power flow or load flow , as it is often called in the industry given the amount of power delivered and where it comes from, power flow analysis tells us how it flows to its destination. Owing mainly to the peculiarities of AC, but also to the sheer size an complexity of a real power system—its elaborate topology with many nodes and links, and the large number of generators and loads—it turns out to be no mean feat to deduce what is happening in one part of the system from what is happening elsewhere, despite the fact that these happenings are intimately related through well - understood, deterministic laws of physics Even a small network of a handful of AC power sources and loads defies our ability to write down formulas for the relationships among all the variables: as a mathematician would say, the system cannot be solved analytically; there is no closed – form solution. We can only get at a numerical answer through a process of successive approximation or iteration. In order to find out what the voltage or current at any given point will be, we must in effect simulate the entire system .Historically, such simulations were accomplished through an actual miniature DC model of the power system in use. Generators were represented by small DC power supplies, loads by resistors, and transmission lines by appropriately sized wires. The voltages and currents could be found empirically by direct measurement. To find out how much the current on line A would increase, for example, due to Generator X taking over power production from Generator Y, one would simply adjust the values on X and Y and go read the ammeter on line A. The DC mode l does not exactly match the behavior of the AC system, but it gives an approximation that is close enough for most practical purposes. In the age of computers, we no longer need to physically build such models, but can create them mathematically. With plenty of computational power, we can not only represent a DC system, but the AC system itself in a way that accounts for the subtleties of AC Such a simulation constitutes load flow analysis. Load flow uses a mathematical algorithm of successive approximation by iteration, or the Repeated application of calculation steps. These steps represent a process of trial and error That starts with assuming one array of numbers for the entire system, comparing the Relationships among the numbers to the laws of physics, and then repeatedly adjusting the numbers until the entire array is consistent with both physical law and the conditions stipulated by the user. In practice, this looks like a computer program to which the operator gives certain input information about the power system, and which then provides output that completes the picture of what is happening in the system. There are variations on what types of information are chosen as input and output, and there are also different computational techniques used by different programs to produce the output. Beyond the straight forward load flow program that simply calculates the variables pertaining to a single, existing system condition, there are more involved programs that analyze a multitude of hypothetical situations or system conditions and rank them according to some desired criteria; such programs are known as optimal power flow (OPF).load flow study is instrumental in the planning, design, and operation of distribution system for industrial facilities. This study can be used to evaluate the effects of various equipment configurations, additions or modifications to generators, motors, or other electrical loads. Modern systems are complex and have many paths or branches over which power can flow. Electric power flow will divide among these branches until a balance is reached in accordance with Kirchoff's laws. The computer programs to solve load flows are divided into two types; static and dynamic. This discussion is concerned with only static network models and their analysis. As the load distribution , and possibly the network, will vary considerably during different time periods , it is necessary to obtain solutions representing the major different system conditions such as peak load, normal load, light or no load. These solutions will be used to determine either optimum operating modes for normal conditions, such as the proper setting of voltage control devices, or how the system will respond to abnormal conditions, such as outages of lines or transformers. It also serves as the basis for other types of studies such as shortcircuit, stability , motor starting, and harmonic studies. It provides the network data and an initial condition for these studies.

Typically the input data is divided into

(a) Bus data

(b) Branch data

(c) Generator data

(d) Transformer data

(e)Load data

This data is included (or should be) with every load flow output file in order to Document the system , load configuration that the solution applies for. The load flow Study should have a predefined set of criteria that the system evaluated must meet. These criteria include:

(a) Voltage criteria

(b) Power flows on cables and transformers must be within equipment ratings.

(c) Generator reactive outputs must be within the limits defined by the generator capability curves.

The load flow analysis is used to design a system that has a good voltage profile during normal operation and that will continue to operate acceptably when one or more lines become inoperative due to line damage, lightning strokes, failure of transformers, etc. In addition , the size and placement of power factor correction capacitors and the setting of generator scheduled voltages and transformer tap positions can be studied with load flows. The great importance of load flow studies is in the planning the future expansion of power systems as well as in determining the best operation of existing systems . The principal information obtained from the load flow study is the magnitude and phase angle of the voltage at each bus and the real and reactive power flowing in each line.

1.14 Structure of the Thesis

Chapter 1 presents the introduction of distribution system, load-flow, literature survey on load flow and distribution system , objectives of the research , scope of the research and organization of the research.

Chapter 2 Introduction to distribution systems is given where various basics have been introduced. Types of existing distribution system models have also been discussed, a thorough analysis has been done on the existing methods. History of distribution system, modern distribution system, requirement of distribution system etc. is also explained in this chapter.

Chapter 3 In this chapter various assumptions , various load flow methods are first explained, followed by constraints concerned to load flow for distribution system. Significance of load flow, need of load flow, different types of load flow methods is also discussed.

Chapter 4 The role of power flow in distribution system is explained in this chapter thoroughly. The methods used for this purpose is also explained. Voltage injection method are used to solve this purpose.

Chapter 5 Results and Discussion.

Chapter 6 Conclusion and Scope for Future Work.

1.15 Objective Of Thesis

In this thesis work, the main aim was to develop a computationally efficient load flow algorithm for radial distribution System based on an efficient load flow technique developed in Ref. [1]. And calculate the new current sensitivity index.

CHAPTER 2

LITERATURE REVIEW

Literature Survey

In the literature, there are a number of efficient and reliable load flow solution techniques, such as: Gauss-Seidel, Newton-Raphson's and Fast Decoupled Load Flow. However they are successfully and widely used for power system operation , control and planning However, it has repeatedly been shown that these methods may become inefficient in the analysis of distribution systems with high R/X ratios or special network.

Kumar K.Vinoth and Selvan M.P [1] proposed a simple approach for load flow analysis of a radial distribution network. The proposed approach utilizes forward and backward sweep algorithm based on Kirchoff's current law (KCL) and Kirchoff's voltage law (KVL) for evaluating the node voltages iteratively. In this approach, computation of branch current depends only on the current injected at the neighboring node and the current in the adjacent branch. This approach starts from the end nodes of sub lateral line, lateral line and main line and moves towards the root node during branch current computation. The node voltage evaluation begins from the root node and moves towards the nodes located at the far end of the main, lateral and sub lateral lines.

Ghosh S and Das D. [2] proposed a method involves only the evaluation of a simple algebraic expression of receiving- end voltages. The main aim of the authors has been to developed a new load-flow technique for solving radial distribution networks. The proposed method involves only the evaluation of a simple algebraic expression of receiving - end voltages. The proposed method is very efficient. It is also observed that the proposed method has good and fast convergence characteristics. Loads in the present formulation have been presented as constant power. However, the proposed method can easily include composite load modelling , if the composition of the loads is known. Several radial distribution feeders have been solved successively by using the proposed method. The speed requirement of the proposed method has also been compared with other existing methods.

