Chapter 2

Distribution Systems

2-1 Introduction:

Distribution systems serve as the link from the distribution substation to the customer. This system provides the safe and reliable transfer of electric energy to various customers throughout the service territory. Typical distribution systems begin as the medium -voltage three- phase circuit, typically about 30–60 kV, and terminate at a lower secondary three- or single-phase voltage typically below 1 kV at the customer's premise, usually at the meter.

Distribution feeder circuits usually consist of overhead and underground circuits in a mix of branching laterals from the station to the various customers. The circuit is designed around various requirements such as required peak load, voltage, distance to customers, and other local conditions such as terrain, visual regulations, or customer requirements. These various branching laterals can be operated in a radial configuration or as a looped configuration, where two or more parts of the feeder are connected together usually through a normally open distribution switch. High-density urban areas are often connected in a complex distribution underground network providing a highly redundant and reliable means connecting to customers. Most three-phase systems are for larger loads such as commercial or industrial customers.

The transmission of electrical power requires many long, interconnected power lines, to carry the electrical current from where it is produced to where it is used. However, overhead power transmission lines require much planning to ensure the best use of our land. The location of overhead transmission lines is limited by zoning laws and by populated areas, highways, railroads, and waterways, as well as other topographical and environmental factors. Today, an increased importance is being placed upon environmental and aesthetic factors. Power transmission lines ordinarily operate at voltage levels from 110 kV to 220 kV of AC. Common transmission line voltages are in the range of 50 to 150 kV of AC. High voltage direct current overhead transmission lines may become economical, although they are not being used extensively at the present time Another option is ultra high-voltage transmission lines, which use higher AC transmission voltages. Also, underground transmission methods for urban and suburban areas must be considered, since the right-of way for overhead transmission lines is limited. AC overhead transmission voltages have increased to levels in the range of 765 kV, with research now dealing with voltages of over 1000 kV. One advantage of overhead cables is their ability to dissipate heat. The use of cryogenic cable may bring about a solution to heat dissipation problems in conductors [1] as shown in fig (2-1)

2-2Underground Distribution:

The use of underground cable is ordinarily confined to the short lengths required in congested urban areas. The cost of underground cable is much more than that of aerial cable. Temperatures and have a large power handling capability.[2]

