G.PULLAIAH COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPT OF EEE

Electrical Distribution Systems

UNIT-2

BASIC TERMS AND DEFINITIONS:

Distribution System	Electric power distribution is the final stage in the delivery of electric power; it carries electricity from the transmission system to individual consumers
primary distribution	The primary distribution system is that part of the electric distribution system between the distribution substation and distribution transformers
DC distribution	The DC distribution system is simply an extension of the multiple DC links that already exist in all propulsion and thruster drives, which usually account for more than 80 percent of the electrical power consumption on electric propulsion vessels.
Underground Power Distribution Systems	Underground Power Distribution Systems have long been an integral part of industrial, renewable, and large campus projects. Underground systems are better protected from the elements of nature and other outside damages than overhead distribution systems, and since they often cost less to install, they are worthy of your consideration.
Overhead distribution System	Overhead distribution, through lines on wood poles, is the basic mode used in most areas of Québec. This system comprises over 97,000 km of lines, and 99% of its 2,500,000 poles are made of wood. Hydro-Québec serves 2.8 million customers through the overhead system.
Feeder	In electric power distribution, Feeder is “voltage power line transferring power from a distribution substation to the distribution transformers” In an electrical wiring circuit in a building which Feeder is a “wire/line that carries power from a transformer or switch gear to a distribution panel.”
Voltage Drop	Wires carrying current always have inherent resistance, or impedance, to current flow. Voltage drop is defined as the amount of voltage loss that occurs through all or part of a circuit due to impedance
Power factor	In electrical engineering, the power factor of an AC electrical power system is defined as the ratio of the real power flowing to the load to the apparent power in the circuit, and is a dimensionless number in the closed interval of 0 to 1.

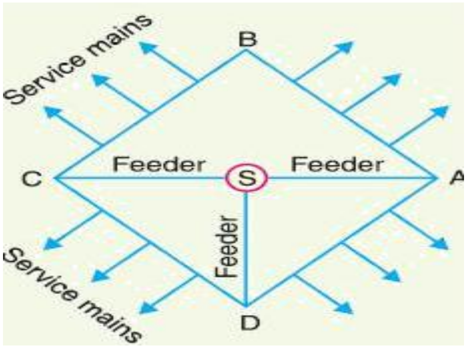
Concepts

Distribution System:

That part of power system which distributes electric power for local use is known as distribution system.

In general, the distribution system is the electrical system between the sub-station fed by the distribution system and the consumers meters. It generally consists of feeders, distributors and the service mains.

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



(ii) **Distributo**r. A distributor is a conductor from which tappings are taken for supply to the consumers. In Fig. 12.1, AB, BC, CD and DA are the distributors. The current through a distributor is not constant because tappings 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 ± 6% of rated value at the consumers' terminals.

(iii) **Service mains.** A service mains is generally a small cable which connects the distributor to the consumers' terminals.

Classification of Distribution Systems

A distribution system may be classified according to

(i) **Nature of current**. According to nature of current, distribution system may be classified as (a) d.c. distribution system (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.

(ii)**Type of construction.** According to type of construction, distribution system may be classified as (a) overhead system (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.

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

A.C. Distribution:

•Now-a-days electrical energy is generated, transmitted and distributed in the form of alternating current.

•Alternating current in prefered to direct current is the fact that alternating voltage can be conveniently changed by means of a transformer.

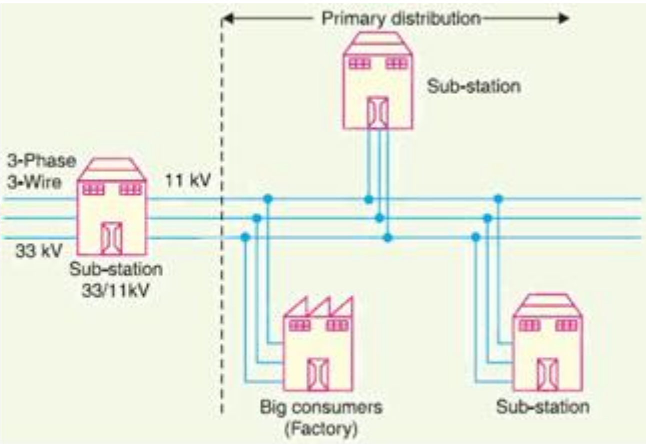
•High distrubution and distribution voltages have greatly reduced the current in the conductors and the resulting line losses.