Aravindhababu P [3] presented a new, robust, and fast technique to obtain the load flow Solution in distribution networks. The proposed method is based on the Newton-Raphson's Technique using equivalen t current-injection and rectangular coordinates. The load flow problem is considered as an optimization problem and is decoupled into two sub-problems. The assumptions on voltage magnitudes, angles, and r/x ratios necessary for decoupling the network in the conventional FDPF are eliminated in the proposed method. This method is simple, insensitive to r/x ratios of the distribution lines, and uses a constant Jacobian matrix. It is solved similar to FDPF.

Rajicic D and Tamura Y [4] a modification to the FDLF is presented named MFDLF. It is shown that its convergency is much better than that of FDLF for ill conditioned systems. In this,it is done by multiplying unitary (rotation) operators to the bus injection complex power and each row of the admittance matrix. In the literature, other methods have been proposed for improving FDLF's convergency. But these methods suffer from slower convergency if a transmission line is a part of a loop.

Stott B [5] presented a survey on the currently available numerical techniques for power system load-flow calculation using the digital computer. The review deals with methods that have received widespread practical application, recent attractive developments , and other methods that have interesting or useful characteristics. The analytical bases , computational requirements, and comparative numerical performances of the methods are discussed.

K. Prakash and M . Sydulu[6] presented an effective topological primitive impedance and distribution power flow algorithm is developed . This method fully exploits the radial structure of the Network and solve the distribution load flow directly. An effective data structure is proposed to identify all those lines that are incident to the path between feeding bus and any selected bus . primitive impedances of the lines , only diagonal element of the distribution load flow matrix are computed and stored in single dimension vector to obtain the distribution load flow analysis .

R. Ranjan and Das[7] has proposed a new method to solve radial distribution networks . They had used simple algebraic recursive expression of voltage magnitude and the proposed algorithm used the basic principle of circuit theory.

Zimmerman Ray D. and Chiang Hsiao-Dong [8] successfully presented and concluded a novel power flow formulation and an effective solution method for general unbalanced radial distribution system. In this paper the authors exploited the radial structure (*physical property*) and the decoupling *numerical property* of a distribution system to develop a fast decoupled Newton method for solving unbalanced distribution load flow. The objective of this work was to develop a formulation and an efficient solution algorithm for the distribution power flow problem which takes into account the detailed and extensive modeling necessary for use in the distribution automation environment of a real world electric power distribution system.

The modelling includes unbalanced three-phase , two-phase , and single – phase branches, constant power , constant current , and constant impedance loads connected in Wye or Delta formations, co-generators , shunt capacitors , line charging capacitance, switches, and three-phase transformers of various connection types.

Bose A. and Rajicic D [9] tells that Fast Decoupled Method is probably the most popular because of its efficiency. Its reliability for most power systems is very high but it does have difficulties in convergence for systems with high ratios of branch resistance to reactance. Modifications, that retain the advantages of this method but can handle high r/x ratios, are of great interest and certain compensation techniques have been used forth is purpose. Both the series and parallel compensation techniques, however give mixed results and a new modification is presented here that performed better on several test systems.

A.M, Van Amerongen [10] presented the general purpose fast decoupled power flow, he tells that probably almost all the relevant known numerical methods used for solving the nonlinear equations have been applied in developing power flow models. Among various methods, *power* flow models based on the Newton- Raphson (NR) method have been found to be most reliable. Many decoupled polar versions of the NR method have been attempted for reducing the memory requirement and computation time involved for power flow solution. Among decoupled versions, the fast decoupled load flow (FDLF) model developed.

Eid R. et al [11] presented an Improved Fast Decoupled Power Flow Method (IFDPFM) based on different strategies of updating the voltage angle (δ) and the bus voltage (V) in each iteration . This method was tested on many bus test systems. When compared with the Newton-Raphson's and with the classical Fast Decoupled methods, the IFDPFM resulted in large computing savings in the order of 70 %, thus in faster convergence.

Mekhamera S.F. et al [12] presented a new method for solving the load flow problem for radial distribution feeder , without solving the conventional well –known load flow methods. They should have high speed and low storage requirement, especially for real time large system application; they should also be highly reliable especially for ill-conditioned problem, outage studies and real time application.

Stott B. and Alsac O [13] paper described a simple, very reliable and extremely fast load-flow solution method with a wide range of practical application. It is useful for accurate or approximate off- and on-line routine and contingency calculations for networks of any size, and can be implemented efficiently on computers with restrictive core-store capacities. It combines many of the advantages of the existing "good" methods . The algorithm is simpler, faster and more reliable than Newton's method, and has lower storage requirements for entirely in-core solutions. The method is equally suitable for routine accurate load flows as for outage contingency evaluation studies performed on- or off-line.

Das D. et al. [14] had proposed a load-flow technique for solving radial distribution networks by calculating the total real and reactive power fed through any node. They have proposed a unique node, branch and lateral numbering scheme which helps to evaluate exact real and reactive power loads fed through any node. Methods developed for the solution of ill-conditioned radial distribution systems may be divided into two categories. The first group of methods is based on the forward-backward sweep process for solution of ladder networks. On the other hand, the second group of methods is utilized by proper modification of existing methods such as Newton-Raphson's.

Chapter-3

Concept & Theory of the Problem

3.1 Introduction:

The distribution system interconnects transmission and the consumer point. In the order to evaluate the performance of a power distribution network during operation and to examine the effectiveness of proposed alterations to a system in the planning stage, it is essential that a load flow analysis of the network is carried out. The load flow studies are normally carried out to determine: (a) node voltage and branch current, (b) the flow of active and reactive power in network branches, (c) no circuits are overloaded and voltages are within acceptable limits, (d) effect of loss of circuits under emergency conditions, (e) optimum system loading conditions and, (f) optimum system losses.

The distribution system, which have separate feeders radiating from a single sub-station and feed the distributors at one end only are called Radial Distribution System (RDS). Radial distribution system have high R/X ratio. Due to this reason, conventional Newton-Raphson method and Fast Decoupled Load Flow methods fails to converge in many cases. Kersting & Mendive [15] & Kersting have developed load flow techniques based on ladder theory & Stevens et al. modified it & proved faster than earlier methods. However, it fails to converge in 5 out of 12 case studies. Baran & Wu have developed a load flow method based on the Newton Raphson method, but it requires a Jacobain matrix, a series of matrix multiplication, and at least one matrix inversion. Hence, it is considered numerically cumbersome and computationally inefficient. With the development of microcomputer, distribution substation-owned computer programs have become necessity. However, the choice of solution method merits and demerits of those methods available in respect of memory storage requirements, computation speed and convergence criterion.

3.2 Literature survey

A new power flow method for radial distribution networks with improved convergence characteristics have been reported in [18], which is based on polynomial equation on the forward process and backward ladder equation for each branch of RDS. In the reported method[19] line shunt capacitance and exponents of static load are included in the power flow solution. The authors of [19]have developed an improved Backward/ forward (BW/FW) sweep approach for load flow analysis of RDS which includes two steps: the backward sweep and the decomposed forward sweet. In the backward sweep and the decomposed forward sweep. In the backward sweep, Kirchhoff's current Law (KCL) and Kirchhoff's Voltage Law (KVL) are sued to find the calculated voltage for each upstream bus of a line or a transformer branch. In the decomposed forward sweep, the linear proportional principle is employed to update the voltage at each downstream bus. After performing each backward sweep, the mismatch of the calculated and specified voltage at the substation is checked. The solution algorithm repeats until the convergence tolerance of the substation voltage is satisfied.

