4TH SEM (ELECTRICAL ENGG.)

GENERATION, TRANSMISSION AND DISTRIBUTION

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ECONOMIC ASPECTS

CAUSES OF LOW POWER FACTOR:

(*i*) Most of the a.c. motors are of induction type (1ϕ and 3ϕ induction motors) which have low lagging power factor. These motors work at a power factor which is extremely small on light load (0·2 to 0·3) and rises to 0·8 or 0·9 at full load.
(*ii*) Arc lamps, electric discharge lamps and industrial heating furnaces operate at low lagging power factor.
(*iii*) The load on the power system is varying; being high during morning and evening and low at other times. During low load period, supply voltage is increased which increases the magnetisation current. This results in the decreased power factor.

METHODS OF IMPROVEMENT OF POWER FACTOR:

Power factor can be improved by the following methods:

1.Static capacitors.

2. Synchronous condenser.

3. Phase advancers

1. Static capacitor. The power factor can be improved by connecting capacitors in parallel with the equipment operating at lagging power factor.The capacitor draws a leading current and partly or completely neutralises the lagging reactive component of load current. This raises the power factor of the load.
2. Synchronous condenser. A synchronous motor takes a leading current when over-excited and, therefore, behaves as a capacitor. An over-excited synchronous motor running on no load is known as *synchronous condenser.* When such a machine is connected in parallel with the supply, it takes a leading current which partly neutralises the lagging reactive component of the load. Thus the power factor is improved.

3. Phase advancers. Phase advancers are used to improve the power factor of induction motors. The low power factor of an induction motor is due to the fact that its stator winding draws exciting current which lags behind the supply voltage by 90o. If the exciting ampere turns can be provided from some other a.c. source, then the stator winding will be relieved of exciting current and the power factor of the motor can be improved. This job is accomplished by the phase advancer which is simply an a.c. exciter. The phase advancer is mounted on the same shaft as the main motor and is connected in the rotor circuit of the motor. It provides exciting ampere turns to the rotor circuit at slip frequency. By providing more ampere turns than required, the induction motor can be made to operate on leading power factor like an over-excited synchronous motor.

FACTORS AFFECTING THE ECONOMICS OF GENERATION:

1.LOAD CURVES:

The curve showing the variation of load on the power station with respect to (*w.r.t*) *time is known as a* **load curve.**

The load on a power station is never constant; it varies from time to time. These load variations during the whole day (*i.e.,* 24 hours) are recorded half-hourly or hourly and are plotted against time on the graph. The curve thus obtained is known as *daily load curve* as it shows the variations of load *w.r.t.* time during the day.

The *monthly load curve* can be obtained from the daily load curves of that month. For this purpose, average values of power over a month at different times of the day are calculated and then plotted on the graph. The monthly load curve is generally used to fix the rates of energy. The *yearly load curve* is obtained by considering the monthly load curves of that particular year. The yearly load curve is generally used to determine the annual load factor.

2. DEMAND FACTOR:

It is the ratio of maximum demand on the power station to its connected load i.e.,

Demand factor = Maximum demand/Connected load

The value of demand factor is usually less than 1. It is expected because maximum demand on the power station is generally less than the connected load.

3. MAXIMUM DEMAND:

It is the greatest demand of load on the power station during a given period.

The load on the power station varies from time to time. The maximum of all the demands that have occurred during a given period (*say* a day) is the maximum demand.

4.LOAD FACTOR:

The ratio of average load to the maximum demand during a given period is known as **load factor** *i.e.*,

Load factor =Average load/Max. demand

If the plant is in operation for T hours,

Load factor = Average load* T /Max. demand *T

=Units generated in T hours/Max. demand × T hours

The load factor may be daily load factor, monthly load factor or annual load factor if the time period considered is a day or month or year. Load factor is always less than 1 because average load is smaller than the maximum demand.

5. **Diversity factor.** *The ratio of the sum of individual maximum demands to the maximum demand on power station is known as* **diversity factor** *i.e.,*

Diversity factor = Sum of individual max. demands /Max. demand on power station

A power station supplies load to various types of consumers whose maximum demands generally do not occur at the same time. Therefore, the maximum demand on the power station is always less than the sum of individual maximum demands of the consumers. Obviously, diversity† factor will always be greater than 1.