•The a.c. distribution system is the electrical system between the stepdown substation fed by the distrubution system and the consumers' meters.

The a.c. distribution system is classified into

(i)primary distribution system and (ii) secondary distribution system.

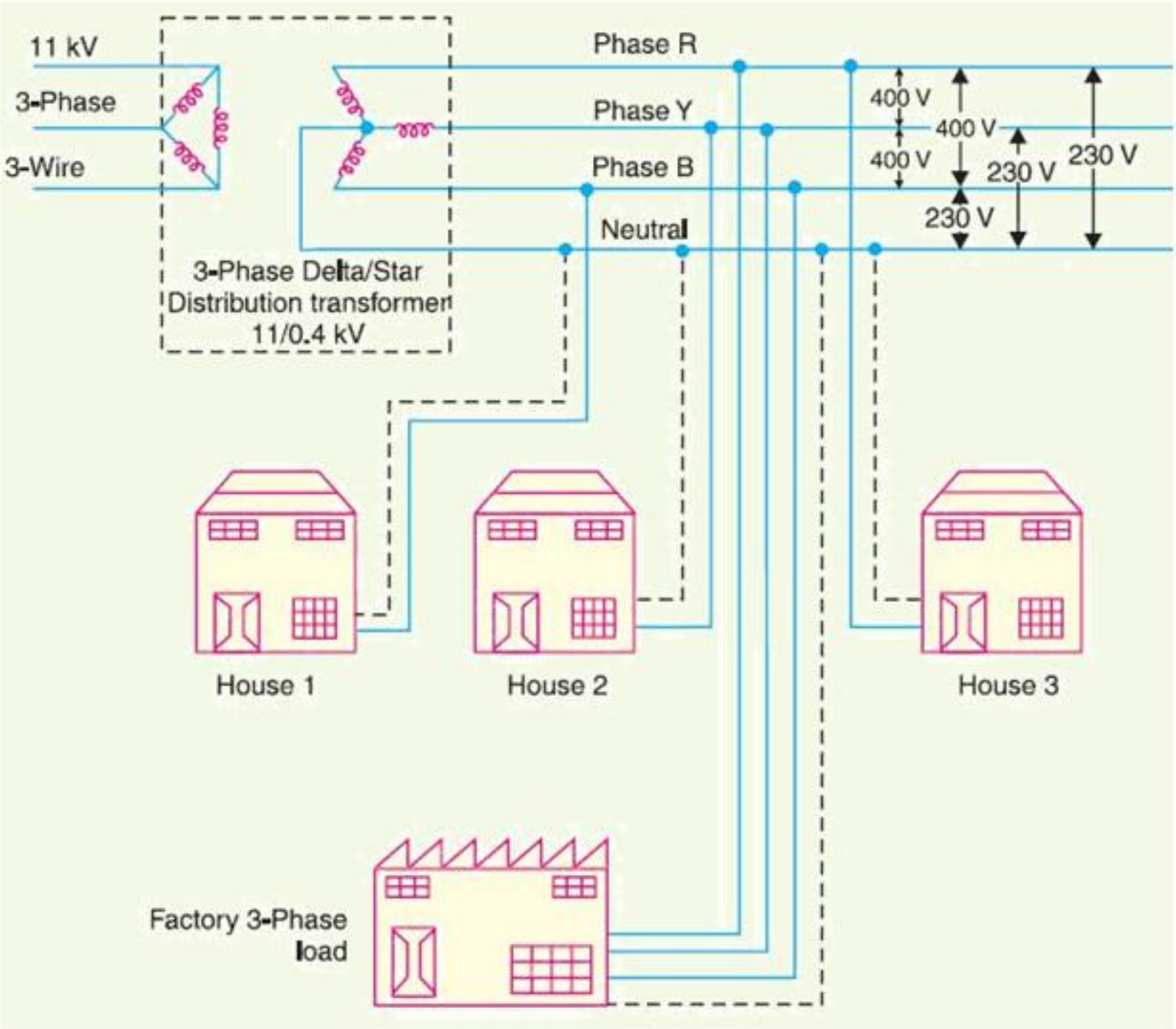
PRIMARY DISTRIBUTION SYSTEM:



• It is that part of a.c. distribution system which operates at voltages somewhat higher than general utilisation than the average low-voltage consumer uses.