In many cases, it is observed that the RDS are unbalanced because of single-phase, two phase and three phase loads. Thus, load flow solution for unbalanced case and, hence special treatment is required for solving such networks. Therefore a simple three phase load flow method is presented in [20] to solve three phase unbalanced RDS. It solves a simple algebraic recursive expression of voltage magnitude, and all the data are stored in vector form. The algorithm uses basic principles of circuit theory and can be easily understood. Mutual coupling between the phases has been included in the mathematical model. A new power flow method for solving weakly meshed distribution and transmission networks, using a multi-port compensation technique and basic formulation of Kirchhoff's Laws, which has excellent convergence characteristics and is very robust.. A computer program implementing this power flow solution scheme was developed and successfully applied to several practical distribution and transmission networks with radial and weakly meshed structure. The method can be applied to the solution of both the three phase (unbalanced) and single phase (balanced) representation of network. A new method is to handle distribution transformers of various winding connections in the backward/forward sweep based power flow analysis for unbalanced RDS. This method takes advantages of available nodal admittance matrices of distribution transformers, and can automatically solve the problem of conductively isolated sub networks to obtain their equivalent phase to reference voltages. In addition, this paper presents a limitation of backward/forward sweeps and an extension of the power summation method for distribution power flow analysis from single-phase to unbalanced three-phase.

In a modern Distribution Management System (DMS), State Estimation (SE) plays a critical role to estimate the real time system states that are difficult to obtain from the limited measuring instruments at the distribution system state that are difficult to obtain the limited measuring instruments at the distribution system level. With Distribution SE (DSE) the operators can calculate the theoretical power loss, implement voltage/var optimization, guide network reconfiguration, and prevent distribution line from overloading. Therefore, they can improve the capability of monitoring and, controlling distribution system and finally improve the power quality and reliability of distribution system. DSE is a fundamental function in DMS. State estimation techniques have been developed and applied at the generation and transmission levels for more than 30 years. The most commonly used approach is the Weighted Least Square (WLS) method. The features of distribution networks include their wide range of resistance and reactance ratio values, low number of meshes, very limited measurement sets and the large number of current measurements which makes the problem of state estimation for distribution systems very challenging. Therefore, it is important for a distribution state estimator to consider these features.

Thus, above literature study highlights, various Load Flow Algorithms developed to solve balanced and unbalanced three-phase RDS, along with energy allocation techniques for RDS, which are helpful for this current research work.

CHAPTER 4

Present Work

4.1 Load flow method:

Load flow calculation is an important and basic tool in the field of power system engineering. It is used in planning and design stages as well as operation stages of the power system. Some applications especially in the fields of optimization of power system need fast converging load flow solutions. The proposed method uses vector distributed load flow method.

Consider a line connected between two nodes as shown in the fig 4.1

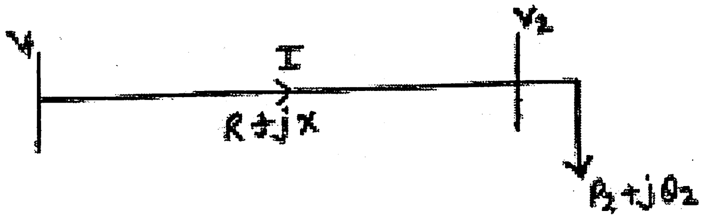


Fig 4.1. line connected between two nodes

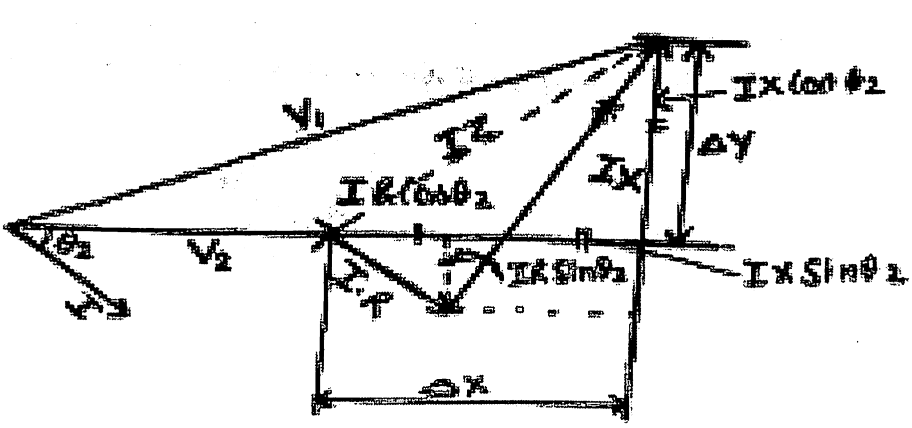


Fig: 4.2 Basic phasor diagram of a line connected between two nodes

From fig 4.2 the following equations are derived

$$V_1^2= (V_2+\Delta x) + (\Delta y)^2 \tag{4.1}$$

Where

$$\Delta x=IR\cos (\theta_2) + IX\sin (\theta_2) \tag{4.2}$$

$$\Delta y=IX \cos (\theta_2) - IR \sin (\theta_2) \tag{4.3}$$

Using the equations 4.2 and 4.3 in 4.1 we have

$$V_1^2= (V_2+ IR\cos (\theta_2) + IX\sin (\theta_2))^2+ (IX\cos (\theta_2) - IR\sin (\theta 2))^2$$

$$V_1= (V_2+ IR\cos (\theta_2) +IX\sin (\theta_2))^2+ (IX\cos (\theta_2) - IR\sin (\theta_2))^{1/2} \tag{4.4}$$

To eliminate I from the equation 4 use

$I\cos (\theta_2) = P_2/ V2$

$I\sin (\theta_2) = Q_2/ V2$

Where P_2=Total active power load including active power loss beyond node 2.

Q_2= Total reactive power load including reactive power loss beyond node 2.

Thus $\Delta x= IR\cos (\theta_2) + IX\sin (\theta_2)= (P_2R+Q_2X)/ V_2$

$\Delta y= IX\cos (\theta_2) - IR\sin (\theta_2)$

$= (P_2X- Q_2R)/V2$

Thus equation 3.4 becomes

$$V_1^2=((V_2+ (P_2R+ Q_2X)/ V_2) + ((P_2X- Q_2R)/ V_2))^2$$

$$= (V_2^2+ (P_2R+ Q_2X)^2/ V_2^2+ (P_2R- Q_2X)^2/ V_2^2$$

$$V_1^2 V_2^2= V_2^4+ (P_2R + Q_2X)^2+2 V_2^2 (P_2R+ Q_2X)+(P_2X- Q_2R)^2$$

$$V_2^4+ 2 V_2^4 (P_2R+ Q_2X) + (P_2^2+ Q_2^2) (R_2^2+X_2^2) - V_1^2 V_2^2=0$$

$$V_2^4+ 2 V_2^2 (P_2R+ Q_2X-V_1^2/2) + (P_2^2+ Q_22) (R_2^2+X_2^2)=0 \tag{4.5}$$

Equation 4.5 is in the form of $ax^2+bx+c=0$, the roots of this equation are

(-b+ (b2-4ac)1/2)/2a and (-b-(b2-4ac)1/2)/2a.