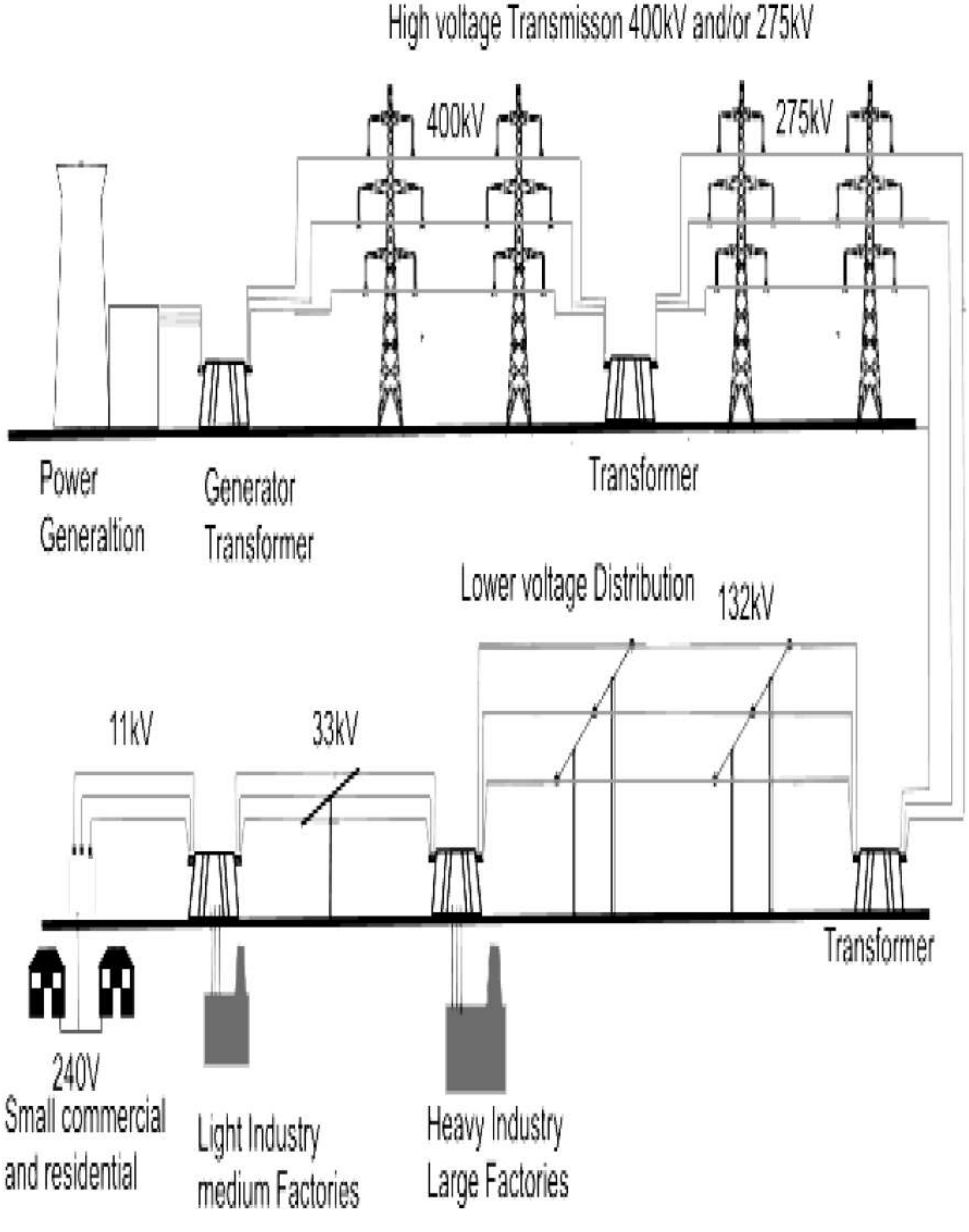

Fig (2-1) generation, transmission, and distributer power system

2-3 High-voltage Direct Current (DC) Transmission:

An alternative to transmitting AC voltages for long distances is high-voltage direct current (HVDC) power transmission. HVDC is suitable for long-distance overhead power lines, or for underground power lines. DC power lines are capable of delivering more power per conductor than equivalent AC power lines. Because of its fewer power losses, HVDC is even more desirable for underground distribution. The primary disadvantage of HVDC is the cost of the necessary AC-to-DC conversion equipment. There are, however, some HVDC systems in operation in the United States. At present, HVDC systems have been designed for transmitting voltages in the range of 600 kV. The key to the future development of HVDC systems may be the production of solid state power conversion systems with higher voltage and current rating. With a continued developmental effort, HVDC should eventually play more significant role in future electrical power transmission systems.[2]

2-4 Parallel Operation of Power Systems:

Electrical power distribution systems are operated in a parallel circuit arrangement. When more power sources generators in parallel are added, a greater load demand or current requirement can be met. On a smaller scale, this is like connecting two or more batteries in parallel to provide greater current capacity. Two parallel-connected three-phase alternators are depicted in Figure (2-2).

