The Supply System

- It is the interlink between the generating stations and the consumers over which energy is transferred.

Or, in a more simple way -

- Energy is generated in the generating stations and this energy is made available to the consumers by the supply system.
- It consists of network of conductors and associated items/equipment over which the energy is transferred from generating stations to the consumers.

The supply system is subdivided into two distinct parts:

1. Transmission system and
2. Distribution system.

- Transmission system may further be subdivided into:

(i) Primary transmission (765kV, 400kV, 275kV & 220kV) and

(ii) Secondary transmission (132kV & 66kV).

- Distribution system may further be subdivided into:

(i) Primary distribution (33kV),

(ii) Secondary distribution (11kV & 6.6kV) and

(iii) Tertiary distribution (400kV – Line to line, 230V – Line

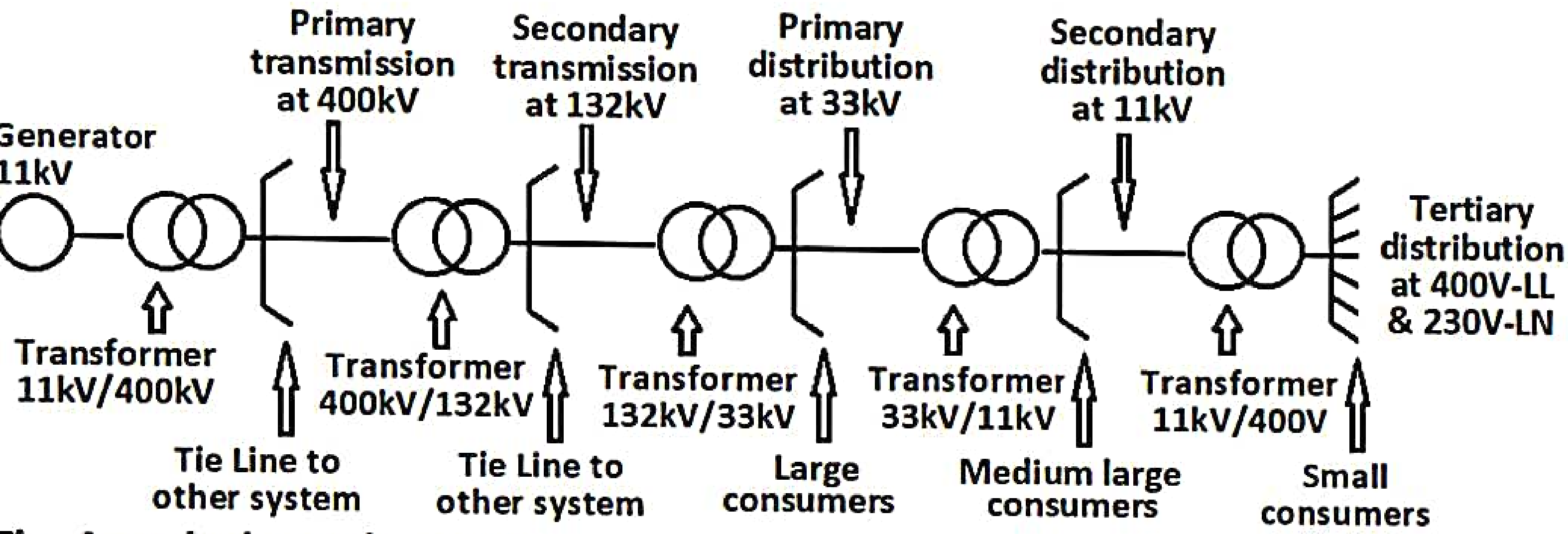


Fig. A typical supply system

Points to note:

- There are several working voltages in the same system.
- Change of voltage takes place where is a subdivision → at a place known as substation.
- Change of voltage is effected by means of a transformer.
- For equipment manufacturing reasons & for interconnections, voltages are standardized.
- Standard frequency in our country is 50Hz.

Feeder: Connecting link between the substation and the area served by the station.