From the two solutions for V^2 only positive root of quadratic equations gives a realistic value. Thus V^2 is solved as follows:

$$V^2= \{[(P_2R+ Q_2X+0.5V12) - (P_2^2+ Q_2^2)(R22+X22)]1/2- P_2R+ Q_2X+0.5V_1^2)\}^{½} \tag{4.6}$$

This is straightforward solution and doesn't depend on the phase angle, which simplifies the formulation of the problem. In distribution system the voltage angle is not so important because the variation of voltage angle from the substation to tail of distribution feeder is only few degrees. However, if complex power flows in lines are required phase angles also considered.

The equation 4.6 can be written in general form as

$$V_2= (B[j]-A[j])^{1/2} \quad (4.7)$$

Where subscript '2' is the receiving end of j^{th} branch.

subscript '1' is the sending end of j^{th} branch.

$$A[j] = P_2R[j] +Q_2X[j]-0.5V_1^2 \quad (4.8)$$

$$B[j] = [A[j]^2- (P_2^2+Q_2^2) (R[j]^2+X[j]^2)]^{1/2} \quad (4.9)$$

Where P_2 and Q_2 are total real and reactive power load feed through node 2

After calculating the effective loads at all nodes, the voltages can be calculated using equations 4.7,4.8 and4. 9. Let Ploss[j] and Qloss[j] be the real and reactive power loss of branch 'j', then the initial estimates of loads are taken as the loads are taken as the effective loads at all nodes and then losses are calculated using the equations

$$Ploss[j] =R[j]* (P_2^2+ Q_2^2)/ V_2^2 \quad (4.10)$$

$$Qloss[j] =X[j]* (P_2^2+ Q_2^2)/ V_2^2 \quad (4.11)$$

$$\text{Angle } \theta_2 =\text{Angle of } V_1-(1/\cos((1-(P_2R_2-Q_2X_2)/(V_2V_1))))$$

4.1.1Current in the branch

$$I_2 = ((P_2^2+ Q_2^2)/ V_2^2)^{1/2}$$

4.1.2 Current Sensitivity Index

CSI = Current at that particular node /Summation of all the current

4.2 Mathematical Model of Radial Distribution Networks

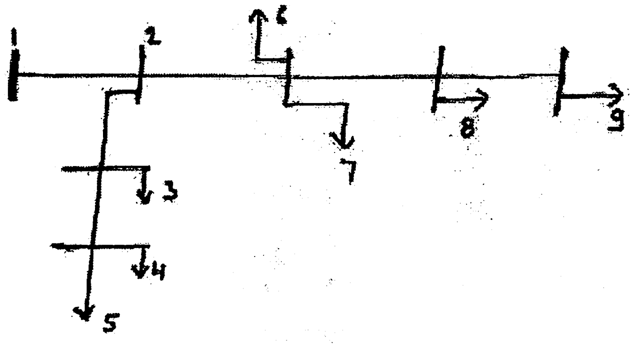


Fig.4.3 Sample Radial Distribution System.

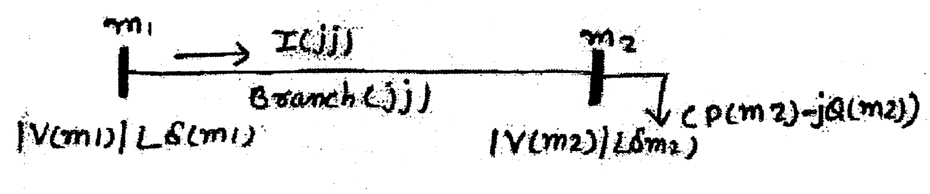


Fig.4.4 Electrical Equivalent of one branch of Fig 4.3

The mathematical model of radial distribution network can be easily derived from fig.4.4.

$$I(jj) = \frac{|V(m1)|\angle\delta(m1) - |V\angle\delta(m2)}{Z(jj)} \qquad \textbf{(4.12)}$$

$$P(m2) - jQ(m2) = V(m2) \times I(jj) \qquad \textbf{(4.13)}$$

Where Z(jj)=R(jj)+|X)jj),m1 and m2 are the sending end and receiving end nodes respectively. (m1=S(jj)) and (m2=R(jj))

P(m2)= sum of the real power loads of all the nodes beyond node m2.

Q(m2)= sum of the reactive power-loads of all the nodes beyond node m2 plus reactive power load of the node m2 itself plus the sum of the reactive power of the reactive power losses of all the branched beyond node m2.

From equations (4.8 & 4.9) we get,

$$|V(m2)| = \sqrt{(B(jj) - A(jj))} \tag{4.14}$$

Where

$$A(jj) = P(m2) \times R(jj) + Q(m2) \times X(jj) - 0.5 \times |V(m1)|^2 \tag{4.15}$$

$$B(jj) = \sqrt{\{A^2(jj) - \{Z^2(jj) \times (P^2(m2) + Q^2(m2))\}\}} \tag{4.16}$$

$$LP(jj) = \frac{R(jj) \times (P^2(m2) + Q^2(m2))}{|V(m2)|^2} \tag{4.17}$$

$$LQ(jj) = \frac{X(jj) \times (P^2(m2) + Q^2(m2))}{|V(m2)|^2} \tag{4.18}$$

$$LQ(jj) = LP(jj) \times 24 \times 365 \tag{4.19}$$

Using equation (4.14), voltage at each receiving end node is computed. The new voltage is compared with the old voltage in each iteration, and if the difference is less the 0.0001 p.u. for each node the algorithm is assumed to have converged. Thus convergence condition is

$|V''(i) - V'(i)| < 0.0001$ p.u. for $i = 1....NN$

Where V(i) and V'(i) are the same node voltages in two successive iterations. To calculate the voltage from equation (4.14) A(jj) and B(jj) should be known and to calculate A(jj) and B(jj) values of P(m2) and Q(m2) should be known. Load Flow Algorithm has been explained in section 4.3

4.3 Load Flow Algorithm

4.3.1 Computation of P(m2) and Q(m2)

Upon carefully analyzing load flow equation 4.14 to 4.19, it can be inferred that efficiency of the Load Flow Algorithm depends on efficient computer logic to find P(m2) and Q(m2). In this section a novel computer algorithm is proposed that makes the Load Flow Algorithm faster. The modified computer logic is presented in this section for automatic computation of

P (m2) and Q (m2), for the requirements of the computer logic presented. In fig.4.4 a sample RDS is considered for explaining the logic. In Table 4.1 branch number, sending end and receiving end nodes of the feeder (Fig. 4.4) are tabulated.