- The most commonly used primary distribution voltages are 11 kV, 6•6kV and 3•3 kV
- Primary distribution is carried out by 3-phase, 3-wire system.
- Fig. shows a typical primary distribution system.
- Electric power from the generating station is transmitted at high voltage to the substation located in or near the city. At this substation, voltage is stepped down to 11 kV with the help of step-down transformer. Power is supplied to various substations for distribution or to big consumers at this voltage. This forms the high voltage distribution or primary distribution.

SECONDARY DISTRIBUTION SYSTEM:



•It is that part of a.c. distribution system employs 400/230 V, 3-phase, 4-wire system.

•Figure shows a typical secondary distribution system.

•The primary distribution circuit delivers power to various substations, called distribution substations. The substations are situated near the consumers' localities and contain step down transformers.

•At each distribution substation, the voltage is stepped down to 400 V and power is delivered by 3-phase,4-wire a.c. system.

•The voltage between any two phases is 400 V and between any phase and neutral is 230 V.

•The single phase domestic loads are connected between any one phase and the neutral,.

•Motor loads are connected across 3-phase lines directly.

D.C. Distribution:

•For certain applications, d.c. supply is absolutely necessary. d.c. supply is required for the operation of variable speed machinery (i.e., d.c. motors storage battery.

•For this purpose,a.c. power is converted into d.c. power at the substation by using converting machinery e.g.,mercury arc rectifiers, rotary converters and motor-generator sets.

The d.c. supply obtained in the form of (i) 2-wire or (ii) 3-wire for distribution.

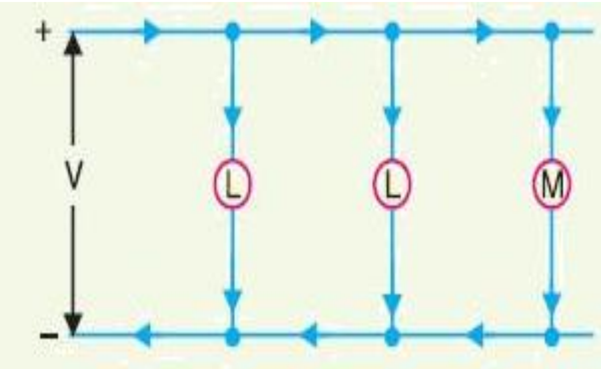
2-Wire D.C. System:

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

•One is the outgoing or positive wire and the other is the return or negative wire.

•The loads such as lamps, motors etc. are connected in parallel between the two wires as shown in Fig.

•This system is never used for distrubution purposes due to low efficiency but may be employed for distribution of d.c. power.



3-wire D.C. system:

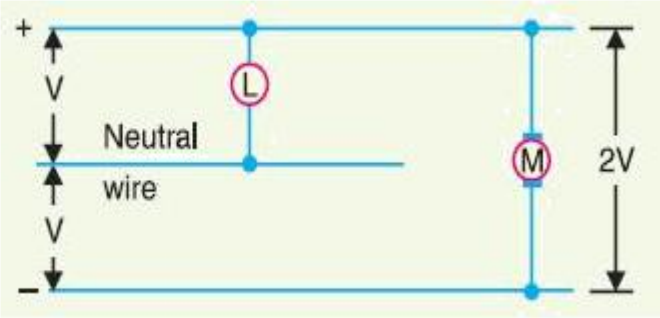
•It consists of two outers and a middle or neutral wire which is earthed at the substation.

•The voltage between the outers is twice the voltage between either outer and neutral.

•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 theouters.

•Loads requiring high voltage (e.g., motors) are connected across the outers, whereas lamps and heating circuits requiring less voltage are connected between either outer and the neutral.