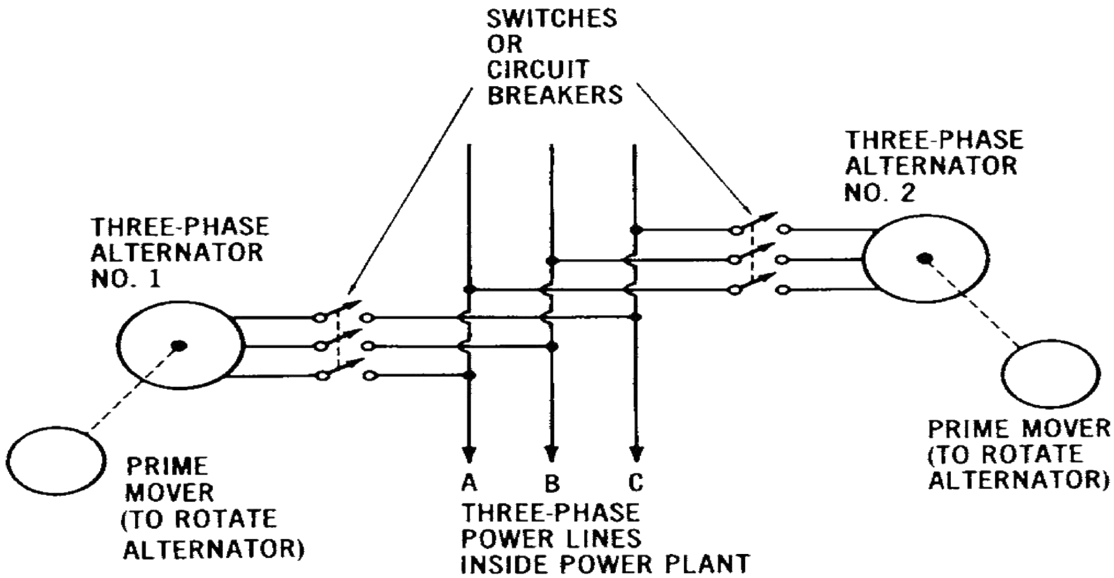

Fig (2-2) two parallel-connected three-phase alternators

Expands the concept of parallel-connected systems. An illustration of two power plants joined together through a distribution substation is shown in Fig (2-3).

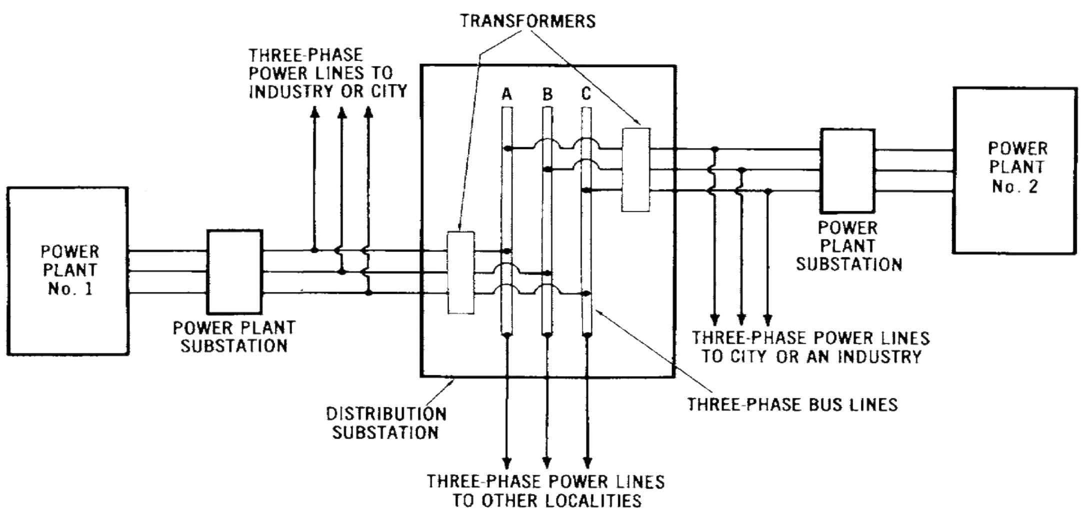

Fig (2- 3) Joining two power plants in parallel as part of a regional power system

The two power plants might be located 100 miles apart, yet they are connected in parallel to supply power to a specified region. If, for some reason (such as repairs on one alternator), the output of one power plant is reduced, the other power plant is still available to supply power to the requesting localities. It is also possible for power plant number one to supply part of the load requirement ordinarily supplied by power plant number two, or vice versa. These regional distribution systems of parallel-connected power sources provide automatic compensation for any increased load demand in any area.

Most power plants have more than one alternator connected to any single set of power lines inside the plant. These power lines, or “bus” lines, are usually large, copper bar conductors that can carry very high amounts of current. At low-load demand times, only one alternator would be connected to the bus lines. The major problem of parallel-connected distribution systems occurs when excessive load demands are encountered by several power systems in a single region. If all of the power plants in one area are operating near their peak power-output capacity, there is no back-up capability. The equipment-protection system for each power plant, and also for each alternator in the power plant, is designed to disconnect it from the system when its maximum power limits are reached. When the power demand on one part of the distribution system becomes excessive, the protective equipment will disconnect that part of the system. This places an even greater load on the remaining parts of the system. The excessive load now could cause other parts of the system to disconnect. This cycle could continue until the entire system is inoperative. This is what occurs when blackouts of power systems take place. No electrical power can be supplied to any part of the system until most of the power plants are put back in operation. The process of putting the output of a power plant back on-line, when the system is down during power outages, can be a long and difficult procedure.[2]

2-5 Distribution system components:

In general the distribution system is electrical system between the substation fed by transmission system and the consumers.