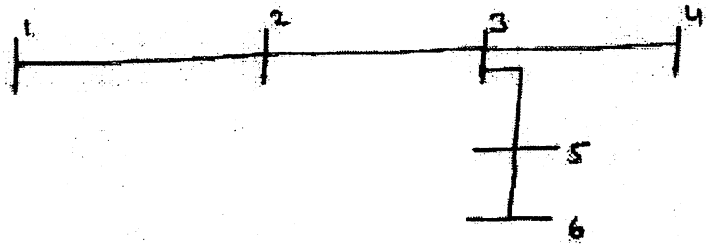


Fig.4.5 Sample Radial Distribution System For Explanation of the Program

Computer program for calculation of P (m2) and Q (m2) is written below and explained for the ease of understanding:

Table 4.1

Sending receiving end data of fig 4.5

Branch No. *Jj*	Sending end node *S(jj)*	Receiving end node R(*jj)*
1	1	2
2	2	3
3	3	4
4	4	5
5	5	6

```
For (i=NN;I>=2;i--)

{

PT[i]=P[i]+PT[i] ;

QT[i]=Q[i]+QT[i] ;
```

```
For(jj=1;jj<LB;jj++)

{

If(i=s(jj))

{

PT[i]=P[i]+PT[r[jj]]+PL[jj] ;

QT[i]=Q[i]+QT[r[jj]]+QL[jj] ;

}

}

}
```

4.3.2 Explanation of the Program written in section 4.3.1.

Each step written in above program in section 4.2(a) is explained now in section 4.2(b). This program is explained using fig. 4.4 from which following variables can be assigned the values as written below.

NN = number of nodes = 6

LB = number of branches = 5

jj = counter of branch (*jj* = 1…5)

i= counter of node (i= 1….6)

1st statement:- *I* = *NN* :- 1:2

In this statement negative sign indicates that counting is in reverse direction i.e. from last node towards the 2nd node (for the example considered counting will be from 6 to 2). Counting of *is* is limited to 2 because 1 is the substation node and voltage of this node is fixed 1<0° p.u. and no load is connected specifically to this node.

I= ;

2^{nd} statement:- PT[i] = P[i] + PT[i]; and

3^{rd} statement:- QT[i] = Q[i] + QT[i];

PT (*i*) is the total real load at *I* and QT (*i*) is the total reactive load at node *I* initially an array of PT (*i*) and QT (*i*) its formed containing zero values before the start of iterations. After every iterations the values of PT (*i*) and QT(*i*) are modified accordingly.

```
 for( i=1; i<NN; i++)

{

PT[i]=0;

QT[i]=0;

}
```

PT = [0 0 0 0 0];   QT = [0 0 0 0 0];

P[*i*] *and* Q[*i*] are the real & reactive loads connected at node *I* and their values are obtained from the data table given for the respective RDS i.e. total power at node *I* is equal to real power load at node i_+ total power at node *I* obtained from previous iteration.

4^{th} statement: - for jj = 1: LB

Jj is the counter for branch. The total number of branches for Fig. 4.1 is 5, i.e., LB = 5

Jj = 1, 2,3,4,5.

5^{th} statement: - if   *I* == s[jj]

S (jj):- is the sending end node for branch jj.

This logic is used to check the connectivity of node *I* with other nodes.

The total real and reactive power at node *i*= Loads connected to node *I* + Load connected to nodes beyond node *I* + Real & power losses of all the branches connected beyond node *i*.

Initially the real & reactive power losses in the branches are assumed zero.

```
for( i=1; i<LB; i++)

{

PL[i]=0;

QL[i]=0;

}

PL = [0 0 0 0 0];  QL = [0 0 0 0 0];
```

Now the computer will do the counting for branches *jj* i.e. -1, 2,3,4,5.

The computer will scan the Table 4.1 and find that node '6' is the sending end node for which branches. It is found from Table 4.1 that node '6' is not sending end node for any of the branches:

∴PT [6] =P [6]

∴QT [6] =Q [6]

I.e. total real & reactive power connected to node 6 will be real & reactive power load connected to this particular node '6' only.

I=5

PT [5] =P [5]+PT [5]

QT [5] =Q [5] +QT[5]

Again the computer will scan the Table 4.1 to check whether node '5' is the sending end node for any of the branches. (I.e. jj= 1, 2, 3, 4, 5). It is found that, node '5' is the sending end node for branch '5' & 6th node is the receiving end for branch 5.

6th and 7th statement:

PT [i] =P [i] +PT[r [jj]] +PL [jj];

QT[i]=Q [i] +QT[r [jj]] +QL [jj];

Where r (jj) is receiving end node of branch jj.

This statement means that total power at node I is equal to total power at node I obtained from, data table + total power at the receiving end node of branch jj for which node I is the sending end node + total real power loss of branch jj.

PT [5] =PT [5] +PT [6] +PL [6]

P [5] =Load at node 5

PT [6)]=Total power at node 6

PL [5] =Power loss of branch 5

QT [5] =Q[5] + QT[6] +QL[6]

I= 4

PT [4] =P [4] +PT [4]

QT [4] =Q [4] +QT [4]

Again the computer will scan the Table 4.1 for jj=1, 2,3,4,5 i.e. for all the branches, '4' is the sending end node for which branch.

Now from Table 4.1 it is observed that node 4 is not the sending end node for any of the branches.

PT [4] =P [4]

QT [4] =Q [4]

I=3

PT [3] =P [3] + PT [3]

QT [3] =Q [3] +QT [3]

Again the computer will scan Table 4.1 to check node '3' is the sending end node for which branches.

It is observed from Table 4.1; node '3' is the sending end node for branch 3 & branch 4.

PT[3]=P[3]+PT[4]+PT[5]+PL[3]+PL[4]

QT[3]=Q[3]+QT[4]+QT[5]+QL[3]+QL[4]

I=2

PT [2] =P [2] +PT [2]

QT [2]=Q [2] +QT [2]

Again the computer will scan Table3.1 for jj=1, 2,3,4,5

From the Table 4.1, it is observed that node ‘2’ is the sending end node for branch 2.

PT [2]=P [2] +PT [3] +PL [2]

QT [2] =Q [2] +QT [3] +QL[2]

Once P (m2) and Q (m2) are computed by the above logic then voltage magnitude at each node, real and reactive power losses are computed using Equation 4.14, 4.18 and 4.19.