- Current loading of a feeder is same along the whole length.
- No tapping/connection is taken from the feeder along the length.

Distributor: Connecting link between the feeder & the service mains.

- It is characterised by numerous tappings in the form of service mains for connecting the consumers.
- Current loading of distributor decreases from the feeding point to the far end of it.

Service mains: Connecting link between the distributor & the terminals of the consumer.

Distribution Systems

In general conductors in distribution system may be grouped under three distinct categories:

1. Feeder,
2. Distributor &
3. Service mains.

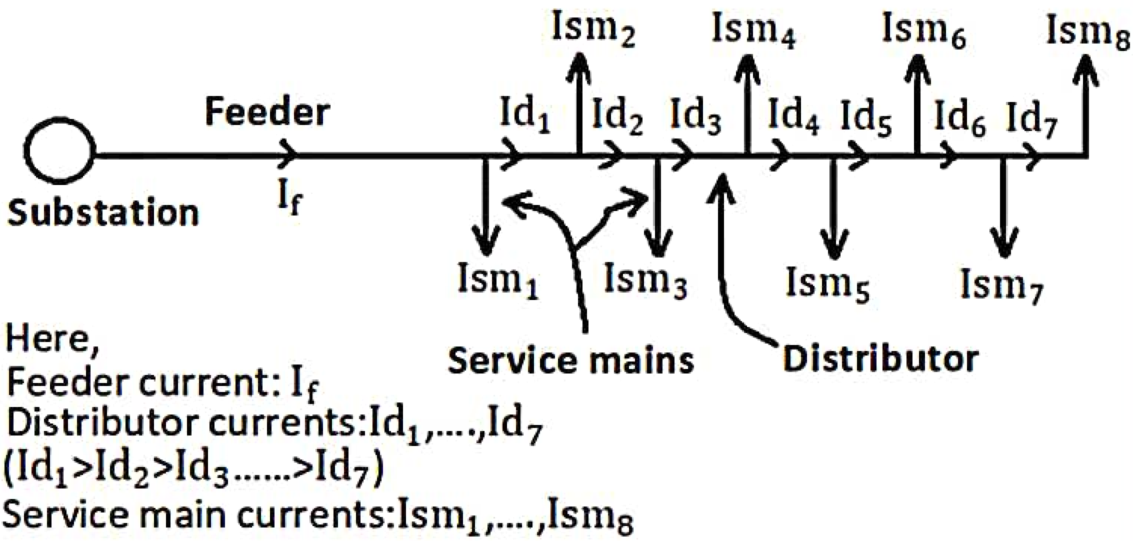


Fig. A typical distribution system

Copper Efficiency Comparison for Various Systems

- It is necessary to design the supply systems most economically → i.e. use of resources as much as possible.
- Accordingly, it is necessary to compare the amounts of copper necessary for various possible systems of supply.

➢ **Assumptions:**

(1) To supply the same power P.

(2) Distance 'l' is same for all the systems.

(3) Efficiency of transmission is same, i.e. losses are same for all the systems.

(4) Cost of insulation is same for all the systems.

- For overhead lines maximum voltage 'V' between conductor to earth is same for all the systems.

- For under ground cables maximum voltage 'V' between the

Systems under consideration:

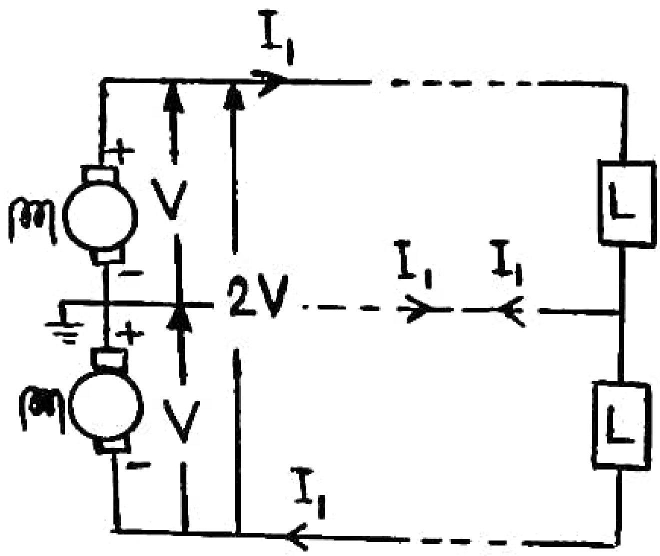
(i) D.C. three wire,

(ii) A.C. single phase,

(iii) A.C. three phase three wire,

(iv) A.C. three phase four wire,

(v) D.C. two wire system.



D.C. Three Wire System

- The two outer wires are at

Potentials $\pm$ V.

- The centre wire is earthed.

- Voltage between lines is 2V

Line current $I_1 = \frac{P}{2V}$

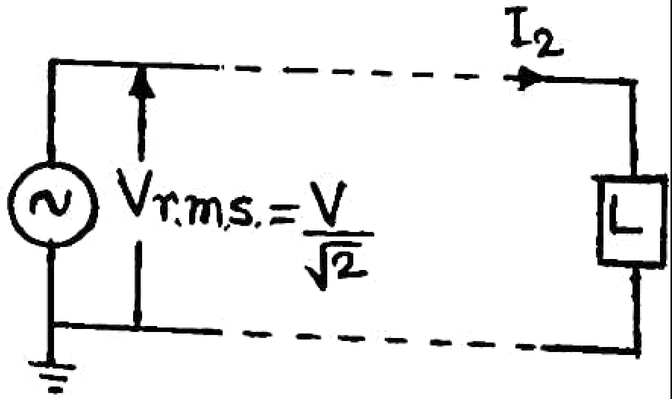
Line loss $= 2I_1^2 R_1 = 2\left(\frac{P^2}{4V^2}\right) \cdot R_1$

$$= \frac{P^2}{2V^2} \cdot R_1 \quad ----(1)$$

where,

R_1 is the resistance per conductor.

A.C. Single Phase System



Line current $I_2 = \frac{P}{\frac{V}{\sqrt{2}} \cdot \cos\phi} = \frac{\sqrt{2}P}{V \cdot \cos\phi}$

where, $\cos\phi$ is the power factor.

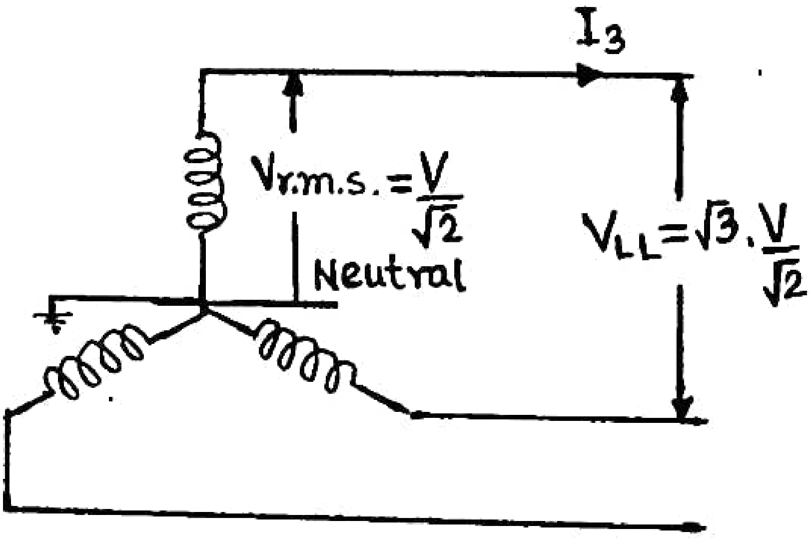
Line loss $= 2I_2^2 \cdot R_2 = 2 \cdot \left(\frac{2P^2}{V^2 \cdot \cos^2\phi}\right) \cdot R_2$

$$= \frac{4P^2}{V^2 \cdot \cos^2\phi} \cdot R_2 \quad ----(2)$$

where,

A.C. Three Phase Three Wire System

- In this case neutral is earthed but it is not provided to the consumers.
- Load is assumed to be balanced.