Generally distribution system consists of feeder distributer and service main[3] as Shown in fig (2-4)

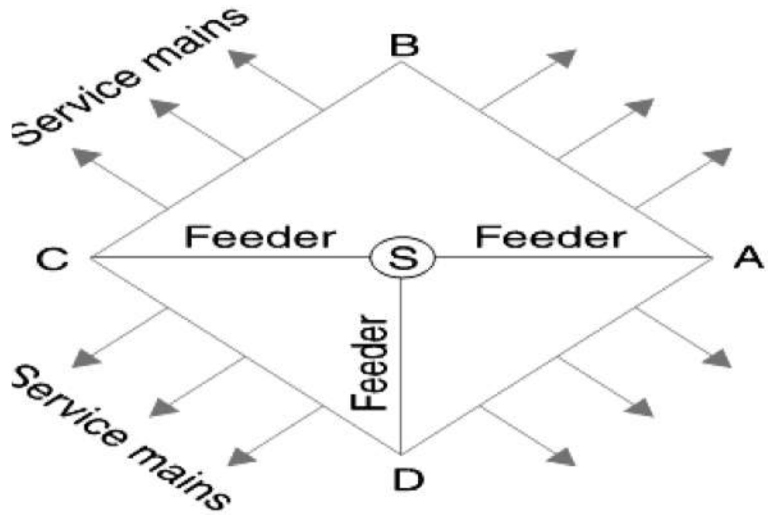

Fig (2-4) Distribution system components

Feeders:

It is a conductor from which connects the substation or localized generating station to the area where power is to distributed no tapping are taken from the feeder .The main consideration in the design of a feeder is the current carrying capacity.[3]

Distributer:

It is a conductor from which tapping are taken for supply to the consumers (AB, BC, CD, DA) are the distributor .The current through a distributer is not constant because tapping are taken at various places along its length. The main consideration in the design of a distributor is a voltage drop since the statutory limit of voltage is ±6% of rated value at consumers.[3]

Service main:

It is generally a small cable which connects the distributer to the consumers.[3]

2-6 Distribution system classifications:

The distribution system is classified in order to the following types:

- **Type of construction:** It s classified as:

(i) Overhead system.

(ii) Underground system.

The overhead system is cheaper than underground system but the underground system is used at places where overhead construction is impracticable by the local law. As stated previously, initial overhead line construction is less expensive than underground cabling for the same kVA load. In rural or semi-rural areas, the sheer cost of underground cabling would make it impossible for customers to be able to afford the cost of supply. The down side is that overhead lines operate under continual mechanical stress with exposure to varying climatic conditions.

This results in progressive deterioration in time as a result of corrosion, mechanical wear and fatigue, timber rot, etc.

All components must be periodically inspected and replaced as required.

They are exposed to environmental impacts such as storms, lightning, wind-blown debris and traffic impact (of poles) which means overhead systems are rarely as reliable as underground ones.

The greater spacing of overhead line conductors generally results in higher system inductance than for a cable system.

This means an overhead line has a greater voltage drop than an underground cable of equal current-carrying capacity and hence cannot supply power over as long a distance as the underground equivalent, particularly for lower voltage distribution systems.

Even though poles are considered unsightly in urban locations, the capacity of an overhead feeder can be readily increased by replacing it with larger conductors and/or increasing the voltage insulation/operating level. This flexibility is one big advantage of overhead systems.

The reliability of underground distribution is greater than for overhead systems because of the lower number of fault interruptions, as discussed above.

However, when interruptions do occur they are generally of much longer duration than those associated with overhead lines.

Underground cables have comparatively higher capacitance, and under light load conditions can affect system power factor.

In some cases, high charging currents and high transient voltages may accompany switching of cable systems that are open-circuited (especially at the higher distribution voltages.