Comparison of D.C. and A.C. distribution:

The electric power can be distributed either by means of d.c. or a.c. Each system has its own merits and demerits

1.D.C distribution:

Advantages:

i) It requires only two conductors as compared to three for a.c. distribution.

(ii) There is no inductance, capacitance, phase displacement and surge problems in d.c. distribution.

(iii) Due to the absence of inductance, the voltage drop in a d.c. distribution line is less than the a.c. line for the same load and sending end voltage. For this reason, a d.c. distribution line has better voltage regulation.

(iv) There is no skin effect in a d.c. system. Therefore, entire cross-section of the line conductor is utilized.

(v) For the same working voltage, the potential stress on the insulation is less in case of d.c. system than that in a.c. system. Therefore, a d.c. line requires less insulation.

(vi) A d.c. line has less corona loss and reduced interference with communication circuits.

(vii) The high voltage d.c. distrubution is free from the dielectric losses, particularly in the case of cables.

(viii) In d.c. distrubution, there are no stability problems and synchronising difficulties.

Disadvantages:

(i) Electric power cannot be generated at high d.c. voltage due to commutation problems.

(ii) The d.c. voltage cannot be stepped up for distrubution of power at high voltages.

(iii) The d.c. switches and circuit breakers have their own limitations.

2. A.C. distribution:

Advantages:

(i) The power can be generated at high voltages.

(ii) The maintenance of a.c. sub-stations is easy and cheaper.

(iii) The a.c. voltage can be stepped up or stepped down by transformers with ease and efficiency. This permits to transmit power at high voltages and distribute it at safe potentials.

Disadvantages:

(i) An a.c. line requires more copper than a d.c. line.

(ii) The construction of a.c. distrubution line is more complicated than a d.c.
distrubution line.

(iii) Due to skin effect in the a.c. system, the effective resistance of the line is increased.

(iv) An a.c. line has capacitance. Therefore, there is a continuous loss of power due to charging current even when the line is open.

Overhead Vs 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 underground system uses conduits, cables and manholes under the surface of streets and sidewalks.

The choice between overhead and underground system depends upon a number of widely differing factors.

(i) 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.

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

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

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

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

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

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

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

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

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

It is clear from the above comparison that each system has its own advantages and disadvantage

Design Considerations In Distribution System:

Good voltage regulation of a distribution network is probably the most important factor responsible for delivering good service to the consumers. For this purpose, design of feeders and distributors requires careful consideration.

(i) Feeders. A feeder is designed from the point of view of its current carrying capacity while the voltage drop consideration is relatively unimportant. It is because voltage drop in a feeder can be compensated by means of voltage regulating equipment at the substation.

(ii) Distributors. A distributor is designed from the point of view of the voltage drop in it. It is because a distributor supplies power to the consumers and there is a statutory limit of voltage variations at the consumer’s terminals (± 6% of rated value). The size and length of the distributor should be such that voltage at the consumer's terminals is within the permissible limits.

Requirements Of A Distribution System:

Requirements of a good distribution system are : proper voltage, availability of power on demand and reliability.

(i) **Proper voltage**. One important requirement of a distribution system is that voltage variations at consumer's 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 ± 6% of the rated value at the consumer's 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.

(ii) **Availability of power on 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.

(iii) **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) interconnected system (b) reliable automatic control system (c) providing additional reserve facilities.

Connection Schemes Of Distribution System:

(i) Radial System.

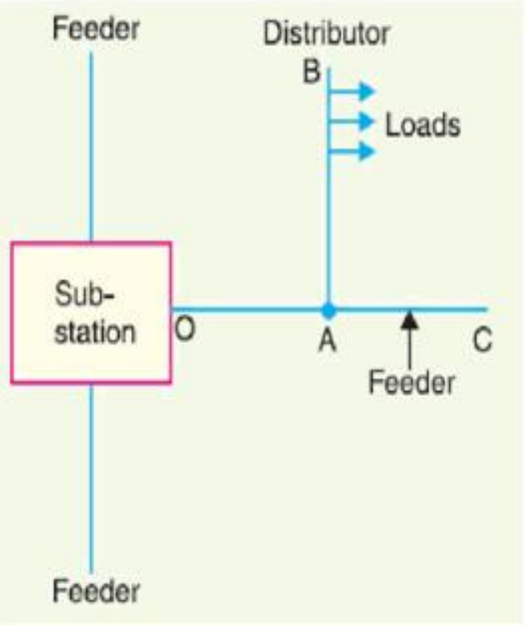
•In this system, separate feeders radiate from a single substation and feed the distributors at one end only.