$$\text{Line current } I_3 = \frac{P}{\sqrt{3}.V_{LL}.\cos\phi}$$

$$= \frac{P}{\sqrt{3}.\sqrt{3}\frac{V}{\sqrt{2}}\cos\phi} = \frac{\sqrt{2}P}{3V\cos\phi}$$

$$\text{Line loss} = 3I_3^2 R_3 = 3\left(\frac{\sqrt{2}P}{3V\cos\phi}\right)^2.R_3$$

$$= \frac{2P^2}{3V^2\cos^2\phi}R_3 \quad ----(3)$$

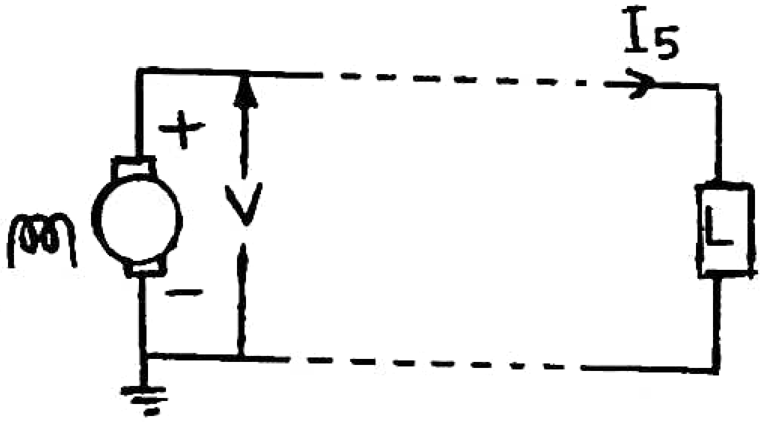
where,

R_3 is the resistance per conductor.

D.C. Two Wire System

Line current $I_5 = \frac{P}{V}$

Line loss $= 2 I_5^2 R_5 = 2 \frac{P^2}{V^2} \cdot R_5$ ----(5)



where,

R_5 is the resistance per conductor.

- Let, a_1, a_2, a_3, a_4 and a_5 be the areas of cross sections for the five cases respectively.

Again,

$R_1 = \rho \cdot \frac{l}{a_1}$; $R_2 = \rho \cdot \frac{l}{a_2}$; $R_3 = \rho \cdot \frac{l}{a_3}$; $R_4 = \rho \frac{l}{a_4}$ and $R_5 = \rho \frac{l}{a_5}$

Then,

$\frac{R_1}{R_2} = \frac{a_2}{a_1}$; $\frac{R_1}{R_3} = \frac{a_3}{a_1}$; $\frac{R_1}{R_4} = \frac{a_4}{a_1}$ and $\frac{R_1}{R_5} = \frac{a_5}{a_1}$ ----(6)

Equating losses of the first two cases,

$$\frac{P^2}{2V^2} \cdot R_1 = \frac{4P^2}{V^2 \cos^2\phi} \cdot R_2$$

$$\text{Or, } \frac{R_1}{R_2} = \frac{8}{\cos^2\phi} = \frac{a_2}{a_1} \text{ ----(7)}$$

Equating losses of the 1st and 3rd Cases,

$$\frac{P^2}{2V^2} \cdot R_1 = \frac{2P^2}{3V^2 \cos^2\phi} \cdot R_3$$

$$\text{Or, } \frac{R_1}{R_3} = \frac{4}{3\cos^2\phi} = \frac{a_3}{a_1} \text{ ----(8)}$$

Equating losses of the 1st and the 4th Cases,

$$\frac{P^2}{2V^2} \cdot R_1 = \frac{2P^2}{3V^2 \cos^2\phi} \cdot R_4$$

Or, $$\frac{R_1}{R_4} = \frac{4}{3\cos^2\phi} = \frac{a_4}{a_1} \quad \text{----(9)}$$

