A Method For Selection of Optimal Conductor in Radial Distribution Network

Thesis submitted in partial fulfillment of the requirements for the award of degree of

Masters of Engineering
in
Power System & Electric Drives

Thapar University, Patiala

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Certificate

I hereby certify that the work which is being presented in the thesis entitled **" A method for selection of Optimal Conductor in Radial Distribution Network"** in partial fulfilment of the requirements for the Award of Degree of Masters of Engineering in Power System & Electric Drives submitted in Electrical & Instrumentation Department , Thapar University, Patiala, is an authentic record of my own work carried under the supervision of **Dr. Smarajit Ghosh, Prof. and Head EIED.**

The matter presented in this thesis has not been submitted for the award of any other degree of this and any other university.

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This is to certify that the above statement made by the candidate is correct and to the best of my knowledge.

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Last but not the least, my family and the one above all of us, the omnipresent God, for answering my prayers for giving me the strength to plod on despite my constitution wanting to give up and throw in the towel, thank you so much Dear Lord.

TANVI PAUL

Abstract

The demand for electrical energy is ever increasing. Today over 21% (apart from theft) of the total electrical energy generated in India is lost in transmission (4-6%) and distribution (15-18%). The electrical power deficit in the country is currently about 18%. Clearly, reduction in distribution losses can reduce this deficit significantly.

The main reason for having high losses in developing countries like India is stretching of distribution lines beyond the limits of load centres, increase of load abnormally without considering the current carrying capacity of the conductors and imbalance of generation and load causing reactive power generation, etc.

The optimal conductor type should be determined for each feeder segment to maintain an acceptable voltage profile along the entire feeders, minimizing capital investments and the cost of feeder losses.

The ultimate aim of this thesis work is to plan distribution networks which satisfy the growing demand for electricity, fulfill specific technical operational constraints and which are also characterized by the minimum overall cost and losses.

In this Thesis, a method of optimal conductor selection has been proposed based on stability index and the variation of temperature and its effect on resistance has been incorporated. One example of 20-node radial distribution network has been considered. Results shows that the selection of non uniform conductor reduces the losses compared to the uniform conductor. Obviously the planning cost will also be reduced.

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NB	Total number of Nodes
LN1	Total number of Branches
jj	Branch number i.e., jj = 1,2,3,……LN1
m1	IS(jj) be the sending node of branch jj
m2	IR(jj) be the receiving end node of branch jj
V(m1)	voltage of sending end node of branch jj
V(m2)	voltage of receiving end node of branch jj
R(jj)	resistance of branch jj
X(jj)	reactance of branch jj
Z(jj)	impedance of branch jj
LP(jj)	Real power loss of branch jj
LQ(jj)	reactive power loss of branch jj
IL	Load current in node i
DVMAX	Maximum voltage difference
C1	Composite cost of losses (Rs per kW)
R(k)	Per unit resistances
L(i)	Length of feeder segment i
P(i)	Power flow through segment i (kVA)
D	Levelized annual demand cost of losses per kW
LSF	Loss factor
E	Energy cost of losses (Rs/ kWh)
PP(k)	Purchase price of conductor k (Rs/ Unit length)
CC	Carrying charge rate (feeders)
NTYPE	Total number of conductors

CHAPTER 1
INTRODUCTION

1.1 Distribution System

In general, the definition of an electric power system includes a generation, a transmission and a distribution system. The distribution system was estimated to be roughly equal in capital investment to the generation facilities, and together they represented over 80 percent of the total system investment.

It is essential to assure that the growing demand for electricity can be satisfied by distribution system additions which are both technically adequate and reasonably economical.

Power distribution is the final and most significant link in the electricity supply chain and, unfortunately, the weakest one in the country. The sector is facing the problem of high distribution losses (30% overall) along with theft of electricity, low metering levels and poor financial health of utilities with low cost recovery. It assumes great importance as the distribution segment has a great impact on the sector's commercial success, and ultimately on the consumers who pay for power services. Due to the above, the distribution companies have not been able to undertake corresponding investments in infrastructure augmentation.

The distribution segment continues to carry electricity from the point where transmission leaves off, that is, at the 66/33 kV level. The standard voltages on the distribution side are therefore 66kV, 33 kV, 22 kV, 11 kV and 400/230 volts, besides 6.6 kV, 3.3 kV and 2.2 kV. Depending upon the power and the distance involved, lines of appropriate voltages are laid. The main distribution equipment comprises HT and LT lines, transformers, substations, switchgears, capacitors, conductors and meters. HT lines supply electricity to industrial consumers while LT lines carry it to residential and commercial consumers.

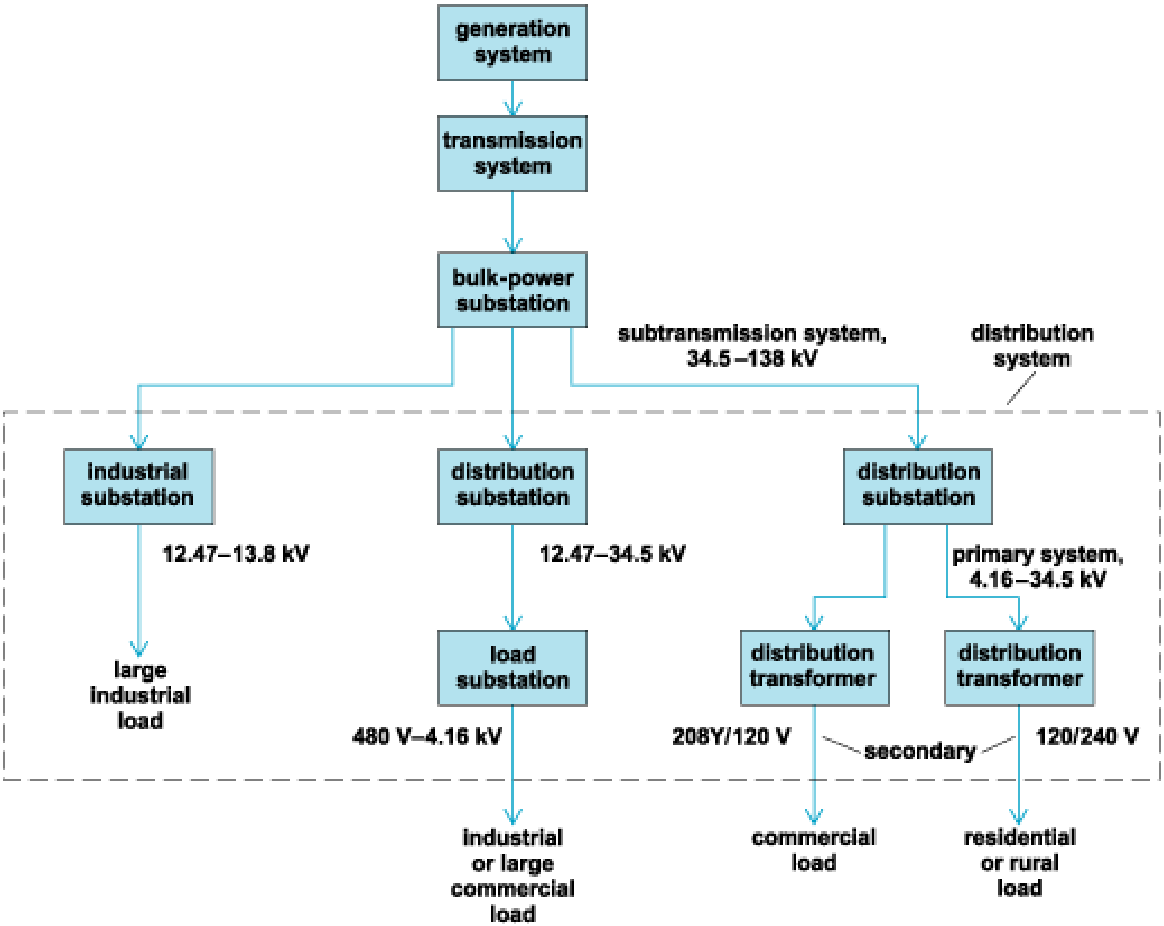

FIGURE 1.1 ELECTRICAL DISTRIBUTION SYSTEM IN INDIA

1.2 Distribution System Considerations

In determining the design of distribution systems, three broad classifications of choices need to be considered:

1. The type of electric system: dc or ac, and if ac, single-phase or polyphase.
2. The type of delivery system: radial, loop, or network.
3. The type of construction: overhead or underground.

1.2.1 Desired Features

Electrical energy may be distributed over two or more wires. The principal features desired are safety, smooth and even flow of power, and economy.

Safety

The voltage should be low enough to be safe when the electric energy is used by the ordinary consumer.

Smooth and Even Flow of Power

Power flow should be steady, uniform, non-fluctuating for lighting and for the operation of motors for power purposes.

Although a direct current system fills these requirements positively, but the distance over which we can economically supply power at utilization voltage is limited.

Alternating current systems deliver power in a fluctuating manner following the cyclic variations of the voltage generated. Such fluctuations of power are not objectionable for heating, lighting and small motors, but are not entirely satisfactory for the operation of some devices such as large motors, which must deliver mechanical power steadily and therefore require a steady input of electric power. This may be done by supplying electricity to the motors by two or three circuits, each supplying a portion of the power, whose fluctuations are purposely made not to occur at the same time, thereby decreasing or damping out the effect of the fluctuations. These two or three separate alternating current circuits (each often referred to as a single-phase circuit) are combined into one polyphase (two- or three-phase) circuit. The voltages for polyphase circuits or systems are supplied from polyphase generators.

Economy

The use of conductors should be minimum for delivery of electric energy. This requires the use of higher voltages where conditions permit and the elimination of some conductors by providing a common return path for two or more circuits.

1.3 Types Of Electric Systems

1.3.1 Direct Current Systems

Direct current systems are essentially the same as single phase ac systems of two or three wires. It usually consist of two or three wires. This type of distribution systems are no longer employed, except in very special cases like older systems which now exist and will continue to exist for some time.

1.3.2 Alternating Current Single-Phase Systems

Two-wire Systems

This is the simplest and oldest circuit which consists of two conductors between which a constant voltage is maintained and the load is connected between the two conductors.

In most of the cases, one conductor is grounded. The grounding of one conductor, called the neutral, is basically for safety purpose. When the live conductor come in contact accidentally with the neutral conductor, the voltage of the live conductor will be dissipated through-out a large body of earth and therefore is harmless.