6.Plant capacity factor. *It is the ratio of actual energy produced to the maximum possible energy that could have been produced during a given period i.e.,*

Plant capacity factor = Actual energy produced/ Max. energy that could have been produced
=Average demand *T /Plant capacity *T
=Average demand/Plant capacity

Base Load and Peak Load on Power Station:
The changing load on the power station makes its load curve of variable nature.
(*i*) Base load. *The unvarying load which occurs almost the whole day on the station is known as* **base load.**
(ii)Peak load. *The various peak demands of load over and above the base load of the station is known as* **peak load.**

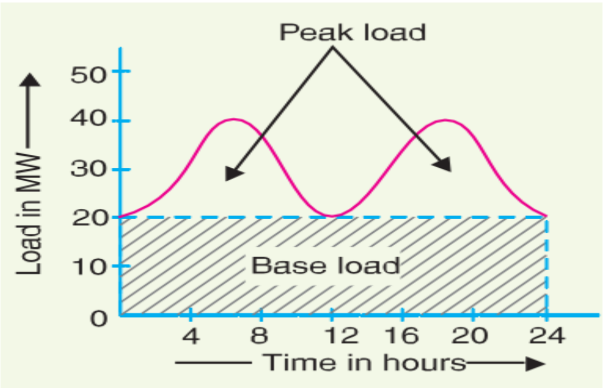

Fig. 3.13

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TYPES OF TARIFF:

Tariff: *The rate at which electrical energy is supplied to a consumer is known as* **tariff**.

Desirable characteristics of Tariff:

(i)Proper return : The tariff should be such that it ensures the proper return from each consumer. In other words, the total receipts from the consumers must be equal to the cost of producing and supplying electrical energy plus reasonable profit. This will enable the electric supply company to ensure continuous and reliable service to the consumers.

(*ii*) *Fairness* : The tariff must be fair so that different types of consumers are satisfied with the rate of charge of electrical energy. Thus a big consumer should be charged at a lower rate than a small consumer. It is because increased energy consumption spreads the fixed charges over a greater number of units, thus reducing the overall cost of producing electrical energy. Similarly, a consumer whose load conditions do not deviate much from the ideal (*i.e*., non variable) should be charged at a lower rate than the one whose load conditions change appreciably from the ideal.

(*iii*) *Simplicity* : The tariff should be simple so that an ordinary consumer can easily understand it. A complicated tariff may cause an opposition from the public which is generally distrustful of supply companies.

(*iv*) *Reasonable profit* : The profit element in the tariff should be reasonable. An electric supply company is a public utility company and generally enjoys the benefits of monopoly. Therefore, the investment is relatively safe due to non-competition in the market. This calls for the profit to be restricted to 8% or so per annum.

(*v*) *Attractive* : The tariff should be attractive so that a large number of consumers are encouraged to use electrical energy. Efforts should be made to fix the tariff in such a way so that consumers can pay easily.

1.Flat rate tariff. *When different types of consumers are charged at different uniform per unit rates, it is called a* **flat rate tariff**.

2.Block rate tariff. *When a given block of energy is charged at a specified rate and the succeeding blocks of energy are charged at progressively reduced rates, it is called a* **block rate tariff**.

3. Two-part tariff. *When the rate of electrical energy is charged on the basis of maximum demand of the consumer and the units consumed, it is called a* **two-part tariff**.

4. Maximum demand tariff. It is similar to two-part tariff with the only difference that the maximum demand is actually measured by installing maximum demand meter in the premises of the consumer. This removes the objection of two-part tariff where the maximum demand is assessed merely on the basis of the rateable value. This type of tariff is mostly applied to big consumers.
However, it is not suitable for a small consumer (*e.g.*, residential consumer) as a separate maximum demand meter is required.

Substations:

The assembly of apparatus used to change some characteristic (e.g. voltage, a.c. to d.c., frequency, p.f. etc.) of electric supply is called a **sub-station.**

LAYOUT OF SUBSTATION:

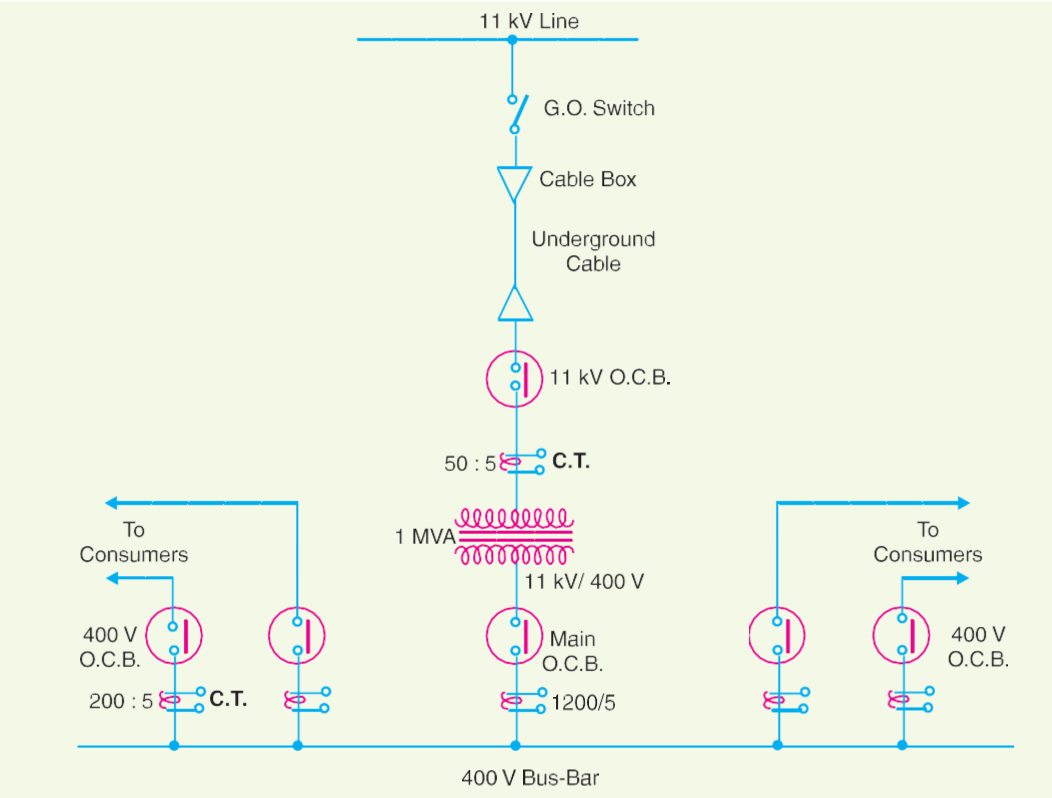


Fig. 25.11

Underground Cables

- By Monalisa Pani

- Due to Safety and space constraints cables are used for underground transmission ~~of~~ and distribution of electrical energy in cities.
- A 'cable' is basically an ~~is~~ insulated conductor. External protection against mechanical injury, moisture entry and chemical reaction is provided on the cable.

- CLASSIFICATION OF CABLES :

Cables can be classified according to
1) Types of insulation material
II) Voltage at which they are required to operate.

Usually, voltage decides the insulation material. Hence, cables are divided into the following groups :

a)	Low tension cables	upto 1000 V	LT
b)	High tension cables	upto 11 kV	HT
c)	Super tension cables	upto 33 kv (from 22 kv)	ST
d)	Extra High tension cables	from 33 kv to 66 kv	EHT
e)	Extra Super voltage	Beyond 132 kv	

- CABLE INSULATION :

'Insulation' is used to cover the conductor of the cable so, as to isolate it from surroundings.

Insulation material should have following properties
- High insulation resistance
- High di-electric strength
- High mechanical strength
- Non-hygroscopic (should not absorb moisture from air)
- Non-inflammable (should not catch fire)
- Low cost
- Less reactive (not affected by acid or alkali)

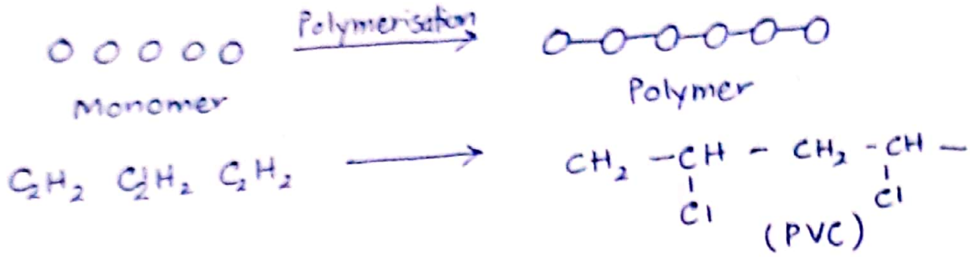
Materials used for cable insulation

a) Polyvinyl Chrolide (PVC)

- It is a synthetic compound (Not available in nature, man-made)
- Obtained from polymerisation of acetylene

  * Polymerisation : a chemical reaction in which two or more molecules combine to form larger molecules repeating structrucal unit

  * Acetylene : C_2H_2 (also known as ethylene)



CL - chroline

- PVC is chemically combined with a plastic compound. A gel is formed, which is used over the conductor to form insulation cover.