Chapter 5

Interpretation of Results

5.1 Result of Load Flow Solution of 33 nodes System

Table 5.1

S.no	Node No.	Voltage Magnitude(p.u.)	Angle
1	1	1	0
2	2	0.997024	-1.8464
3	3	0.982924	-1.8305
4	4	0.975433	-1.8407
5	5	0.96802	-1.8407
6	6	0.949553	-1.8382
7	7	0.946025	-1.8533
8	8	0.932363	-1.8307
9	9	0.926024	-1.8411
10	10	0.92016	-1.8419
11	11	0.918198	-1.8523
12	12	0.916681	-1.8474
13	13	0.910499	-1.8417
14	14	0.908206	-1.8489
15	15	0.906778	-1.8484
16	16	0.905395	-1.8483
17	17	0.903344	-1.8488
18	18	0.90273	-1.8499
19	19	0.996496	-1.8502
20	20	0.992919	-1.8464
21	21	0.992214	-1.8502
22	22	0.991789	-1.8497
23	23	0.979339	-1.8456
24	24	0.972667	-1.842
25	25	0.969342	-1.8463
26	26	0.947625	-1.849
27	27	0.945062	-1.8485
28	28	0.933624	-1.8506
29	29	0.925405	-1.8512
30	30	0.921847	-1.8486
31	31	0.917686	-1.8464
32	32	0.91677	-1.8501
33	33	0.916487	-1.8508

5.1.2 Result of Load Flow Solution of 28 node System

Table 5.2

S.No.	Node No.	Voltage Magnitude(p.u.)	Angle
1	1	1	0
2	2	0.95678	-1.7739
3	3	0.91151	-1.7672
4	4	0.88726	-1.8023
5	5	0.87129	-1.8197
6	6	0.81281	-1.7331
7	7	0.77494	-1.7685
8	8	0.75626	-1.8074
9	9	0.72416	-1.7759
10	10	0.685	-1.8488
11	11	0.66035	-1.7562
12	12	0.64956	-1.7772
13	13	0.62187	-1.8166
14	14	0.60039	-1.7643
15	15	0.58758	-1.7753
16	16	0.57835	-1.8056
17	17	0.57036	-1.8225
18	18	0.5675	-1.8195
19	19	0.9501	-1.841
20	20	0.94787	-1.8332
21	21	0.94509	-1.8474
22	22	0.94309	-1.8461
23	23	0.90572	-1.8463
24	24	0.90195	-1.8361
25	25	0.89877	-1.8434
26	26	0.80928	-1.8416
27	27	0.80807	-1.8395
28	28	0.80751	-1.8471

5.1.3 Result of Load Flow Solution of 10 node System

Table 5.3

S.No.	Node No.	Voltage Magnitude(p.u.)	Angle
1	1	1.0	0
2	2	0.9999999647	-1.8508
3	3	0.9999999366	-1.8508
4	4	0.9999998047	-1.8508
5	5	0.9999997237	-1.8508
6	6	0.9999995583	-1.8508
7	7	0.9999995051	-1.8508
8	8	0.9999994086	-1.8508
9	9	0.9999992502	-1.8508
10	10	0.9999991402	-1.8508

5.2 No. Node Vs CSI/Sending /Receiving End Voltage For 33 node System :

Table 5.4

S.No	**CSI**	**Sending end voltage**	**Receiving end voltage**
1	0.131	1	0.997024
2	0.1167	0.997024	0.982924
3	0.084	0.982924	0.975433
4	0.0799	0.975433	0.96802
5	0.078	0.96802	0.949553
6	0.0367	0.949553	0.946025
7	0.03	0.946025	0.932363
8	0.0232	0.932363	0.926024
9	0.0212	0.926024	0.92016
10	0.0193	0.92016	0.918198
11	0.0177	0.918198	0.916681
12	0.0155	0.916681	0.910499
13	0.0134	0.910499	0.908206
14	0.0089	0.908206	0.906778
15	0.0071	0.906778	0.905395
16	0.0051	0.905395	0.903344
17	0.0031	0.903344	0.90273
18	0.00113	0.90273	0.996496
19	0.0085	0.997024	0.992919
20	0.0056	0.992919	0.992214

21	0.0028	0.992214	0.991789
22	0.0302	0.991789	0.979339
23	0.0272	0.982924	0.972667
24	0.0136	0.972667	0.969342
25	0.0407	0.969342	0.947625
26	0.0389	0.949553	0.945062
27	0.0372	0.945062	0.933624
28	0.0355	0.933624	0.925405
29	0.0315	0.925405	0.921847
30	0.0146	0.921847	0.917686
31	0.0094	0.917686	0.91677
32	0.0022	0.91677	0.916487