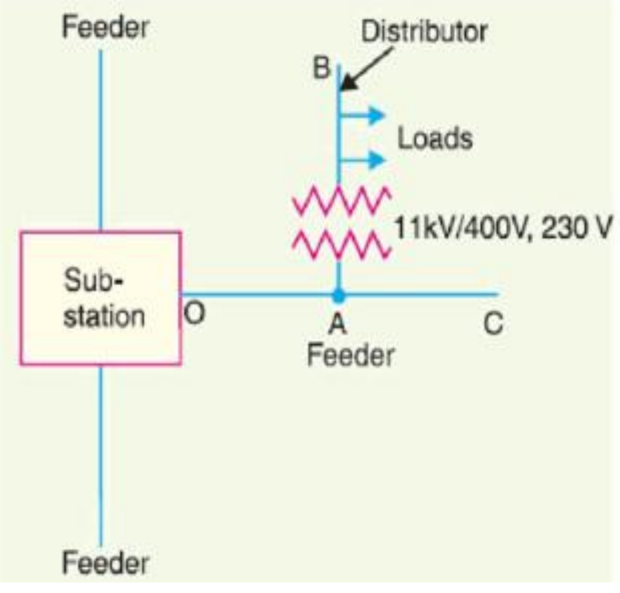
•Fig. shows a single line diagram of a radial system

•for d.c. distribution where a feeder OC supplies a distributor AB at point A.

•distributor is fed at one end only i.e., point A is this case.

•Fig. (ii) shows a single line diagram of radial system for a.c. distribution





•This is the simplest distribution circuit and has the lowest initial cost.

Drawbacks :

(a) The end of the distributor nearest to the feeding point will be heavily loaded. (b any fault on the feeder or distributor cuts off supply to the consumers who are on the side of the fault .

(c) The consumers at the distant end of the distributor would be subjected to serious voltage fluctuations when the load on the distributor changes.

Due to these limitations, this system is used for short distances only.

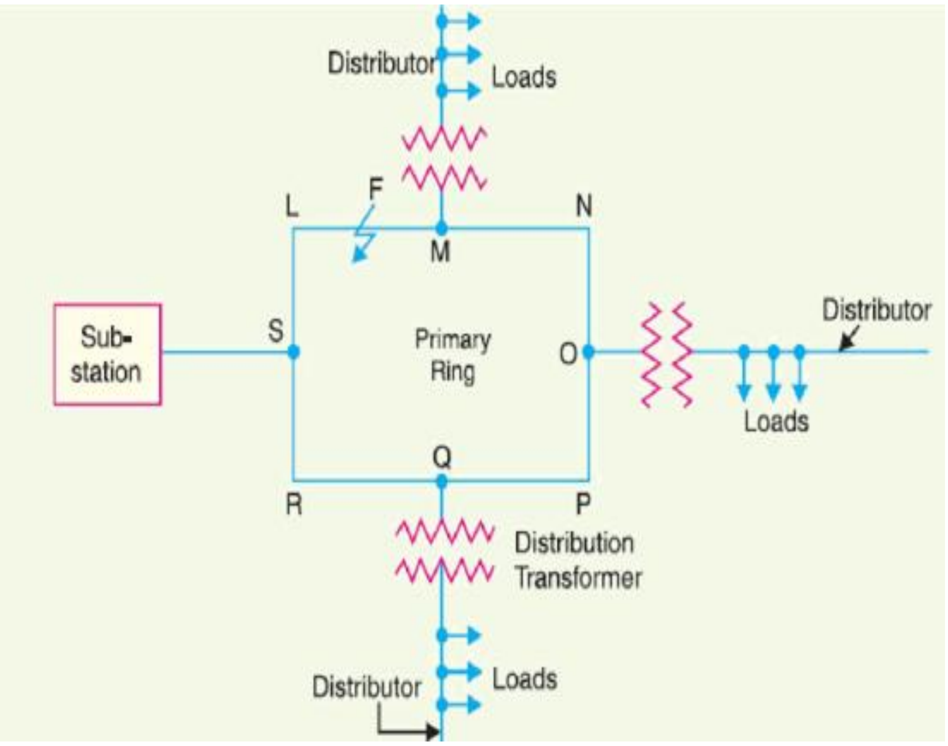
(ii) Ring main system.