This light-load performance can limit total underground feeder length. On the other hand, this does mean they can supply heavy load, especially when it is inductive in nature, over longer distances than overhead lines.[3]

- **Nature of current**: It is classified as:

(i) AC distributer system.

(ii) DC distributer system.

(i) AC distributer system:

One of important reason to use alternating current in preference to direct current is the fact that alternating voltage can be conveniently changed in magnitude by transformers .Transformer has made to transmit Ac power at high voltage and utilize it at safe potential .There is no definite line between transmission and distribution according to the voltage or bulk capacity .The Ac distribution system is the electrical system between the step down substation fed by the transmission system and the consumer.[3]

The AC distribution system is classified as:

Primary distribution system:

The voltage used for primary distribution depends upon the amount of power to be conveyed and the distance of the substation required to be fed

The most commonly used primary distribution voltages are (11kv, 6.6kv , 3.3kv) to economic consideration .The primary distribution carried out by 3 phase , 3wire system [3] as shown in fig(2-5)

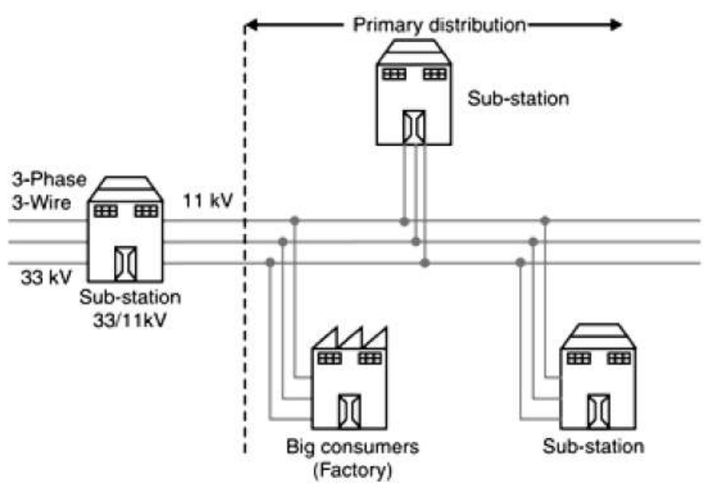

Fig (2-5) Primary distribution system

Secondary distribution systems:

Its includes the range of voltages at which the ultimate consumer utilizes the electrical energy. The secondary distribution employs (400/230v) 3 phase 4wire system [3] as shown in fig (2- 6)

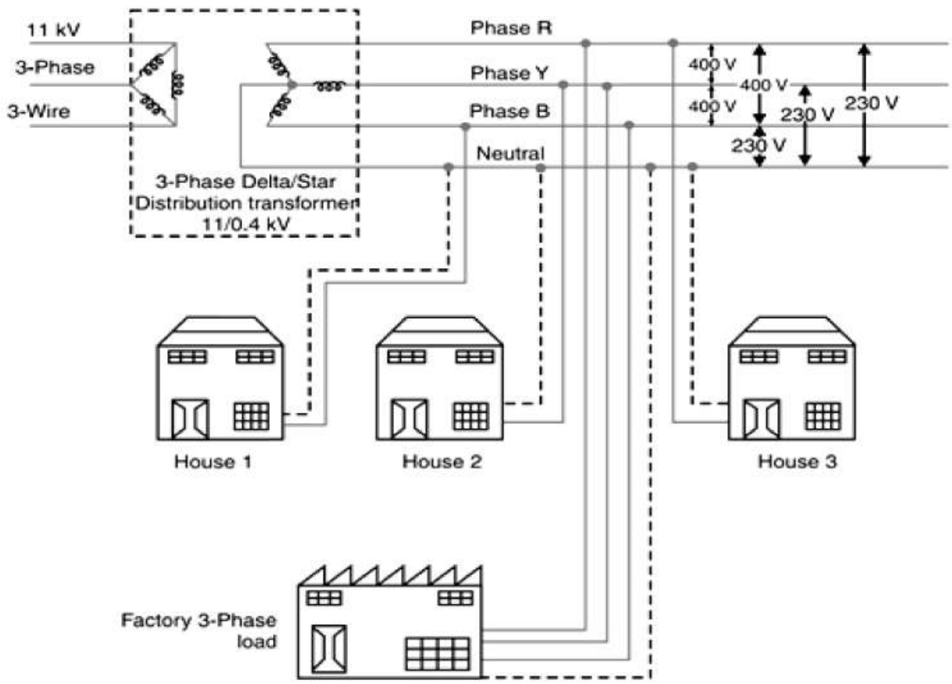

Fig (2-6) Secondary distribution systems

(ii) DC Distributer system:

For a certain application dc is necessary as dc motors and storage battery reserves. The Ac power is converted in to Dc power at substation by using converting machinery as mercury arc rectifiers rotary, converters, motor, and generator .The DC supply from the substation may be obtained in the form of:

(i) 2 wires. (ii) 3 wires.

(i) 2-wires DC system:

As the name implies, this system of distribution consists of two wires. One is the outgoing or positive wire and the other is the return or negative wire. The loads such as lamps, motors etc. are connected in parallel between the two wires as shown in Fig (2-7)

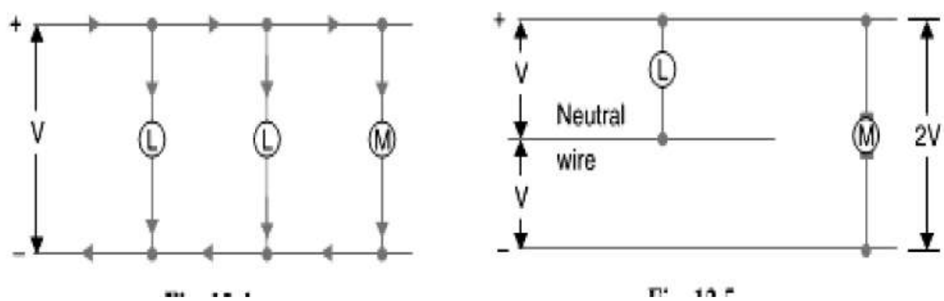

Fig (2-7) 2-wire DC system

This system is never used for transmission purposes due to low efficiency but may be employed for distribution of DC power.[3]

(ii) 3-wire DC system:

It consists of two outers and a middle or neutral wire which is earthed at the substation. The voltage between the outers is twice the voltage between either outer or neutral wire.

The principal advantage of this system is that it makes available two voltages at the consumer terminals voltage between any outer and the neutral and 2V between the outers. Loads requiring high voltage are connected across the outers, whereas lamps and heating circuits requiring less voltage are connected between either outer and the neutral. [3]

There are several methods of obtaining 3-wire DC system. However, the most important ones are:

- **Two generator method:**

In this method, two shunt wound DC generators G1 and G2 are connected in series and the neutral is obtained from the common point between generators as shown in Fig (2-8)

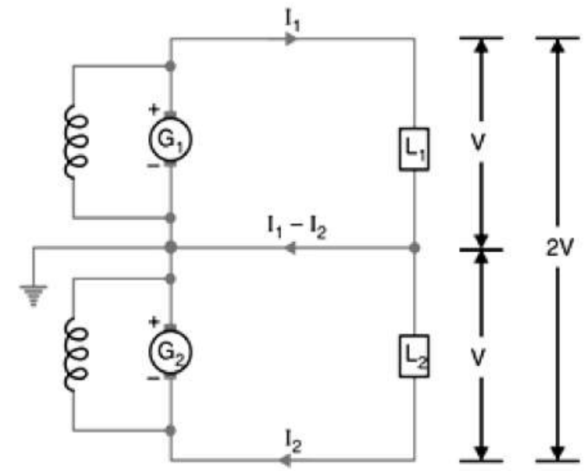

Fig (2-8) two generator method

Each generator supplies the load on its own side. Thus generator G1 supplies a load current of I1, whereas generator G2 supplies a load current of I2. The difference of load currents on the two sides, known as out of balance current (I1   I2) flows through the neutral wire. The principal disadvantage of this method is that two separate generators are required.[3]

- **3-wire DC generator:**

The above method is costly on account of the necessity of two generators for this reason 3-wire DC generator was developed as shown in fig (2-9).