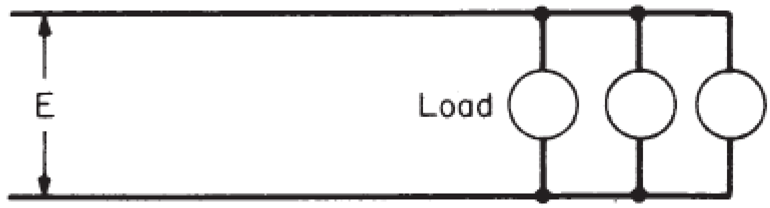

FIGURE 1.2 AC SINGLE PHASE TWO-WIRE SYSTEM

Three-wire Systems

Three-wire system is a combination of two two-wire systems with a single wire serving as the neutral of each of the two-wire systems. At a given instant, if one of the live conductors is *E* volts (say 120 V) “above” the neutral, the other live conductor will be *E* volts (120 V) “below” the neutral, then the voltage between the two live (or outside) conductors will be *2E* (240 V).

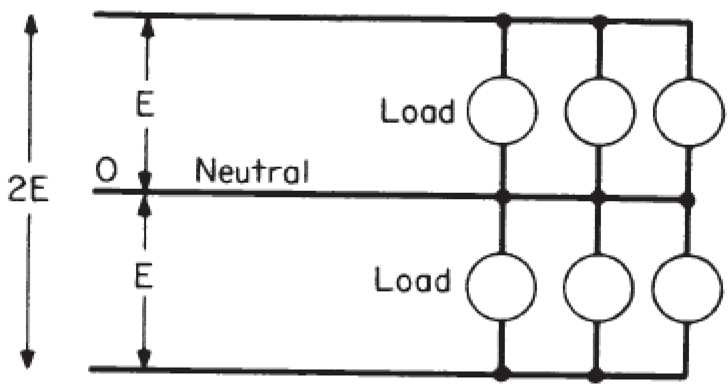

FIGURE 1.3 AC SINGLE PHASE THREE WIRE SYSTEM

Series Systems

It consists of a single-conductor loop in which the current is maintained at a constant value and the loads are connected in series. The voltage between the conductors at the source depends on the amount of load connected beyond that point. The voltage at the source is equal to the vectorial sum of the voltages across the various loads and the voltage drop in the conductor.

The voltage drop in each section of the conductor depends on the current flowing in it and the impedance of that section of the conductor. The power supplied to the circuit is equal to the sum of the power for the individual units of load and the line losses. Power loss in each section of the conductor will depend on the square of the current and the resistance of that section of the conductor. The series type of circuit is used for street lighting and, although being rapidly replaced by multiple-circuit lighting, but still exists in substantial numbers.

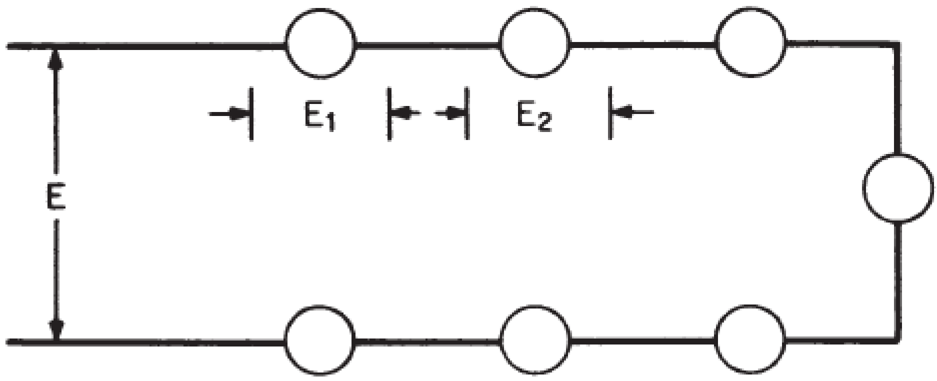

FIGURE 1.4 SERIES SYSTEM

1.3.3 Alternating Current Two-phase Systems

The demand for two-phase system is rapidly decreasing , but a good number of them exist and may continue to exist for some time.

Four-wire Systems

The four-wire system consists of two single-phase two-wire systems in which the voltage in one system is 90° out of phase with the voltage in the other system and are usually supplied from the same generator.

To determine the power, power loss and voltage drops in such a system, the values are calculated as for two separate single-phase two wire systems.

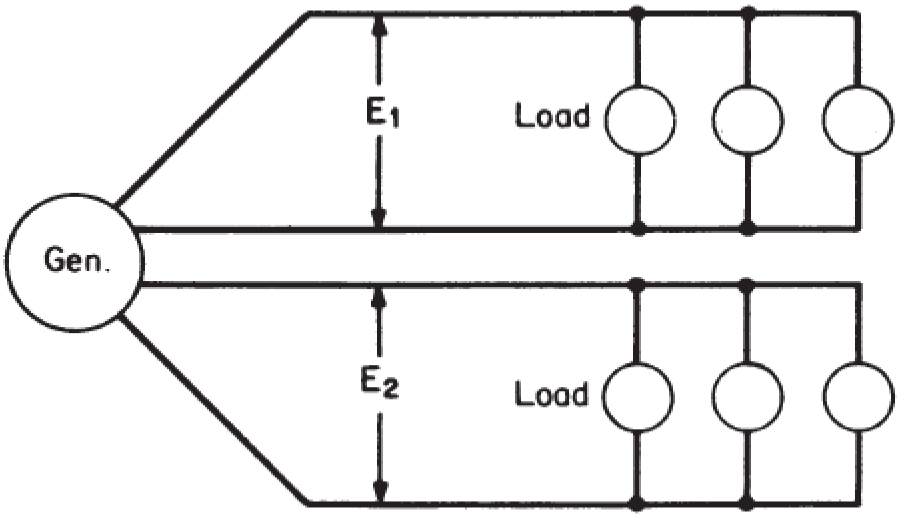

FIGURE 1.5 AC TWO PHASE FOUR WIRE SYSTEM

Three-wire Systems

The three-wire system is equivalent to a four-wire two-phase system, with one wire called neutral made common to both phase. The current in the outside or phase wires is the same as in the four-wire system. The current in the common wire is the vector sum of these currents but opposite in phase. When the load is exactly balanced in the two phases, these currents are equal and 90° out of phase with each other and the resultant neutral current is equal to √2 or 1.41 times the phase current.

The voltage between phase wires and common wire is the normal phase voltage, and, neglecting the difference in neutral IR drop, the same as in the four-wire system. The voltage between phase wires is equal to √2 or 1.41 times that voltage.

The power delivered is equal to the sum of the powers delivered by the two phases. The power loss is equal to the sum of the power losses in each of the three wires.

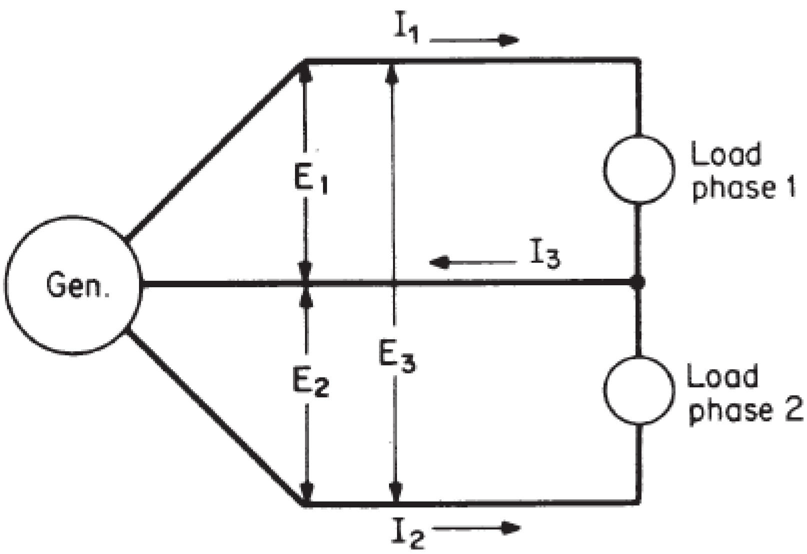

FIGURE 1.6 AC TWO PHASE THREE WIRE SYSTEM

1.4 Substations

The distribution substation transforms the transmission voltage to the proper distribution voltage levels and protects the substation and transmission lines against faults occurring in the feeder circuits. The power source may be generators connected directly to distribution centres. This eliminates the need for substations because the generator generates a usable voltage.

1.4.1 Substation Bus Configuration Design

The substation bus configurations are discussed in this section. The connections of the different switchgear system are also highlighted in this section. The sequential operations of these protective equipments are given. This section deals with the internal substation bus connection deals. Also deal with the substation external connection configurations with the sub-transmission system.

Single (Radial) Bus Scheme

Incoming and outgoing lines, transformers and shunt capacitor banks are shown connected to the bus. The connections are achieved through circuit breakers, circuit switchers, and motor/manually-operated disconnecting switches. A normally opened (N.O.) bypass switch is used to keep the CB line circuit energized. However, to perform CB maintenance, one should isolate the CB and its disconnecting switches, as well as the relays and the control equipment by operating the bypass switch in the closed mode (after opening the CB). It should be mentioned here that this circuit is no longer protected and any fault occurring in this circuit requires the main CB (incoming line CB) to be opened and hence a complete substation outage.

Advantages:

1. Simplest to operate and to install protective relaying
2. Lowest cost and the least land area requirement

Drawbacks:

1. Least system reliability
2. Least system flexibility for operation and maintenance
3. Complete substation outages in case of bus fault or CB failure
4. Requires complete substation shutdown for bus extension
5. Used to supply non-critical loads or in case of other supply existence