Equating losses of the 1st and the 5th Cases,

$$\frac{P^2}{2V^2} \cdot R_1 = 2\frac{P^2}{V^2} \cdot R_5$$

Or, $$\frac{R_1}{R_5} = 4 = \frac{a_5}{a_1} \quad \text{----(10)}$$

Therefore,

$$v_1 : v_2 : v_3 : v_4 : v_5 = 2a_1 l : 2a_2 l : 3a_3 l : 4a_4 l : 2a_5 l$$

$$= 1 : \frac{2a_2 l}{2a_1 l} : \frac{3a_3 l}{2a_1 l} : \frac{4a_4 l}{2a_1 l} : \frac{2a_5 l}{2a_1 l}$$

$$= 1 : \frac{a_2}{a_1} : \frac{3}{2}\frac{a_3}{a_1} : 2\frac{a_4}{a_1} : \frac{a_5}{a_1}$$

$$= 1 : \frac{8}{\cos^2\phi} : \frac{3}{2} \cdot \frac{4}{3\cos^2\phi} : 2 \cdot \frac{4}{3\cos^2\phi} : 4$$

$$= 1 : \frac{8}{\cos^2\phi} : \frac{2}{\cos^2\phi} : \frac{8}{3\cos^2\phi} : 4 \quad \text{-----(11)}$$

1st 5th 2nd 3rd 4th

In the above v_1, v_2, v_3, v_4 and v_5 *are volumes of conductors in the five cases.*

So, according to copper efficiency,

1. D.C. three wire system,
2. A.C. three phase three wire system,
3. A.C. three phase four wire system,
4. D.C. two wire system and
5. A.C. single phase two wire system.

Problem: A 1Φ load of 10MW is transmitted by a pair of overhead conductors. If a third conductor of same cross section be added and a 3Φ supply be thus substituted for the original single phase supply, calculate the 3Φ load which can now be transmitted if voltage between wires and the percentage loss in the systems remain unchanged.

Soln.: Let, 1Φ power be P_1= 10MW and the same for 3Φ system be P_2 MW. Further, assume,

V= voltage between conductors for both the 1Φ & 3Φ system.

I_1= Current in 1Φ system,

I_2= Current in 3Φ system,

Cosφ = p.f. for both 1Φ & 3Φ systems &

R= resistance per conductor.

$$\therefore I_1 = \frac{P_1}{V\cos\phi}$$

Loss in 1ϕ system $= 2I_1^2R = 2.\left(\frac{P_1}{V\cos\phi}\right)^2.R$

$$= \frac{2P_1^2}{V^2\cos^2\phi}R$$

Similarly, $I_2 = \frac{P_2}{\sqrt{3}\,V\cos\phi}$

Loss in 3ϕ System $= 3I_2^2R = 3.\left(\frac{P_2}{\sqrt{3}\,V\cos\phi}\right)^2R$

$$= \frac{P_2^2}{V^2\cos^2\phi}R$$

Equating % losses of the two systems,

$$\frac{\frac{2P_1^2}{V^2 \cdot \cos^2\phi} \cdot R}{V \cdot I_1 \cos\phi} = \frac{\frac{P_2^2}{V^2 \cos^2\phi} \cdot R}{\sqrt{3} V I_2 \cos\phi}$$

$$\text{or, } P_2^2 = 2\sqrt{3} P_1^2 \cdot \frac{I_2}{I_1} = 2\sqrt{3} P_1^2 \cdot \frac{\frac{P_2}{\sqrt{3} V \cos\phi}}{\frac{P_1}{V \cos\phi}}$$

$$= 2\sqrt{3} P_1^2 \cdot \frac{P_2}{\sqrt{3} P_1}$$

$$= 2P_1P_2$$

$$\text{or, } P_2 = 2P_1 = 2 \times 10 \text{MW}$$

$$= 20 \text{MW}$$