•In this system, the primaries of distribution transformers form a loop

•The loop circuit starts from the substation bus-bars, makes a loop through the area to be served, and returns to the substation.

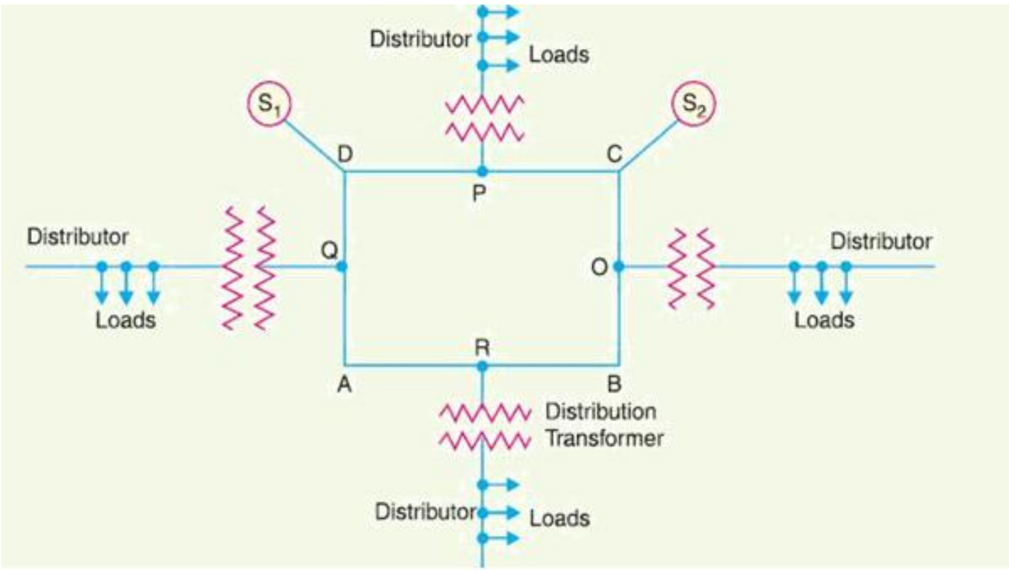
•Fig. shows the single line diagram of ring mainsystem for a.c. distribution where substation supplies to the closed feeder LMNOPQRS.

•The distributors are tapped from different points M, O and Q of the feeder through distribution transformers.



(iii) Interconnected system.

- When the feeder ring is energised by two or more than two generating stations or substations, it is called inter-connected system.
- Fig. shows the single line diagram of interconnected system where the closed feeder ring ABCD is supplied by two substations 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.

ADVANTAGES :

(a) It increases the service reliability.

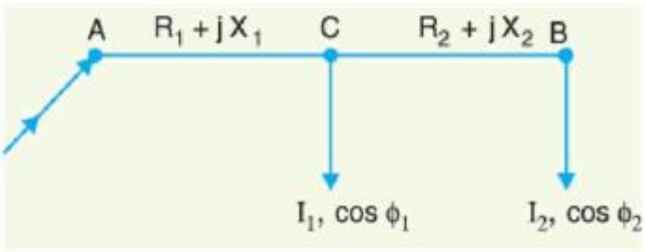
(b) Any area fed from one generating station during peak load hours can be fed from the other generating station. This reduces reserve power capacity and increases efficiency of the system.

A.C. DISTRIBUTION VOLTAGE CALCULATIONS:

In a.c. distribution calculations, power factors of various load currents have to be considered since currents in different sections of the distributor will be the vector sum of load currents and not the arithmetic sum. The power factors of load currents may be given (i) w.r.t. receiving or sending end voltage or (ii) w.r.t. to load voltage itself. Each case shall be discussed separately.