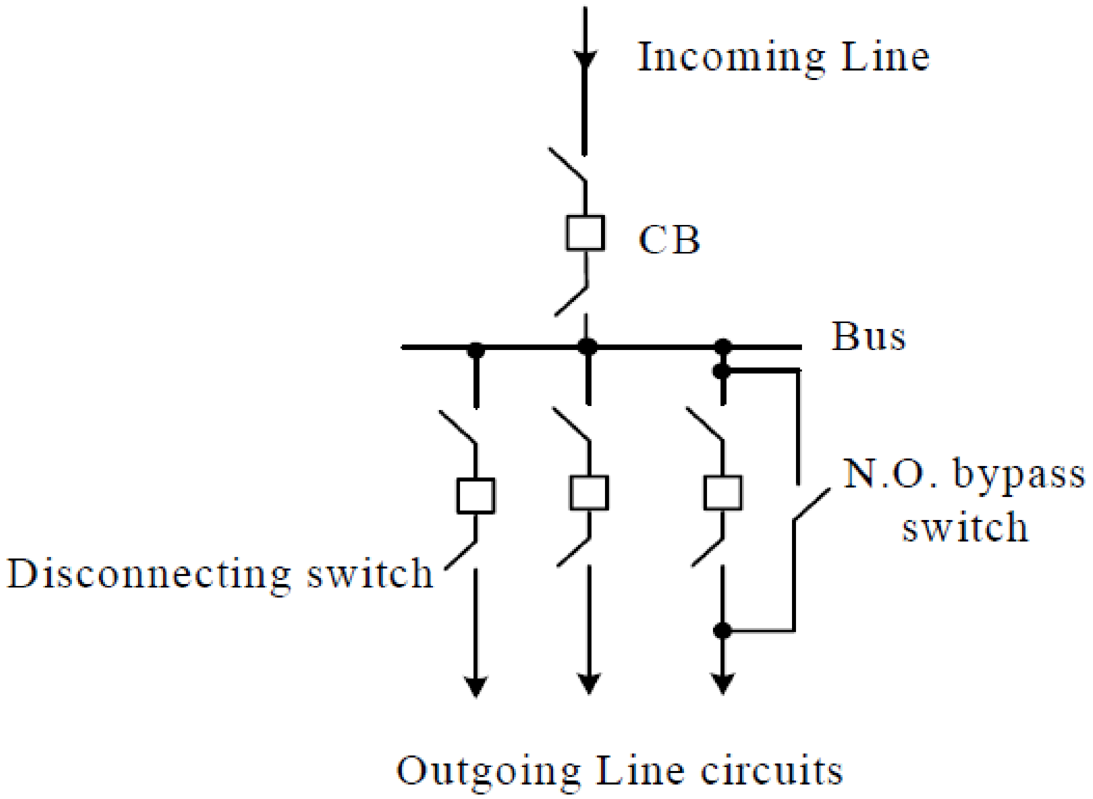

FIGURE 1.7 SINGLE BUS SCHEME

Sectionalized Single (Radial) Bus Scheme

This scheme is the modification of the single bus scheme. It consists of two single bus schemes connected by a normally opened (N.O.) or normally closed (N.C.) sectionalizing switch or bus tie CB. Therefore, circuits supplying the same loads and energized from the same source have to be divided between different sections. The range of operation of voltage level and location is similar to that of the radial scheme. In addition, CB bypass switches can be used.

Advantages:

1. A CB (other than tie CB) failure causes an outage only in its sectionalized section
2. Low required land area
3. More reliable, flexible and easier to expand than the radial scheme

Drawbacks:

1. More complex in operation and protection. More expensive than the radial scheme.

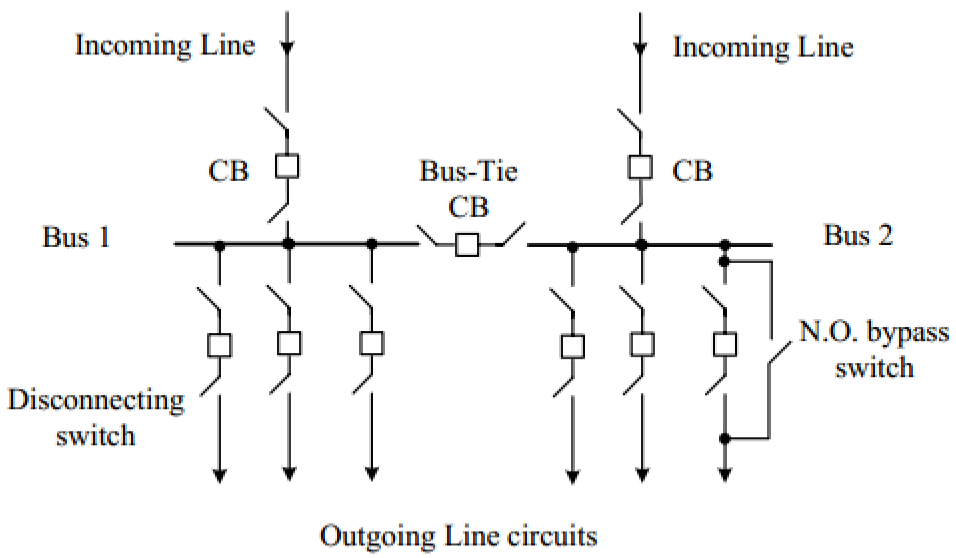

FIGURE 1.8 SECTIONALIZED SINGLE BUS SCHEME

Main-And-Transfer Bus Scheme

It consists of main and transfer buses connected through a N.O. transfer CB. Its operation voltage level and location is similar to that of the radial scheme.

Advantages:

1. Small land area requirement
2. Easier for expansion
3. More flexible in operation and maintenance requirement
4. Low cost
5. CB can be easily removed for maintenance

Drawbacks:

1. Higher cost as it requires a bus transfer CB
2. Increased complexity of operation and protection especially in a CB maintenance Situation
3. No reliability improvement
4. Complete substation shutdown in case of bus or any CB failure

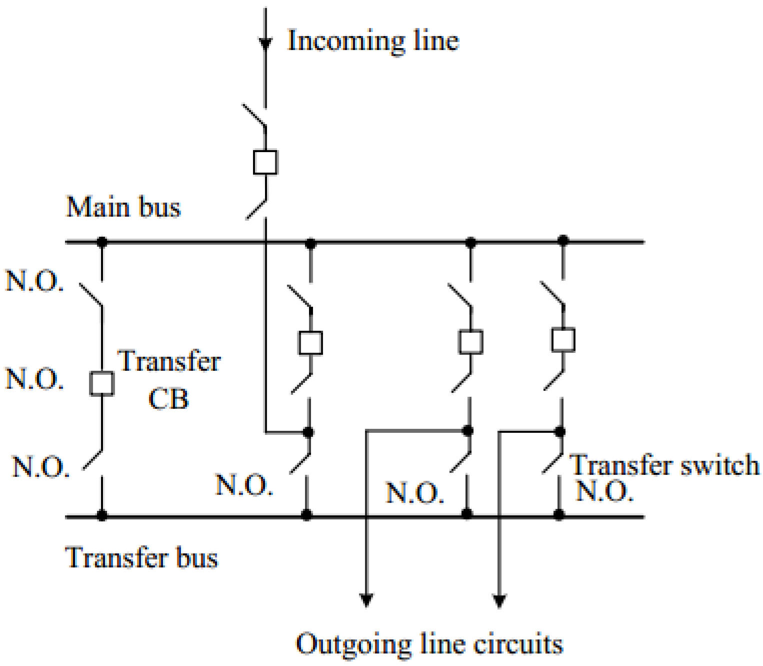

FIGURE NO 1.9 MAIN AND TRANSFER BUS SCHEME

Double Bus-Single Breaker Scheme

This scheme is the modification of the sectionalized single bus scheme where two buses are connected through a tie breaker. It has the same voltage range and location as of the sectionalized single bus schemes. Each circuit can be connected to one bus through CB and disconnecting switches.

Advantages:

1. Loads can be connected on either bus to balance the load and source
2. All loads can be connected to one bus in case of outage or maintenance on the other bus
3. Critical loads can be separated
4. Flexible operation with two buses

Drawbacks:

1. Switching circuits between buses is manual and not automatic
2. More expensive (One tie breaker and four disconnecting switches per circuit)
3. More complex protection model than that of the sectionalized single bus scheme
4. A complete substation outage occurs in case of tie breaker failure

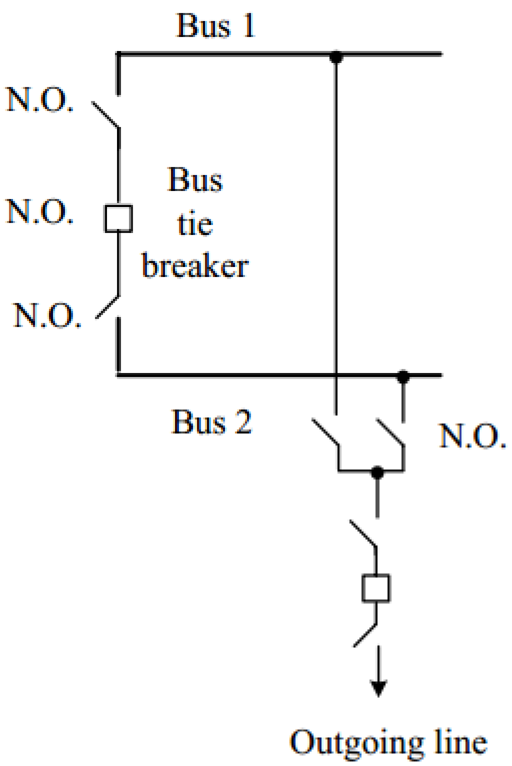

FIGURE 1.10 DOUBLE BUS SINGLE BREAKER SCHEME

Ring Bus Scheme

In this scheme several sectionalized single bus schemes (named position) are connected in an series. It is limited to a maximum of eight positions. In the case of occurrence of bus or circuit fault, one position is disconnected through its CB. In the case of CB operation failure two positions are disconnected. Each line is equipped by a disconnecting switch. To make preparations for this line to go out of service: the two CBs are opened first; then the line disconnecting switch is opened; following that the two CBs are closed. This scheme is used when high reliability is required.

Advantages:

1. Low cost
2. High reliability and flexible CB maintenance and operation
3. Any CB can be disconnected for maintenance without circuit outage
4. Easily expandable
5. Each circuit is fed through two CBs

Drawbacks:

1. More complex protection relaying
2. The ring is separated into two sections in case of CB failure during another CB's maintenance

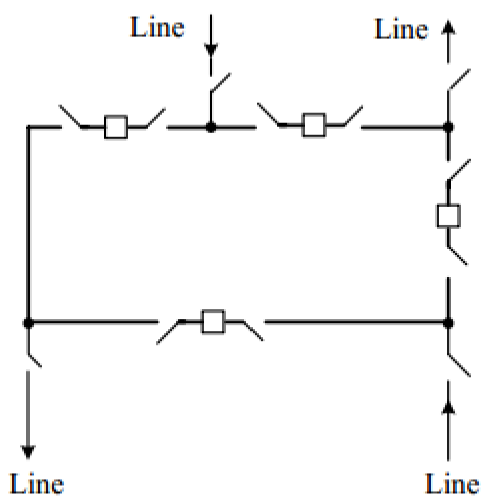

FIGURE 1.11 RING BUS SCHEME

Breaker-And-A-Half Scheme

In this scheme each circuit has its own CB and shares one CB with another circuit (one and one-half CB). A CB failure connecting a bus and circuit causes this circuit to be out of service. A CB operation failure between two circuits causes these two circuits to be out of service. This scheme is utilized for voltages greater than 230 kV and in locations which require high reliability.