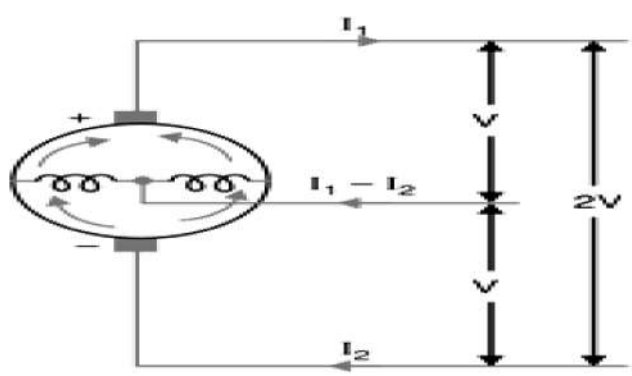

Fig (2-9) 3-wire DC generator

It consists of a standard 2-wire machine with one or two coils of high reactance and low resistance connected permanently to diametrically opposite points of the armature winding .The neutral wire is obtained from the common point.[3]

- **Balancer set:**

The 3-wire system can be obtained from 2-wire DC system by the use of balancer set as shown in fig (2-10)

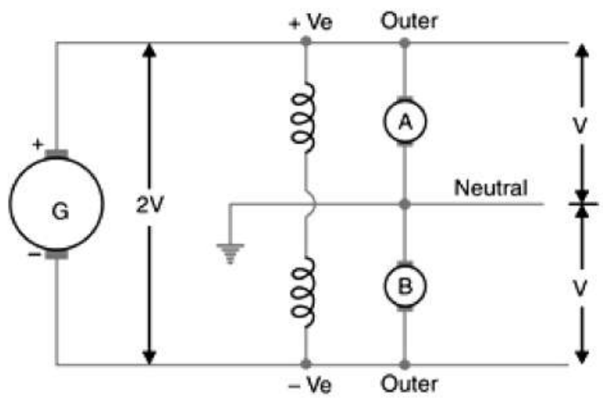

Fig (2-10) Balancer set

G is the main 2-wire DC generator and supplies power to the whole system. The balancer set consists of two identical DC shunt machines A and B coupled mechanically with their armatures and field windings joined in series across the outers. The junction of their armatures is earthed and neutral wire is taken out from here. The balancer set has the additional advantage that it maintains the potential difference on two sides of neutral equal to each other.[3]

- Scheme of connector:

It’s classified as:

(i) Radial

(ii) Ring

(iii) Network distribution systems

(i) Radial system:

The simplest type, since the power comes from one power source. A generating system supplies power from the substation through radial lines that are extended to the various areas of a community as shown in Figure (2-11).

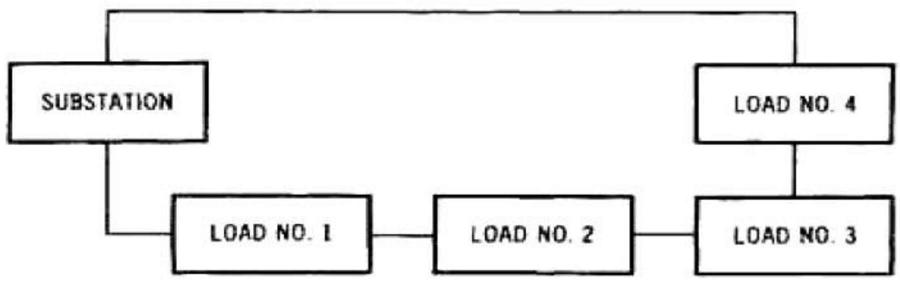

Fig (2-11) Radial system

Radial systems are the least reliable in terms of continuous service, since there is no back-up distribution system connected to the single power source. If any power line opens, one or more loads are interrupted. There is more likelihood of power outages. However, the radial system is the least expensive. This system is used in remote areas where other distribution systems are not economically feasible.[3]

(ii) Ring distribution systems:

Are used in heavily populated areas. The distribution lines encircle the service area. Power is delivered from one or more power sources into substations near the service area. The power is then distributed from the substations through the radial power lines. When a power line is opened, no interruption to other loads occurs. The ring system provides a more continuous service than the radial system. Additional power lines and a greater circuit complexity make the ring system more expensive .as shown in fig (2-12)