(i) Power factors referred to receiving end voltage: Consider an a.c. distributor AB with concentrated loads of I1 and I2 tapped off at points C and B as shown in Fig. Taking the receiving end voltage VB as the reference vector, let lagging power factors at C and B be cos Ø1 and cosØ2 w.r.t. VB.

Let R1, X1 and R2, X2 be the resistance and reactance of sections AC and CB of the distributor.



Impedance of section AC, $\overrightarrow{Z_{AC}} = R_1 + j X_1$

Impedance of section CB, $\overrightarrow{Z_{CB}} = R_2 + j X_2$

Load current at point C, $\vec{I_1} = I_1 (\cos \phi_1 - j \sin \phi_1)$

Load current at point B, $\vec{I_2} = I_2 (\cos \phi_2 - j \sin \phi_2)$

Current in section CB, $\overrightarrow{I_{CB}} = \vec{I_2} = I_2 (\cos \phi_2 - j \sin \phi_2)$

Current in section AC, $\overrightarrow{I_{AC}} = \vec{I_1} + \vec{I_2}$

$= I_1 (\cos \phi_1 - j \sin \phi_1) + I_2 (\cos \phi_2 - j \sin \phi_2)$

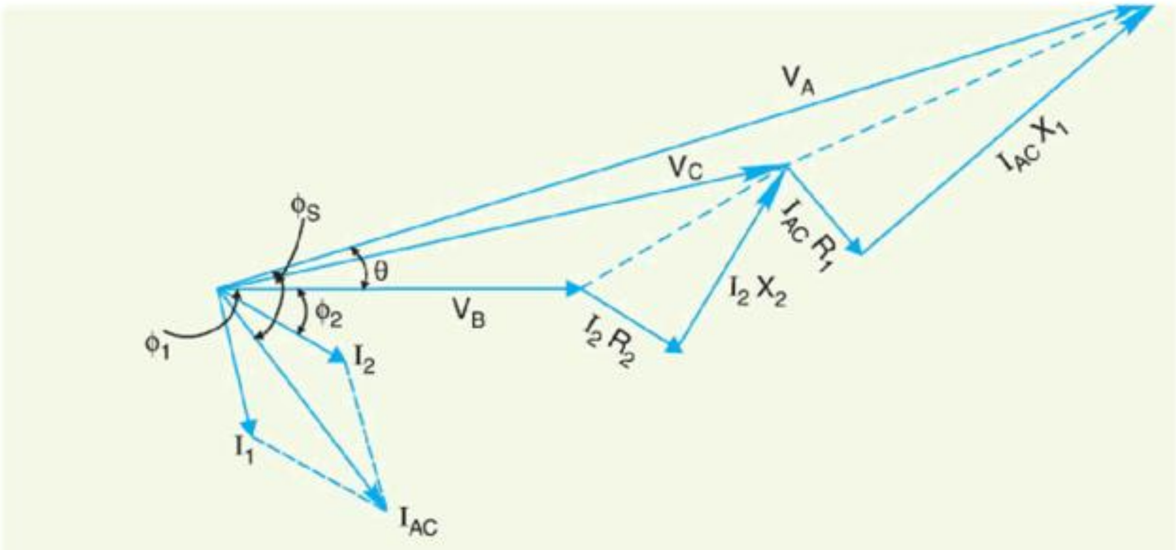
Voltage drop in section CB, $\overrightarrow{V_{CB}} = \overrightarrow{I_{CB}}\,\overrightarrow{Z_{CB}} = I_2 (\cos \phi_2 - j \sin \phi_2)(R_2 + j X_2)$

Voltage drop in section AC, $\overrightarrow{V_{AC}} = \overrightarrow{I_{AC}}\,\overrightarrow{Z_{AC}} = \left(\vec{I_1} + \vec{I_2}\right) Z_{AC}$

$= [I_1(\cos \phi_1 - j \sin \phi_1) + I_2 (\cos \phi_2 - j \sin \phi_2)]\,[R_1 + jX_1]$

Sending end voltage, $\vec{V_A} = \vec{V_B} + \overrightarrow{V_{CB}} + \overrightarrow{V_{AC}}$

Sending end current, $\vec{I_A} = \vec{I_1} + \vec{I_2}$



(*ii*) **Power factors referred to respective load voltages.** Suppose the power factors of loads in the previous Fig. 14.1 are referred to their respective load voltages. Then ϕ_1 is the phase angle between V_C and I_1 and ϕ_2 is the phase angle between V_B and I_2. The vector diagram under these conditions is shown in Fig. 14.3.