Advantages:

1. Any CB can be removed for maintenance without any circuit outage
2. Either bus can be out for maintenance without affecting the operation
3. Bus failure does not cause a circuit outage
4. Most reliable and flexible operation
5. Ease for expansion

Drawbacks:

1. Large required land area
2. High cost (one and half CB is required per circuit)
3. Complex protection relaying

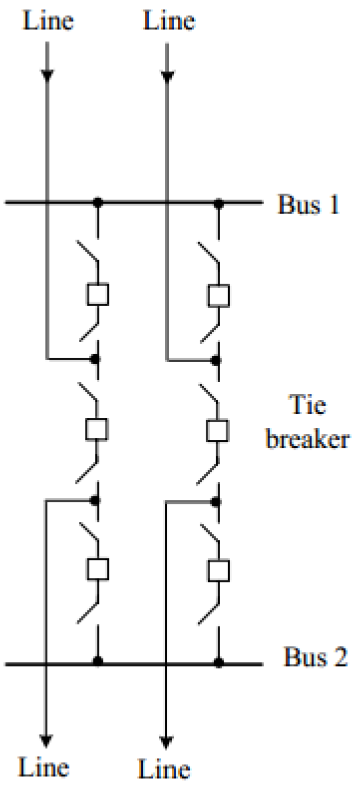

FIGURE 1.12 BREAKER AND A HALF SCHEME

Double Bus-Double Breaker Scheme

For this scheme each circuit has two CBs to connect to either one of the two buses. Each circuit has two CBs. Therefore, only the faulted circuit is disconnected. Furthermore, for a faulted bus no circuit is disconnected. A CB failure to operate in case of a faulted bus causes only one circuit to be out of service.

Advantages:

1. Flexibility in operation and Maintenance
2. Higher reliability

Drawbacks:

1. The most expensive
2. For a CB failure a loss of half the circuit could occur if circuits are not connected to both buses

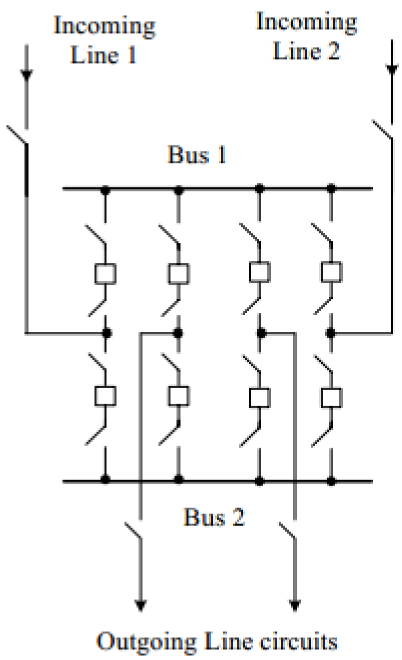

FIGURE 1.13 DOUBLE BUS DOUBLE BREAKER SCHEME

1.5 Types Of Delivery Systems

The delivery of electric energy from the generating plant to the consumer may consist of several more or less distinct parts that are nevertheless somewhat interrelated. The part considered "distribution," i.e., from the bulk supply substation to the meter at the consumer's premises, can be conveniently divided into two subdivisions:

1. Primary distribution, which carries the load at higher than utilization voltages from the substation to the point where the voltage is stepped down to the value at which the energy is utilized by the consumer.

2. Secondary distribution, which includes that part of the system operating at utilization voltages, upto the meter at the consumer's premises.

1.5.1 Primary Distribution

The transmission system voltage is stepped-down to lower levels by distribution substation transformers. The primary distribution system is that portion of the power network between the distribution substation and the utilization transformers. The primary distribution system consists of circuits, referred to as primary or distribution feeders that originate at the secondary bus of the distribution substation. The distribution substation is usually the delivery point of electric power in large industrial or commercial applications.

The primary distribution voltages in widest use are 3.3, 6.6, 11 kV. Primary distribution is carried out by 3-phase, 3-wire system.

Primary distribution systems include three basic types:

a. Radial systems

b. Loop systems

c. Primary network systems

Primary Feeders Primary feeders are those conductors in a distribution system that are connected from the distribution sub-stations and transfer power to the distribution centers. They may be arranged as radial, loop, or network systems and may be overhead or underground.

Radial Distribution System It derives its name from the fact that the feeder radiate from the secondary substation and branches into sub-feeders and laterals which extend into all parts of the area served. This is the most common system used because it is the simple and least expensive to build. It is not the most reliable system because a fault or short circuit in a main feeder may result in a power outage to all the users served by the system. Their service can be improved by installing automatic circuit breakers that will reclose the service at predetermined intervals. If the fault continues after a predetermined number of closures, the breaker will be locked out until the fault is cleared and service is restored.

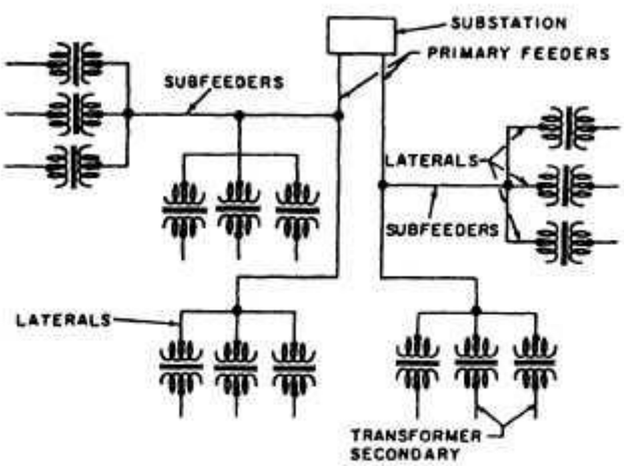

FIGURE 1.14 RADIAL DISTRIBUTION SYSTEM

Primary Loop (or Ring) Distribution System In a loop feeder system, two or more radial feeders originating from the same or different secondary substations are laid on different routes of load areas.

Open Loop System The arrangements having the end of two feeders tied together through normally open switching device is known as open-loop system.

Ring Loop System The arrangement having the ends of two feeders tied together through normally closed switching devices is called ring main feeder or the ring-loop.

The loop system is more expensive to build than the radial type, but it is more reliable and may be successful in areas where continuity of service is required—at a medical centre, for example. In the loop system, circuit breakers sectionalize the loop on both sides of each distribution transformer connected to the loop. A fault in the primary loop is cleared by the breakers in the loop nearest the fault, and power is supplied the other way around the loop without interruption to most of the connected loads. If a fault occurs in a section adjacent to the distribution substation, the entire load can be fed from one direction over one side of the loop until repairs are made.

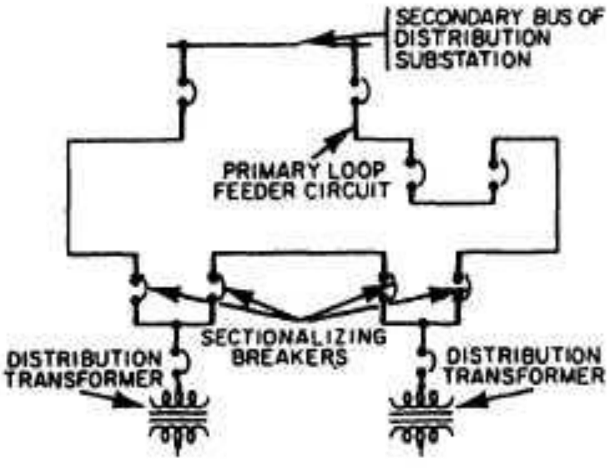

FIGURE 1.15 LOOP DISTRIBUTION SYSTEM

Network System It consist of number of interconnected distribution lines which are supplied from two or more distribution transformers operating in parallel. The network system is the most flexible type of primary feeder system. It provides the best service reliability to the distribution transformers or load centres, especially when the system is supplied from two or more distribution substations. Power can flow from any substation to any distribution transformer or load centre in the network system. The network system is more flexible about load growth than the radial or loop system. Service can readily be extended to additional points of usage with small amounts of new construction. The network system requires large quantities of equipment. That's why more expensive than the radial system.

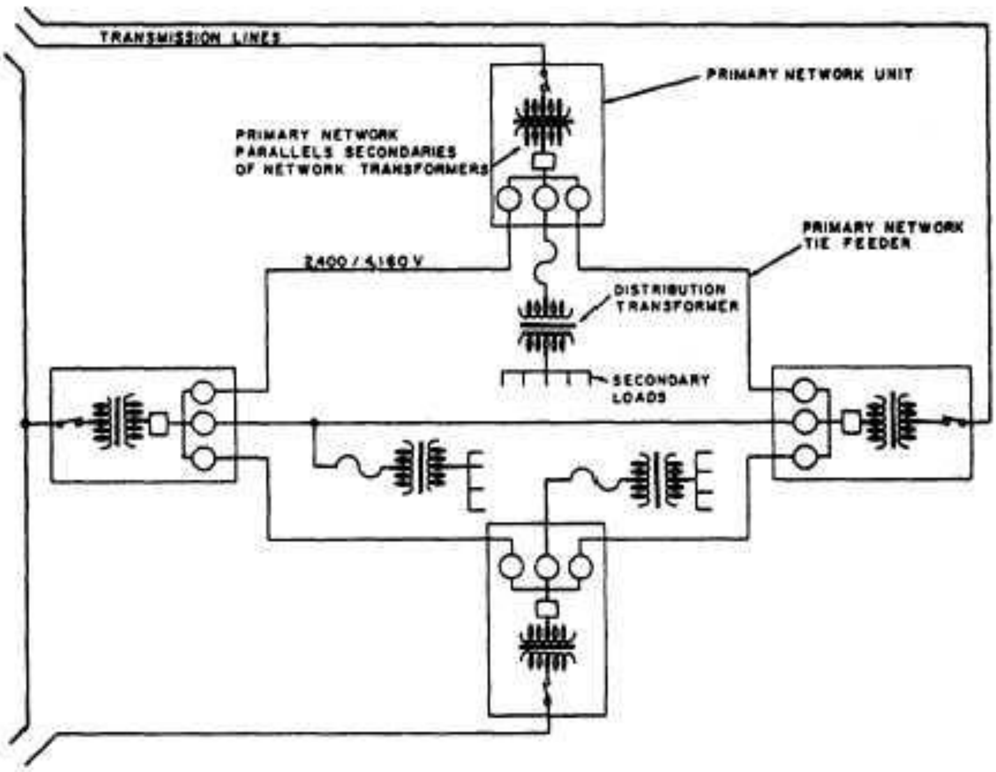

FIGURE 1.16 NETWORK DISTRIBUTION SYSTEM

1.5.2 Secondary Distribution

The secondary distribution system is that portion of the network between the primary feeders and utilization equipment. The secondary system consists of step-down transformers and secondary circuits at utilization voltage levels.

Residential secondary systems are predominantly single-phase, but commercial and industrial systems generally use three-phase power.

The nominal supply for secondary distribution system is 240 V for single-phase and 400 V for 3-phase system.