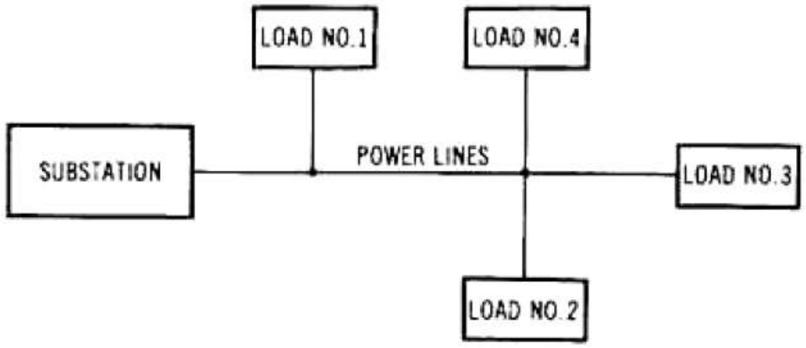

Fig (2-12) Ring system

(iii) Network distribution systems:

Area combination of the radial and ring systems. They usually result when one of the other systems is expanded. This system is more complex, but it provides very reliable service to consumers. With a network system, each load is fed by two or more circuits[3] as shown in fig (2-13)

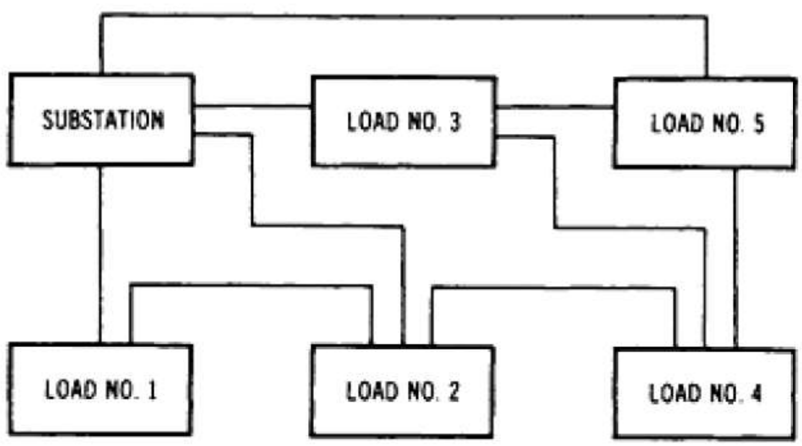

Fig (2-13) Network system

2-7 Distribution Devices:

The devices of distribution system are switches, Circuit breaker, Recloser, Capacitor bank, Fuses, Transformer, Isolator, Lightning arresters, and Earthing switches.

- Switches:

Use to disconnect various parts of the system from the feeder. These switches are manually, remotely, or automatically operated. Switches are designed to break load current but not fault current and are used in underground circuits or tie switches.[3]

- Circuit Breaker:

Is a piece of equipment which can used to disconnect portions of the feeder ability to interrupt fault current. These are tied to a protective relay, which detects the fault conditions and issues the open command to the breaker.[3]

- Recloser:

These are a special type of breaker deployed only on overhead and are designed to reduce the outage times caused by momentary faults. During the reclose operation, the relay detects the fault, opens the switch, waits a few seconds, and issues a close. Many overhead distribution faults are successfully cleared and service is restored with this technique, significantly reducing outage times.[3]

- Capacitor banks:

Are used across the bus so that the voltage does not get down below the required voltage. When the inductive property of the line increases then the voltage lags behind current & causes loss of money, so to raise the voltage up

&prevent loss of money capacitor banks are used. It raises the voltage, raises power factor as well.help improves power factor or support system voltage.[3]

- Fuses:

Is a short piece of metal, inserted in the circuit, which melts when excessive current flows through it and thus breaks the circuit.[3]

- Lightning arresters:

They used to protect the substation devices from the high voltage generated due the lighting stroke the substation.[3]

- Transformer:

Is a static device which transforms electrical energy from one circuit to another without any direct electrical connection and with the help of mutual induction between two windings.It transforms power from one circuit to another without changing its frequency but may be in different voltage level.[3]

- Isolator:

It used to visibly isolate part of a substation during maintenance. An isolator is knife switch and design to operate under no load.[3]

-Earthing switches:

It is used during maintenance to ground the device in order to protect the power system engineers.[3]