5.2.1 Graph Between No. Node and Voltage Magnitude/ CSI

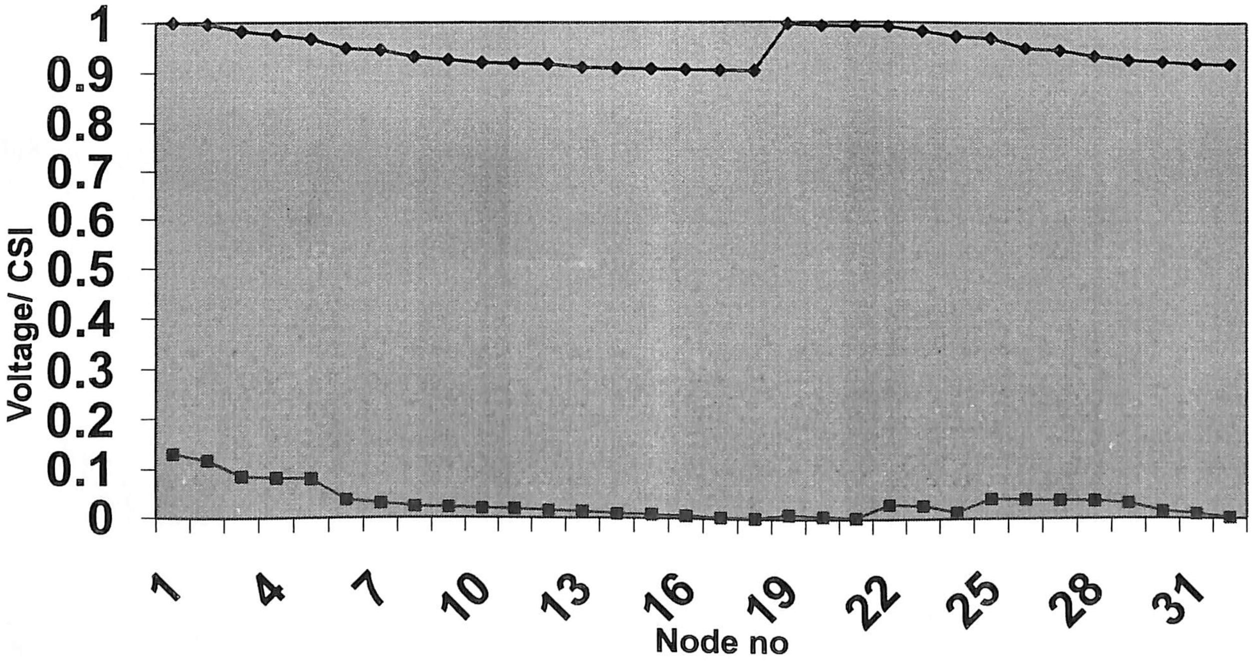


Fig 5.1 Graph Between No.of Node and Voltage magnitude/CSI

5.2.2 Graph Between No. Node and Voltage Angle / CSI

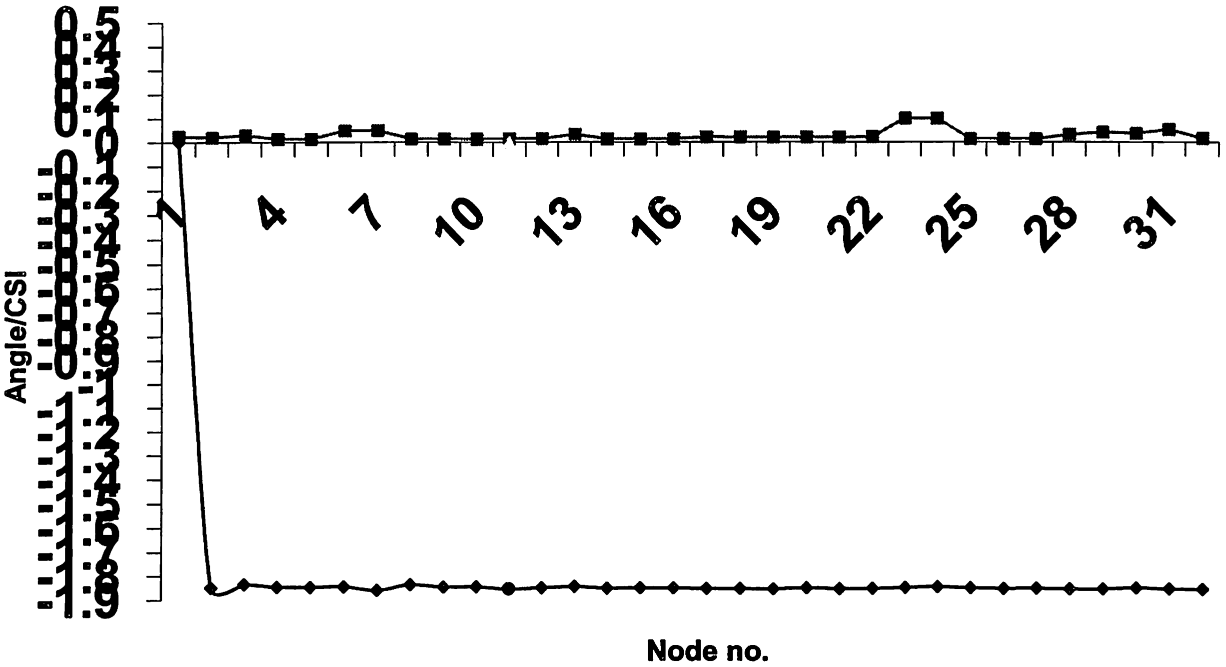


Fig 5.2 Graph Between No. Node and Angle of each node / CSI

5.3 No. Node Vs CSI/Sending /Receiving End Voltage For 10 Node System :

Table 5.5

S.No	CSI	Sending end voltage	Receiving end voltage
1	0.2538	1	0.9999999647
2	0.2171	0.9999999647	0.9999999366
3	0.1969	0.9999999366	0.9999998047
4	0.1613	0.9999998047	0.9999997237
5	0.1216	0.9999997237	0.9999995583
6	0.089	0.9999995583	0.9999995051
7	0.0737	0.9999995051	0.9999994086
8	0.0513	0.9999994086	0.9999992502
9	0.0321	0.9999992502	0.9999991402