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

1. An individual transformer for each consumer; i.e. a single service from each transformer.
2. A common secondary main associated with one transformer from which a group of consumers is supplied.
3. A continuous secondary main associated with two or more transformers, connected to the same primary feeder, from which a group of consumers is supplied. This is sometimes known as banking of transformer secondaries.
4. A continuous secondary main or grid fed by a number of transformers, connected to two or more primary feeders, from which a large group of consumers is supplied. This is known as a low-voltage or secondary network.

Each of these types has its application to which it is particularly suited.

Individual Transformer—Single Service

Individual-transformer service is applicable to certain loads such as in rural areas where consumers are far apart and long secondary mains are impractical, or where a particular consumer has an extraordinarily large or unusual load even though situated among a number of ordinary consumers.

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

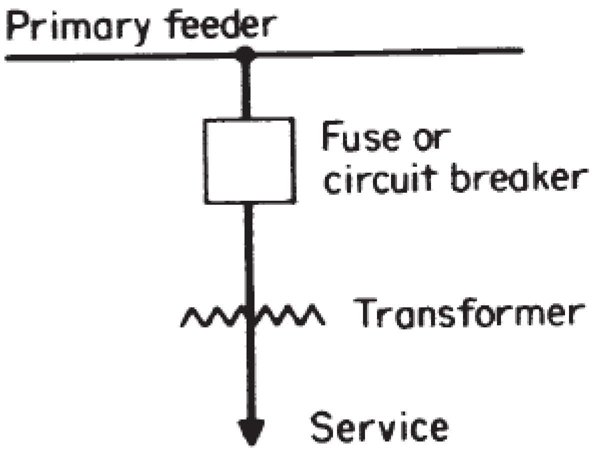

FIGURE 1.17 SINGLE-SERVICE SECONDARY SUPPLY.

Common Secondary Main

The most common type of secondary system in use employs a common secondary main. It takes advantage of diversity between consumer's loads and demands. The larger transformer can accommodate starting currents of motors with less resulting voltage dip than would be the case with small individual transformers.

In many circumstances, the secondary mains installed are more or less continuous, but cut into sections insulated from each other. With change in load, the position of these division points may be readily changed, sometimes delay the need to install additional transformer capacity. Additional separate sections can also be created and a new transformer installed to serve as load or voltage conditions require.

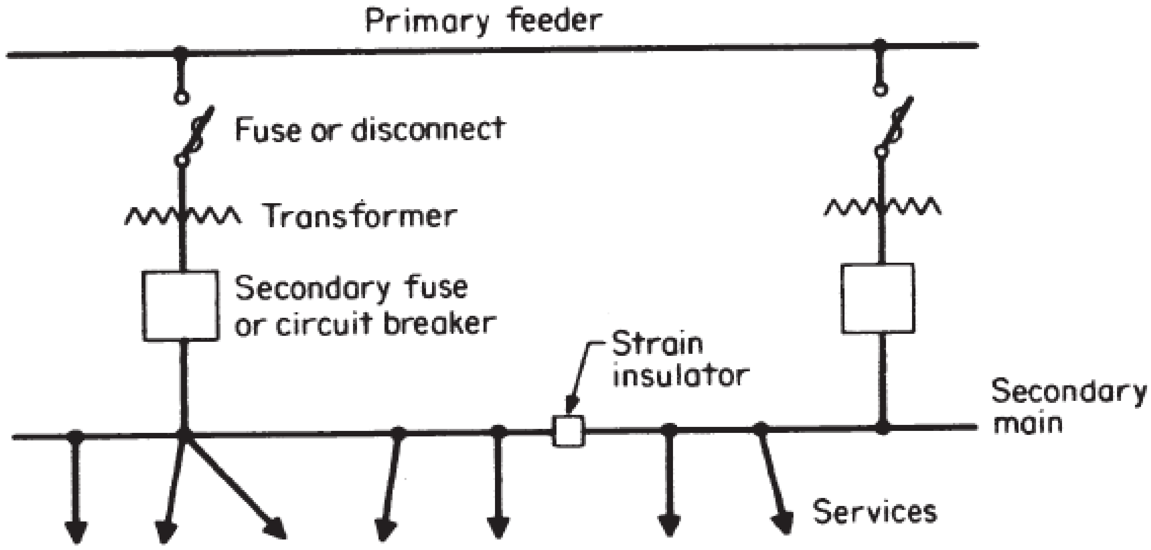

FIGURE 1.18 COMMON-SECONDARY-MAIN SUPPLY

Banked Secondaries

The secondary system employing banked secondaries is not very commonly used but such installations exist and they are usually limited to overhead systems. This type of system can be seen as a single-feeder low-voltage network, and the secondary may be a long section or grid to which the transformers are connected. Fuses or automatic circuit breakers located between the transformer and secondary main serve to clear the transformer from the bank in case of failure of the transformer. Fuses may also be placed in the secondary main between transformer banks.

Some advantages for this type of system include uninterrupted service, but with a reduction in voltage; better distribution of load among transformers; better normal voltage conditions resulting from such load distribution; an ability to accommodate load increases by changing only one or some of the transformers, or by installing a new transformer at some intermediate location without disturbing the existing arrangement; the possibility that diversity between demands on adjacent transformers will reduce the total transformer load; more capacity available for inrush currents that may cause flicker; and more capacity as well to make secondary faults clear.

Some disadvantages of this type of system are as follows: should one transformer fail, the additional loads on adjacent units may cause them to fail, and in turn their loads would cause still other transformers to fail (this is known as cascading); the transformers banked must have nearly the same impedance and other characteristics, or the loads will not be distributed equitably among them; and sufficient reserve capacity must be provided to carry emergency loads safely, obviating the savings possible from the diversity of the demands on the several transformers.

Banked secondaries, providing for failure of transformers, do not provide against faults on the primary main or feeder. A hazard on any transformer disconnected for any reason may result from a back feed if the secondary energizes the primary (which may have been considered safe).

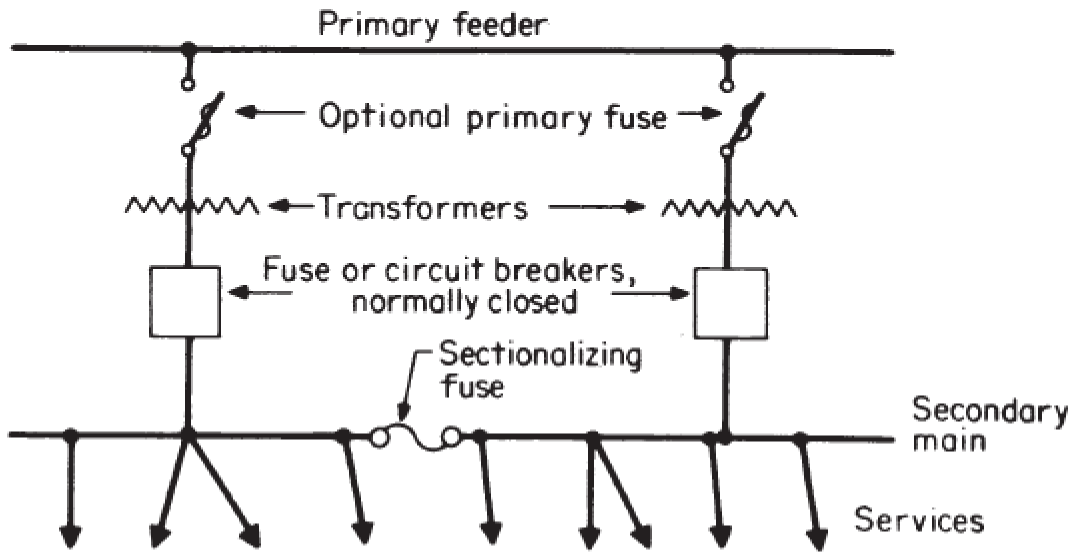

FIGURE 1.19 BANKED SECONDARY SUPPLY

Secondary Networks

Secondary networks at present provide the highest degree of service reliability and serve areas of high load density. In some instances, a single consumer may be supplied from this type of system by what are known as spot networks. In general, the secondary network is created by connecting together the secondary mains fed from transformers supplied by two or more primary feeders. Automatically operated circuit breakers are connected in the secondary connection between the transformer and the secondary mains which is known as network protector. They serve to disconnect the transformer from the network when its primary feeder is de-energized. This prevents a back feed from the secondary into the primary feeder. The circuit breaker or protector is backed up by a fuse so that when the protector fail to operate, the fuse will blow and disconnect the transformer from the secondary mains.

The number of primary feeders supplying a network is very important.With only two feeders, only one feeder may be out of service at a time, and there must be sufficient spare transformer capacity available so as not to overload the units remaining in service; therefore this type of network is sometimes referred to as a single-contingency network.

Most networks are supplied from three or more primary feeders, where the network can operate with the loss of two feeders and the spare transformer capacity can be proportionately less. These are referred to as second-contingency networks.

Because these networks are used for very large loads, their size and capacity may have to be limited to such values as can be successfully handled by the generating or other power sources. When they are de energized, the inrush currents are very large, as diversity among consumers may be lost, and this may be the limiting factor in restricting the size and capacity of such networks.