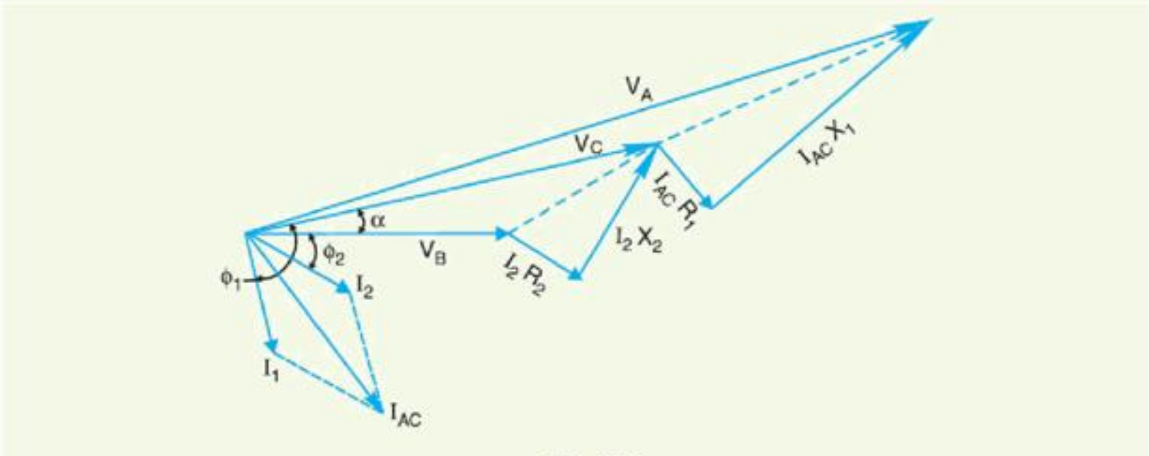


Fig. 14.3

$$\text{Voltage drop in section } CB = \vec{I_2}\,\overrightarrow{Z_{CB}} = I_2(\cos\phi_2 - j\sin\phi_2)(R_2 + j\,X$$

$$\text{Voltage at point } C = \vec{V_B} + \text{Drop in section } CB = V_C\angle\alpha\ \text{(sa}$$

Now $$\vec{I_1} = I_1\angle -\phi_1 \quad w.r.t.\ \text{voltage } V_C$$

$\therefore$ $$\vec{I_1} = I_1\angle -(\phi_1 - \alpha) \qquad w.r.t.\ \text{voltage } V_B$$

i.e. $$\vec{I_1} = I_1[\cos(\phi_1 - \alpha) - j\sin(\phi_1 - \alpha)]$$

Now $$\overrightarrow{I_{AC}} = \vec{I_1} + \vec{I_2}$$

$$= I_1[\cos(\phi_1 - \alpha) - j\sin(\phi_1 - \alpha)] + I_2(\cos\phi_2 - j\sin\phi_2)$$

$$\text{Voltage drop in section } AC = \overrightarrow{I_{AC}}\,\overrightarrow{Z_{AC}}$$

$$\text{Voltage at point } A = V_B + \text{Drop in } CB + \text{Drop in } AC$$

Important Questions:

1. Distinguish between AC and DC distribution systems.

2. Derive the expression for voltage drop over uniformly loaded distributor fed at both ends with equal voltages.

3 .Classify the distribution systems in detail.

4.What are the requirements of good distribution system**.**

5.(a)Explain with neat figures the connection schemes of distribution systems

(b)Write a short notes on

(i) Feeder (ii) Distributor (iii) Service mains

6. (a) Compare Radial system and Ring main system.

(b)Derive the voltage drop calculations for the following.

(i)Power refers to receiving end(or)sending end.

(ii) Power refers to respective load voltages.