5.3.1 Graph Between No. Node and Voltage Magnitude/ CSI

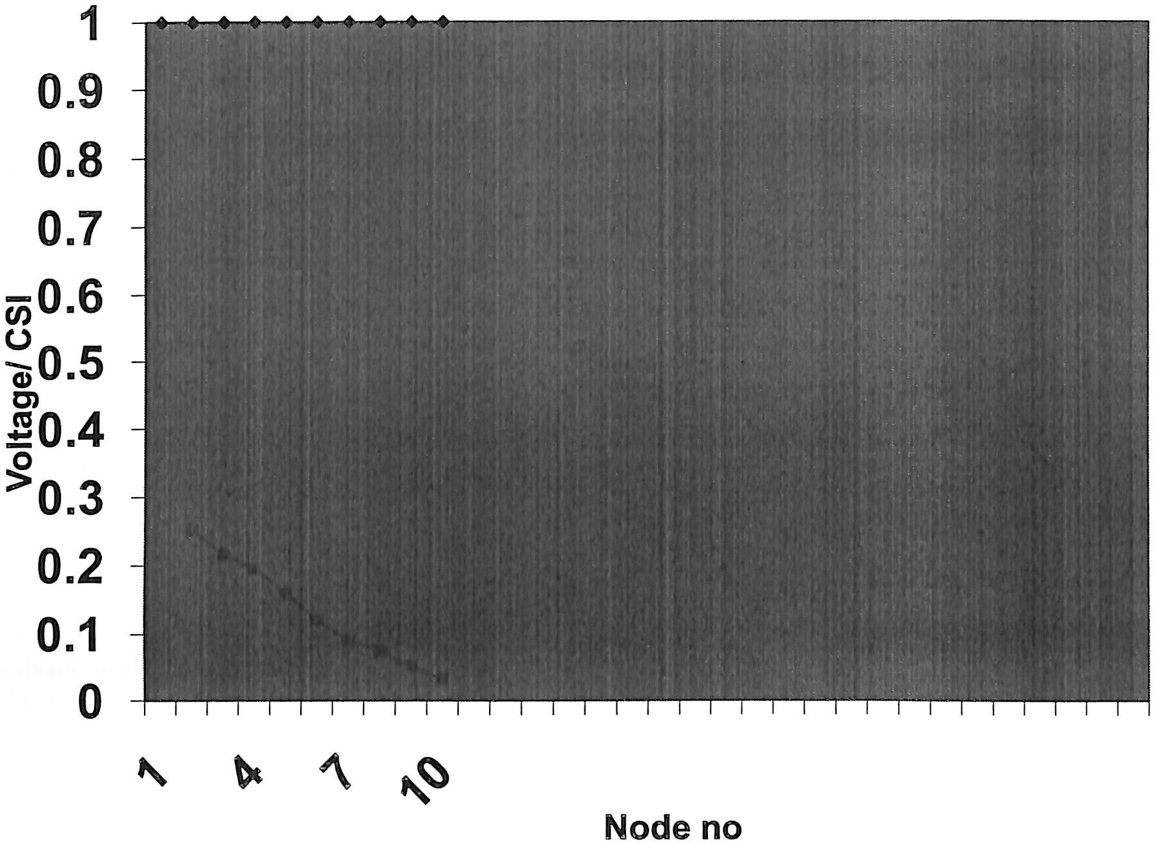


Fig.5.3 Graph Between No. Node Vs Voltage Magnitude / CSI

5.3.2 Graph Between No. Node and Voltage Angle / CSI

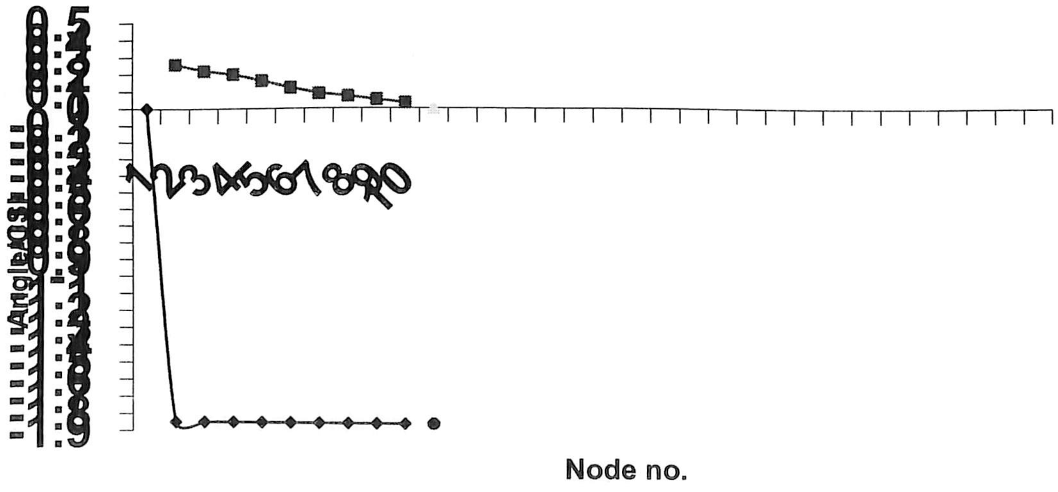


Fig 5.4 Graph Between No.Node Vs Voltage angle / CSI

Table 5.6 Comparison of speed of Proposed method with other existing methods

Proposed method and other method	33-node distribution network		28-node distribution network	
	CPU Time(s)	Iteration no.	CPU Time	Iteration no.
Proposed method	0.0439	2	0.0437	2
K.vinoth Kumar,M.P Selvan,A simplified approach for load flow analysis of RDS	0.047	2	0.078	7
S.Ghosh and D.Das, method for load-flow solution of RDS	0.09	3	0.07	3

Chapter-6

Conclusion and future work

6.1 Conclusion

The research was aimed to develop computationally efficient algorithm for the operation and planning of radial distribution system(RDS). The research work is classified broadly in to :

(1) The algorithms used for the planning and

(2) The algorithm required for the efficient monitoring and secured operation of RDS

This Algorithms may suitable be used for on line and of line as the case may be.

A computationally superior load flow algorithm is proposed that can be used for the planning and operation purpose by utility company. Proposed method is tested on realistic and reported standard RDS to establish the correctness. This Method is tested for 33 –node ,29-node,10-node RDS System and develop a new index Current Sensitivity Index(CSI) for the 33- node and 10 node system. Draw the graph between No. of Node Vs Voltage Magnitude and CSI and No. of Node Vs CSI &Angle.

6.2 Future Scope of Work

Take the CSI as a objective Function to improve the voltage profile of the Radial Distribution System. This is done by using

(1) Reconfiguration of the Network

(2) Placement of the Capacitor

Appendix-A

Input Data of 33 node System

Branch no.jj	Sending End Node S(jj)	Receiving End Node r(jj)	Resistance R(jj) (Ω)	Reactance X(jj)(Ω)	Real Power Load PL(i) (KW)	Reactive Power Load QL(i) (KVAr)
1	1	2	0.0922	0.0477	100	60
2	2	3	0.493	0.2511	90	40
3	3	4	0.366	0.1864	120	80
4	4	5	0.3811	0.1941	60	30
5	5	6	0.819	0.707	60	20
6	6	7	0.1872	0.61188	200	100
7	7	8	1.7114	1.2351	200	100
8	8	9	1.03	0.74	60	20
9	9	10	1.04	0.74	60	20
10	10	11	0.1966	0.065	45	20
11	11	12	0.3744	0.1238	60	35
12	12	13	1.468	1.155	60	35
13	13	14	0.5416	0.7129	120	80
14	14	15	0.591	0.526	60	10
15	15	16	0.7463	0.545	60	20
16	16	17	1.289	1.721	60	20
17	17	18	0.732	0.574	90	40
18	2	19	0.164	0.1565	90	40
19	19	20	1.5042	1.6554	90	40
20	20	21	0.4095	0.4784	90	40
21	21	22	0.7089	0.9373	90	40
22	3	23	0.4512	0.3083	90	50
23	23	24	0.898	0.7091	420	200
24	24	25	0.896	0.7011	420	200
25	6	26	0.203	0.1034	60	25
26	26	27	0.2842	0.1447	60	25
27	27	28	1.059	0.9337	60	20
28	28	29	0.8042	0.7006	120	70
29	29	30	0.5075	0.2585	200	600
30	30	31	0.9744	0.963	150	70
31	31	32	0.3105	0.3619	210	100
32	32	33	0.341	0.5302	60	40

Base voltage =12.66 KV, Base kVA=10

Input Data of 28 node System

Branch no.jj	Sending End Node S(jj)	Receiving End Node r(jj)	Resistance R(jj) (Ω)	Reactance X(jj)(Ω)	Real Power Load PL(i) (KW)	Reactive Power Load QL(i) (KVAr)
1	1	2	1.8218	0.7580	140	90
2	2	3	2.2270	0.9475	80	50
3	3	4	1.3662	0.5685	80	60
4	4	5	0.9180	0.3790	100	60
5	5	6	3.6432	1.5160	80	50
6	6	7	2.7324	1.1370	90	40
7	7	8	1.4573	0.6064	90	40
8	8	9	2.7324	1.1370	80	50
9	9	10	3.6432	1.5160	90	50
10	10	11	2.7520	0.7780	80	50
11	11	12	1.3760	0.3890	80	40
12	12	13	4.1280	1.1670	90	50
13	13	14	4.1280	0.8558	70	40
14	14	15	3.0272	0.7780	70	40
15	15	16	2.7520	1.1670	70	40
16	16	17	4.1280	0.7780	60	30
17	17	18	2.7520	0.7780	60	30
18	2	19	3.4400	0.9725	70	40
19	19	20	1.3760	0.3890	50	30
20	20	21	2.7520	0.7780	50	30
21	21	22	4.9536	1.4004	40	20
22	3	23	3.5776	1.0114	50	30
23	23	24	3.0272	0.8558	50	20
24	24	25	5.5040	1.5560	60	30
25	6	26	2.7520	0.7780	40	20
26	26	27	1.3760	0.3890	40	20
27	27	28	1.3760	0.3890	40	20

Base voltage =11 KV, Base MVA= 100

Data of 10 Node System

Branch no.jj	Sending End Node S(jj)	Receiving End Node r(jj)	Resistance R(jj) (Ω)	Reactance X(jj)(Ω)	Real Power Load PL(i) (KW)	Reactive Power Load QL(i) (KVAr)
1	0	1	0.0007	0.0036	0	0
2	1	2	0.0001	0.0048	0.439	0.109
3	2	3	0.0059	0.00953	0.234	0.0812
4	3	4	0.0052	0.00481	0.427	0.10653
5	4	5	0.0156	0.01367	0.381	0.439
6	5	6	0.00716	0.00624	0.384	0.1433
7	6	7	0.01626	0.00921	0.1863	0.0262
8	7	8	0.0379	0.02149	0.274	0.0143
9	8	9	0.0422	0.0239	0.234	0.031
10	9	10			0.391	0.0477

Base Voltage =11 KV, Base MVA=100 MVA

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