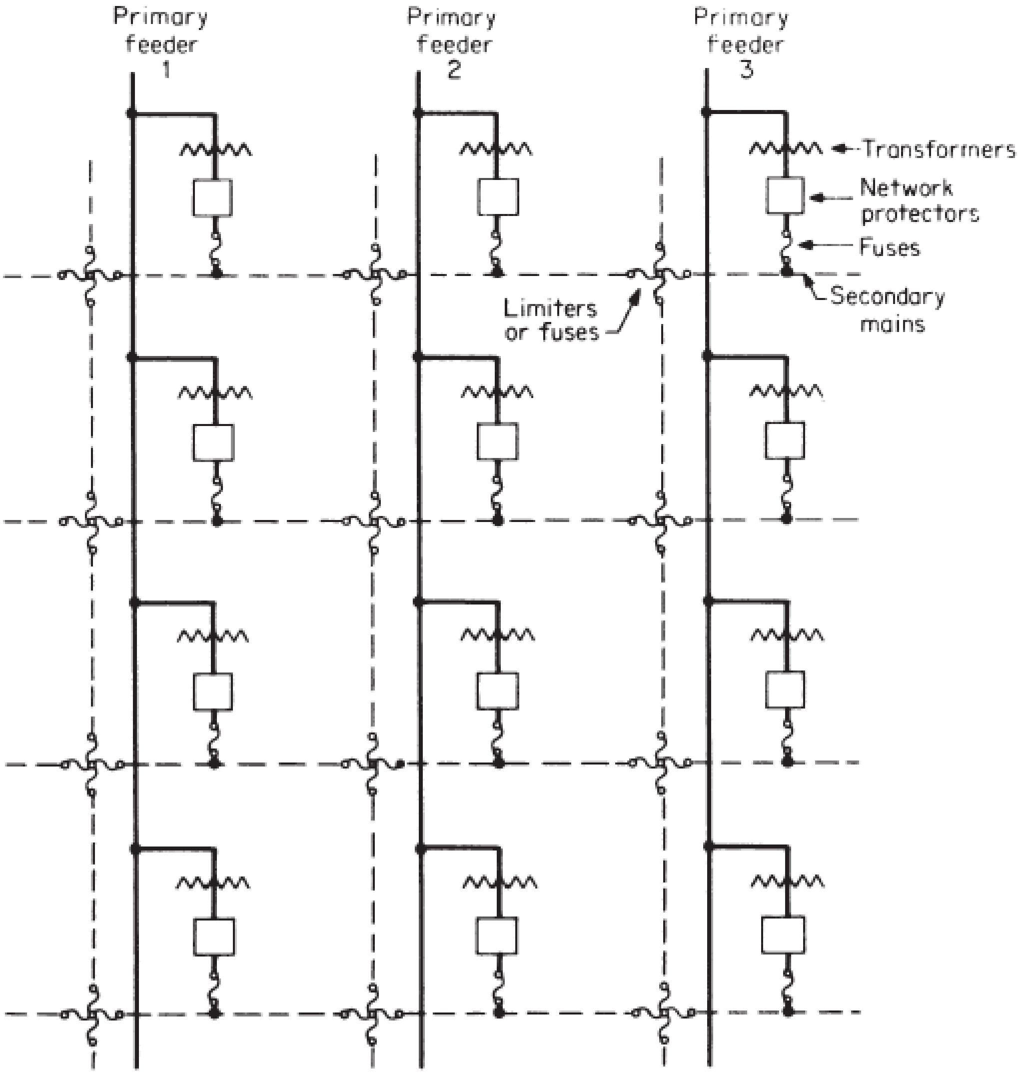

FIGURE 1.20 LOW-VOLTAGE SECONDARY NETWORK

1.6 Overhead Versus Underground

Although the original distribution system introduced by Thomas Edison was a direct current low-voltage system installed underground, the widespread expansion of electric systems was based on the alternating current and overhead type of construction. While the limitation to the adoption of underground systems is economic, there are other reasons that argue against its selection.

1. Underground system require the need of ducts, manholes, and cables that require expensive insulation and lead sheaths and waterproof equipments are required and

safety requirements for installation underground tend to make investment costs several times as great as for overhead systems.

2. When loads become so great such that the number of pole lines and the congestion of conductors on such lines become impractical from safety, operational, and appearance viewpoints, then underground system is used. In such areas, severe traffic conditions arises difficulty in building and maintaining overhead systems. The heavy traffic presents additional hazards from vehicles striking the poles.

3. Although an underground system is not exposed to damage and interruptions from storms, traffic, etc., on the other hand, when trouble does occur, it is very difficult and time-consuming to locate and repair than in the overhead system. For this reason, additional provisions and expenditures are made for maintaining service reliability; these include duplicate facilities, throw over schemes, networks, etc.

4. Also, the lesser ability for heat radiation in an underground system does not permit the loading and overloading of conductors and equipment possible with overhead systems.

5. Because plastics are used for the functions of insulation and sheathing in underground cables which can be buried directly in the ground, the economic advantage of overhead systems is reduced. Environment (appearance) also enhanced the underground installations. Overhead systems will, however, prevail to a very great extent for some time, and will be in almost exclusive use in rural areas.

1.7 Optimal Conductor

The demand for electrical energy is ever increasing. Today over 21% (apart from theft) of the total electrical energy generated in India is lost in transmission (4-6%) and distribution (15-18%). The electrical power deficit in the country is currently about 18%. Clearly, reduction in distribution losses can reduce this deficit significantly.

The main reason for having high losses in developing countries like India is stretching of distribution lines beyond the limits of load centres, increase of load abnormally without considering the current carrying capacity of the conductors and imbalance of generation and load causing reactive power generation, etc.

For any particular situation, there is a site, area and capacity best suited for equipment that meets all criteria and real world conditions. The impact of this approach on the total system cost is minimum. This is ‘optimization’.

Particular area of interest in optimization are

- cost modelling of average networks
- cost modelling of idealized networks
- studies of different network configurations
- optimization of cable or feeder layout to suit a given pattern of substation
- siting and sizing of transformer

The optimal conductor type is determined for each feeder segment to maintain an acceptable voltage profile along the entire feeders, minimizing capital investments and the cost of feeder losses.

Selection of conductors for design and upgrade of distribution systems is an important part of the planning process. An ideal conductor set should have the most economic cost characteristics, sufficient thermal capacity in the largest conductor to take care of situations with very high load and it should provide proper voltage at the farthest end under peak load conditions.

Generally, it is very difficult to select a conductor set which will meet all the criteria of an ideal set and a systematic procedure is not available for selection of a good conductor set. Most utilities choose conductors for their system based on experience and historical applications. Usually, the number of conductors in a set is limited to four or five for proper management of inventory.

1.8 Grading Of Conductors

In normal practise, the conductor used for radial distribution system is of uniform-cross section area. However, the load magnitude at the substation is high and it reduces as we proceed to the tail end of the feeder. This indicate that the use of higher sized conductor, which is capable of supplying load from source point, is not necessary at the tail point.similarly the use different cross-section conductors for the intermediate section will led to a minimum captital investment cost and line losses.

The use of large number of conductors of different cross-sectional area results in increased cost of inventory. A best choice is made in selecting the size of cross-sectional area of optimal design.

1.9 Literature Review

Reference [1-2] are the available books on the electrical distribution system in which the basic concepts of distribution system can be seen.

Funkhouser and Huber [3] suggested a method for determining economical aluminum conductor steel reinforced (ACSR) conductor sizes for distribution systems. In this paper, three conductors (2/0, 266 MCM, 397 MCM) could be standardized and used in combination for the most economical circuit design for the loads to be carried by a 13-kV distribution system. They also mentioned the effect of voltage regulation on the conductor selection process. This method is based on the assumption of uniform load distribution for the feeders. Distribution losses are the major part of the system losses and the capital investment for distribution networks is a considerable part of total capital investment. Therefore, attention has been focused on optimal distribution system planning over the last few years.

Wall and Thomson [4] worked on a primary feeder model using small area demand locations to represent non-uniform loads, and feeder segments having variable distribution costs and limited capacities. A highly efficient transhipment code is used to solve the model which incorporates several recent significant advances thereby decreasing the time of solution of such problems. The computer model to be presented is easily capable of calculating a primary feeder design involving 1000 demand locations and 2000 primary feeder segments and 100 stations.

Ponnavaikko and Rao [5], [6] & [8] suggested an optimal conductor gradation procedure for radial distribution feeders. They represent models to define feeder cost, energy loss cost and voltage regulation as a function of conductor cross-section and an objective function for optimizing the conductor cross-section have been formulated. The problem is based on the multistage decision dynamic programming method and the optimal conductor cross- sections for the feeder segments are obtained by this. They consider the non-uniform distribution of loads along the length of the feeders and also the maximum permissible voltage drop along a feeder. Further, the method takes into account the load growth in future years of the plan period.

Kiran and Adler [7] provided a dynamic model for the development of primary and secondary circuits supplying a residential area. Features of the model which support optimal conductor sizing are the evaluation of annual revenue requirements associated with capital requirement and energy losses as area load evolves.

These revenue requirements are responsive to change in area load (positive or negative) arising with change in the number of residences and change in the load per residence; year by year. Results of optimization trials explore the relative penalties incurred for optimal conductor policies based on incorrect projections of load growth, degree of load management expected, and costs of losses.

Rao [9] suggested a direct solution procedure for conductor grading, thereby eliminating the complexity of the dynamic programming approach. The proposed solution technique is extremely simple, involves very little computation and needs very little computer storage.

When the costs corresponding to different choice of conductor sections are computed for all the feeder segments, it is observed that smaller sections turn out to be economical for the segments near the tail-end of the feeder whereas larger sections result in minimum cost for the segments closer to the substation. The currents in the segments closer to the transformer are larger than the currents in the feeder-end segments. Hence, larger sections would be economical for the source-end segments since they result in lesser losses. Similarly, as the currents are small in the tail-end segments, smaller sections would be economical.

Tram and Wall [10] suggested an efficient computer algorithm for optimal conductor selection to provide feeder voltage support, while recognizing feeder loading requirements. The total cost of capital investment and cost of losses are minimized and they included the lateral branches as well as regulators in this algorithm .This algorithm had been implemented in conjunction with a popular optimal feeder configuration model to provide a powerful tool for the planning of distribution system.

Conductor types were selected based on the need for feeder voltage support as well as the capacity requirements. Motivation behind this additional step is that it might be required to use the larger conductor sizes in order to maintain the voltage down the feeder at an acceptable level. This is especially the case in rural applications where feeders often stretch a long distance to serve very light loads. In this situation the loading on the feeder may very well exceed the limit over which an acceptable voltage level cannot be maintained before it exceed the thermal and economic capacity limit of the conductor.

Salis & Safigianni [11-13] contributed lot of their work on Primary and secondary distribution system analysis and planning. Their method is based on economic criteria leads to a network configuration close to the optimum solution, so that the network has a minimum cost for capital and losses and fulfil the following technical constraints, thermal and economic capacity.

Wang, Liu, Yu, Wang, Song [15] suggested a multi-section, branching feeder model with non-uniform load distribution to best approximate actual conditions found in most distribution systems that had shown how utility engineers could use the proposed method to efficiently select the types and numbers of conductors that are used in a power system. Some fundamental mathematical models developed were employed. The presented approach included an economical current density based method and a heuristic method, which together enabled a satisfactory solution to be quickly achieved. With the standardized types of conductors being considered, the approach stays away from complicated optimization formulations and instead relies on reasonable approximations, and thus makes it very easy for utility engineers to adopt.

Given the feeder configuration, the proposed approach permits for any realistic feeder with:

- lateral branches
- any number of feeder segments
- any number of conductor cross-section areas
- any load distribution.
- To determine the associated conductor cross-sections with the approximately greatest savings.
- This approach is suitable for an inexpensive microcomputer application from the standpoints of memory and time.

Mandal and Pahwa [16] presented a systematic approach for selection of an optimal conductor set. Several financial and engineering factors were considered in his method. His main intention was to arrive at a solution, which could be the most economical when both capital and operating costs are considered. Minimizing the weighted area between the cost characteristics of the conductors and a linear load versus cost representation provided a suitable approach to solve this problem. Analyses showed that fixing a common reach for the conductors before selecting them led to potential savings that would not be available if common reaches were fixed after selecting the conductors.

Kaur and Sharma [17] incorporated the additional factors like cost of power and diversity of load peak at various load points in the model developed in [3] and the problem was reformulated as zero-one integer problem. To reduce the computational efforts, a set of skipping rules was developed. The efficiency and effectiveness of the proposed model was illustrated with the help of two test systems- 19 segments and a large scale 122- segments branched radial system.

Falaghi, Ramezani, Haghifam and Milani [18] suggested a method of the size selection of conductors in radial distribution system by considering the variation of load with time. Maximum saving in capital cost of conductor and energy losses, achieving proper voltages at the buses and maintaining thermal line capacity limit are the objectives of this method.

1.10 Objective Of The Thesis

In this thesis work, the main aim was to develop a computer algorithm for the selection of optimal conductor has been done on the basis stability index. The effect of temperature on resistance of conductor has also been incorporated. The effect of sensitivity index has also been tested. Aim was to reduce the losses and planning cost.

1.11 Structure Of The Thesis

Chapter 1 In this chapter, the various basics of distribution system are explained. Types of existing distribution system models have also been discussed. Literature review done by researchers till date is presented, a through analysis has been done on the existing methods followed by structure of this thesis and objective of the present work.

Chapter 2 In this chapter various assumptions, modified load flow algorithm for optimal branch selection is first explained, followed by constraints concerned to optimal conductor selection. Later on algorithm for optimal conductor selection is demonstrated by one example, 20 node radial distribution network.

Chapter 3 Basing on the observations and results conclusions are made and future scope is presented where certainly the new method needs to improve.

CHAPTER 2

PROPOSED METHOD

2.1 Optimal Branch Conductor Selection

Proper selection of branch conductor for connecting the load point is required because it reduces the planning cost also. Although uniform conductor can reduce the loss of the system, it increases the planning cost. A compromise should be made between loss and cost. To select the optimum conductor selection, the formula proposed by **Tram and Wall [8]** is used with incorporation of change of resistance of conductor with temperature and positive sag. Four different types of conductors **Squirrel, Weasel, Rabbit and Raccon** are considered in this work and the data of these conductors are available in Ranjan et al. [ ].

The data of all conductors are given in **Appendix–A (Table A)**.

The general expression of branch current for branch-jj having k-type conductor is given by

$$I(jj,k) = \sum_{k=1}^{N(jj)} IL\{IE\,(jj,k),k\} \tag{2.1}$$

where

N(jj) is the total number of nodes beyond branch–jj,

IE(jj,k) is the receiving–end node.

The load current of node i is as follows:

$$IL(i,k) = \frac{PL(i) - jQL(i)}{V^{*}(i,k)} \tag{2.2}$$

The voltage of node m2 is given by

$$V(m2) = V(m1) - I(jj)Z(jj) \tag{2.3}$$

where i = 2,3,….NB and k=1,2…..,NTYPE

Equation (2.2) clearly shows that as node voltages are different for different type of conductors, load currents are also different for different type of conductors.

Real and Reactive power losses of branch-jj with k-type conductor are given by:

$$LP(jj,k) = |I(jj,k)|^2 R(jj,k) \quad (2.4)$$

$$LQ(jj,k) = |I(jj,k)|^2 X(jj,k) \quad (2.5)$$

To find the cost of losses the formula proposed by **Tram and Wall [8]** is used and is given by

$$L(i, k) = 10^{-5} \times C1 \times R(k) \times L(i) \times \{P(i)\}^2 \quad (2.6)$$

where

C1 = Composite cost of losses (Rs per kW)

R(k) = Per unit resistances

L(i) = Length of feeder segment i

P(i) = Power flow through segment i (kVA)

To calculate the composite cost of losses (C1) the formula proposed by Tram and Wall [8] is used here

$$C1 = D \times 8760 \times LSF \times E \quad (2.7)$$

where

D = Levelized annual demand cost of losses per kW

LSF = Loss factor

E = Energy cost of losses (Rs/ kWh)

To calculate the cost of capital [C(i,k)], the formula proposed by **Tram and Wall** [8] is used.

$$C(i, k) = CC \times PP(k) \times l(i) \quad (2.8)$$

where

PP(k) = Purchase price of conductor k (Rs/ Unit length)

L(i) = Length of feeder segment i

CC = Carrying charge rate (feeders)

The objective function to be minimized is

$$F(i,k) = L(i,k) + C(i,k) \quad (2.9)$$

subject to

The resistance per unit is modified with variation of temperature and sensitivity index.

$$L(m2) = \{|V(m1)|^4 - 4.0\{P(m1)x(jj) - Q(m2)r(jj)\}^2 - 4.0\{P(m2)r(jj) + Q(m2)x(jj)\}|V(m1)|^2 \quad (2.10)$$

and $I(jj) < I_{max}$ (2.11)

The modified algorithm to find the optimal branch conductor is shown below.

Step 1 : Read real system data and assume a flat voltage start

Step 2 : IT=1 and DVMAX = 0.0

Step 3 : Calculate the load current using equation (2.2)

Step 4 : jj=1

Step 5 : m1 = IR(jj)

Step 6 : m2 = IS(jj)

Step 7 : k = 1

Step 8 : Compute I(jj ,k) and V(m2,k) using Eq. (2.1) and Eq. (2.3) respectively.

Step 9 : Set

VV(k)=|V(m2,k)| and CII(k)=|I(jj,k)|

Step 10 : Compute LP(jj,k) using Eq. (2.4).

Step 11 : Compute L(jj,k) and CC(jj,k) using Eq. (2.6) and Eq. (2.8) respectively.

Step 12 : Compute F(jj,k) using Eq. (2.9).

Step 13 : Set FN(k) = F(jj,k)

Step 14 : Calculate S(m2) using Eq.(2.10)

Step 15 : k = k+1

Step 16 : If (k ≤ NTYPE) go to step-8 otherwise go to step 17

Step 17 : Arrange FN(k) in an ascending order for k=1,2,…….,NTYPE and store different k for ascending order of FN(k) in KS(j).

Step 18 : q=1

Step 19 : A = KS(q)

Step 20 : If {VV(A) > V_{min} and I(A) ≤ IMAX(A)} and S(A) ≥ 0

Go to step 23 otherwise go to step 21

Step 21 : q = q + 1

Step 22 : If (q ≤ NTYPE) go to step 19

Otherwise go to step 21

Step 23	:	Compute receiving-end voltage using Eq.(3)
Step 24	:	Calculate absolute change in voltage at node m2 i.e., DV(m2) = ABS (|V(m2)|-VV(m2)
Step 25	:	If(DV(m2) > DVMAX) DVMAX = DV(m2)
Step 26	:	TYPE(jj) = q
Step 27	:	jj = jj+1
Step 28	:	If (jj ≤ LN1) go to step 6 Otherwise go to step 29.
Step 29	:	If (DVMAX < ε) go to step 31 , otherwise go to step 30
Step 30	:	If (IT≤ITMAX) go to step 5 Otherwise print diagnostics and go to step 32
Step 31	:	Solution has converged. Write results.
Step 32	:	Stop

Example

One example of 20-node radial distribution network shown in Figure 2.1 has been considered. Table 2.1 shows the branch number, sending-end node, receiving-end node and length of each branch of this network. Load data for the system has been shown in Appendix-A. Data for conductors has been shown in Appendix-B. Table 2.2 show the voltage (p.u.) of each node of the network when uniform conductor has been selected. The real and reactive power loss in this case are 21.063145 kW and 5.963809 kVAr respectively. The number of iteration required is 3. Table 2.3 shows the branch number, types of conductor (in this case conductor **1→ SQUIRREL** only) and the current through each branch. The minimum voltage occurs at node 10 and it is 0.940518 p.u. Table 2.4 show the voltage (p.u.) of each node of the network when non-uniform conductor has been selected. The real and reactive power loss in this case are 9.217852 kW and 5.413779 kVAr respectively. The number of iteration required is 3. Table 2.5 shows the branch number, types of conductors (**1→ SQUIRREL, 2→ WEASEL, 3→ RABBIT and 4→ RACCON**) and the current through each branch. The minimum voltage occurs at node 10 and it is 0.968690p.u.

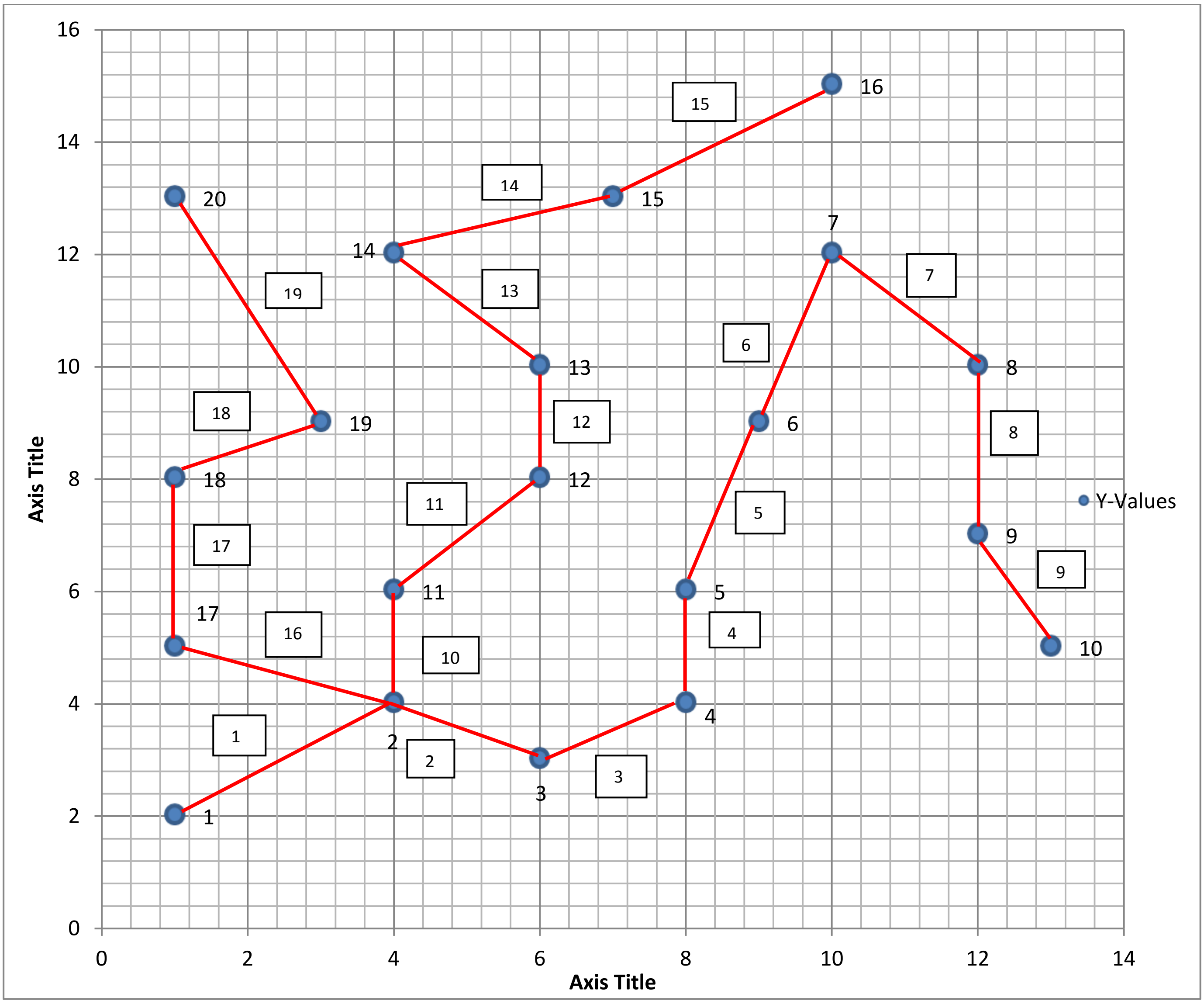

FIGURE 2.1 20-NODE RADIAL DISTRIBUTION SYSTEM

Table 2.1 Branch number, sending-end node, receiving-end node and length of each branch

Branch Number	**Sending-end node**	**Receiving-end node**	**Length of each branch**
1	1	2	3.600000
2	2	3	2.230000
3	3	4	2.230000
4	4	5	2.000000
5	5	6	3.160000
6	6	7	3.160000
7	7	8	2.280000
8	8	9	3.000000
9	9	10	2.230000
10	2	11	9.050000
11	11	12	2.820000
12	12	13	2.000000
13	13	14	2.820000
14	14	15	3.160000
15	15	16	3.600000
16	2	17	13.450000
17	17	18	3.000000
18	18	19	2.230000
19	19	20	4.470000

Table 2.2 Voltage of each node in p.u. for uniform conductor

Node Number	**Voltage (p.u.)**
1	1.000000
2	0.978719
3	0.970805
4	0.963766
5	0.958000
6	0.950812
7	0.946162
8	0.943593
9	0.941441
10	0.940518
11	0.965758
12	0.962477
13	0.960454
14	0.958564
15	0.957571
16	0.957026
17	0.970575
18	0.969115
19	0.968575
20	0.967985

Table 2.3 Branch number, type of conductor, length of each branch and branch current

Branch Number	**Type of conductor**	**Length of each branch (km)**	**Branch current (A)**
B=1	C=1	ld(1)=3.600000	Amp(1)=45.805
B=2	C=1	ld(2)=2.230000	Amp(2)=27.761599
B=3	C=1	ld(3)=2.230000	Amp(3)=24.746794
B=4	C=1	ld(4)=2.000000	Amp(4)=22.595106
B=5	C=1	ld(5)=3.160000	Amp(5)=17.842936
B=6	C=1	ld(6)=3.160000	Amp(6)=11.659186
B=7	C=1	ld(7)=2.280000	Amp(7)=8.954798
B=8	C=1	ld(8)=3.000000	Amp(8)=5.787565
B=9	C=1	ld(9)=2.230000	Amp(9)=3.441385
B=10	C=1	ld(10)=9.050000	Amp(10)=11.0166
B=11	C=1	ld(11)=2.820000	Amp(11)=8.961581
B=12	C=1	ld(12)=2.000000	Amp(12)=7.840812
B=13	C=1	ld(13)=2.820000	Amp(13)=5.295303
B=14	C=1	ld(14)=3.160000	Amp(14)=2.456496
B=15	C=1	ld(15)=3.600000	Amp(15)=1.211039
B=16	C=1	ld(16)=13.450000	Amp(16)=4.673812
B=17	C=1	ld(17)=3.000000	Amp(17)=3.801485
B=18	C=1	ld(18)=2.230000	Amp(18)=2.062874
B=19	C=1	ld(19)=4.470000	Amp(19)=1.124614

Table 2.4 Voltage of each node in p.u. for non-uniform conductor

Node Number	**Voltage (p.u.)**
1	1.000000
2	0.992931
3	0.989365
4	0.986186
5	0.983585
6	0.978687
7	0.974171
8	0.971676
9	0.969586
10	0.968690
11	0.980238
12	0.977030
13	0.975054
14	0.973123
15	0.972171
16	0.971634
17	0.984458
18	0.982949
19	0.982417
20	0.981835

Table 2.5 Branch number, type of conductor, length of each branch and branch current

Branch Number	Type of conductor	Length of each branch	Branch current
B=1	C=4	ld(1)=3.600000	Amp(1)=45.068977
B=2	C=3	ld(2)=2.230000	Amp(2)=27.021368
B=3	C=3	ld(3)=2.230000	Amp(3)=24.063892
B=4	C=3	ld(4)=2.000000	Amp(4)=21.960785
B=5	C=2	ld(5)=3.160000	Amp(5)=17.331833
B=6	C=1	ld(6)=3.160000	Amp(6)=11.323488
B=7	C=1	ld(7)=2.280000	Amp(7)=8.696476
B=8	C=1	ld(8)=3.000000	Amp(8)=5.620314
B=9	C=1	ld(9)=2.230000	Amp(9)=3.341867
B=10	C=1	ld(10)=9.050000	Amp(10)=10.792557
B=11	C=1	ld(11)=2.820000	Amp(11)=8.778824
B=12	C=1	ld(12)=2.000000	Amp(12)=7.691459
B=13	C=1	ld(13)=2.820000	Amp(13)=5.293295
B=14	C=1	ld(14)=3.160000	Amp(14)=2.408545
B=15	C=1	ld(15)=3.600000	Amp(15)=1.192913
B=16	C=1	ld(16)=13.450000	Amp(16)=5.009444
B=17	C=1	ld(17)=3.000000	Amp(17)=4.068058
B=18	C=1	ld(18)=2.230000	Amp(18)=2.033898
B=19	C=1	ld(19)=4.470000	Amp(19)=1.108809

Conclusion

In this thesis work, the selection of optimal conductor has been done on the basis stability index. The effect of temperature on resistance of conductor has also been incorporated. The effect of sensitivity index has also been tested. One example has been considered and the results shows that the selection of uniform conductor increases the losses whereas the selection of non-uniform conductor reduces the losses. Obviously the planning cost will also be reduced.

CHAPTER 4

CONCLUSIONS & FUTURE SCOPE OF WORK

4.1 Conclusions

A method of optimal conductor selection has been proposed based on stability index and the variation of temperature and its effect on resistance has been incorporated. One example of 20-node radial distribution network has been considered. Results shows that the selection of non uniform conductor reduces the losses compared to the uniform conductor. Obviously the planning cost will also be reduced.

4.2 Future Scope of Work

The following are the scopes of future work

i. Optimal conductor selection using Fuzzy logic.
ii. Optimal conductor selection using hybrid algorithm.

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Appendix-A

Table A.1 Load Data For Example

Node Number	Real Power (kW)	Reactive Power (kVAr)
2	25.00	10.00
3	30.00	12.00
4	20.00	11.00
5	45.00	22.00
6	60.00	25.00
7	25.00	13.00
8	30.00	14.00
9	22.00	11.00
10	28.00	22.00
11	20.00	10.00
12	10.50	8.3
13	26.00	10.00
14	30.00	14.00
15	13.00	7.00
16	12.75	11.25
17	10.12	8.40
18	20.00	10.00
19	7.50	6.61
20	9.00	7.90

Appendix-B

Table B1 Data for conductors

Type of Conductor	Area of cross section (mm^2)	Resistance (Ω/km)	Reactance (Ω/km)	Maximum Current carrying capacity(Amp)	Cost of conductor (Rs/km)
Squirrel	12.90	1.3760	0.3896	70.0	2880
Weasel	19.35	0.9810	0.3797	100.0	4338
Rabbit	32.26	0.5441	0.3673	148.0	7306
Raccon	48.39	0.3657	0.3579	200.0	10950
LSF = 0.20 CC = 0.10 V_{min} = 0.96					

Taken From Ranjan et al. [16]

Appendix C

BIOGRAPHY

Ms. Tanvi Paul
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Career Objective

To work in association with professional groups who offer me the opportunity for career advancement and professional growth.

Personal Profile

Name	:	Tanvi Paul
Date of Birth	:	27-10-1988
Father's Name	:	Surinder Paul
Languages Known	:	English, Hindi & Punjabi

Education Qualification

Masters of Engineering- Electrical Engineering, Specialization-Power System and Electric Drives **Thapar University**, Patiala (Punjab), INDIA. July 2010-June 2012(Anticipated).
Current Academic Standing: 9.82 CGPA

Bachelor of Technology-Electrical Engineering
Giani Zail Singh College of Engineering and Technology (Affiliated to Punjab Technical University, Jalandhar), Bathinda (2006-2010). *Academic Standing: 75.8%*

Semester Project: ***Production of Electrical Energy from Biomass Energy Sources***

A case study was carried out *at 8MW Biomass Power Plant run by 'Dee Engineering Developments Ltd. (Abohar)* for the purpose of understanding the potential of biomass energy sources as one of the major alternative source of energy and to study the process of production of energy from biomass energy. Also the study carried out, highlights rural India as a major source of Biomass fuel since it is rich in agricultural and animal wastes.

Research Areas

Radial power distribution systems. Programming in MATLAB & C

Professional Experience

Teaching Assistant- Thapar University, Patiala (Punjab), INDIA.

- Academic Semester- Aug 2011 to Dec 2011
    - Courses Taken- Power Electronics, Analog Electronics and Basic Electrical Science
- Academic Semester- Jan 2012 to June 2012
    - Courses Taken- Power System Analysis and Electrical Science Lab.

Industrial Experience/Trainings

- ***Six month Industrial Training, 'Studies on Generation of Electricity and Control System', Guru Hargobind Thermal Power Plant, Lehra Mohabat, Distt. Bathinda*****:** Study was carried out on various operations involved in the generation of electricity and pollution control equipment. Overview of the protection system equipment.

- ***Six week Industrial Training, 'Study on Switchgear and Switchyard Protection, Maintenance of Equipment', Guru Hargobind Thermal Power Plant, Lehra Mohabat, Distt. Bathinda , Punjab(2010)*****:** Study was carried out on functionality and designing of various equipment of Switchyard and Switchgear Protection.

Campus Placements

- Tata Consultancy Services and Sharda University

Technical Skills

- MATLAB
- Familiar with Programming languages: C and C++