- PVC has
  - high isulation resistance
  - good dielectric strength
  - mechanical toughness over a wide range of temperatures
  - It is inert to oxygen, many alkalies and acid.
  - Generally used for low and medium domestic lights and power installations

b) VULCANISED INDIAN RUBBER (VIR)

- prepared by mixing zinc oxide, red lead and 3-5% sulfur. with pure rubber.
- the compound so formed is rolled into thin sheets and cut into pieces
- Rubber is then applied to conductor and heated to temp of about 150°C. The whole process is known as vulcanisation.

→ has great mechanical strength, durability, resistant to wear.

→ But, sulfur reacts with copper, limiting its use

c) Rubber

Obtained naturally from trees or oil products.

- Its has good dielectric strength and resistivity of insulation.
- It suffers from following drawbacks :
  1) readily absorbs moisture
  2) max. safe temp. is 38°C
  3) Soft and liable to damage

d) Impregnated ~~Rubber~~ Paper :

- It means paper soaked in special chemical compound such as paraffinic or napthenic material.
- It offers low cost, high di-electric strength, high insulation resistance.
- But, it also has disadvantages :
  1) Hygroscopic (absorbs moisture)
- Suitably used for distribution at low voltages in congested areas.

e) Varnished Cambric :

- Cotton cloth impregnated and coated with varnish.
- This type of insulation is also known as empire tape.
- It has dielectric strength about 4 kv/mm and permittivity is 2.5 to 3.8.

Construction of Cables :

C-I-M-B-A-S

- Cores or Conductors : A cable may have one or more core (conductor) depending upon use.
- Insulation : Each core is covered with insulation. Insulation depends upon the voltage rating of application.
- Metallic Sheath : Sheath means cover. In order to protect cable from moisture, acid or alkali in soil and atmosphere a metallic sheath of alluminium or lead is provided.
- Bedding : Consists of fibrous material like jute to protect metallic sheath against corrosion.
- Armouring : One or two layers of galvanised steel to protect from mechanical injury while laying.
- Serving : A layer of fibrous material over armouring, to protect against atmospheric conditions.

Methods of cable laying :

a) Direct laying :

- trench of about 1·5 m deep and 45 cm wide is dug.
- trench is covered with fine sand (10cm thickness). Sand prevents entry of moisture.
- then cable is laid, and another layer of sand covers the cable.
- the trench is covered with bricks and other materials in order to protect the cable from mechanical injury.
- Mutual spacing or gap is provided between cables to prevent heating and fault extension.
- Cables must have bituminised paper and hessian tape as serving to provide protection against corrosion and electrolysis.

b) Draw in System :

- Conduit or duct of glazed stone or cast iron or concrete are laid in the ground with manholes.
- Cables laid this way should not be armoured but, it should be provided with 'Serving' to protect them.

c) Solid system :

- Cable is laid in open pipe or throughs (long narrow container) dug out in earth along the cable route.

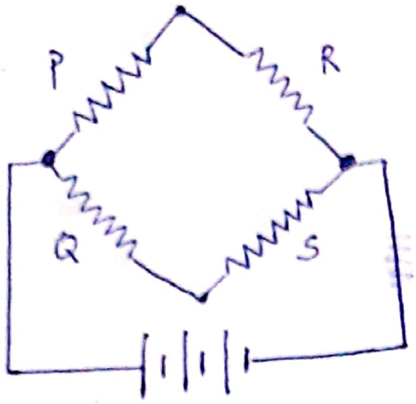
Types of Cable fault :

A fault is an abnormal situation resulting in very high or low value of voltage or current. Types of fault

i) Open circuit fault : when there is a break in conductor

ii) Short Circuit fault : when two conductors of a multi core cable comes in contact with each other.

iii) Earth fault : when conductor of the cable comes in contact with the earth.

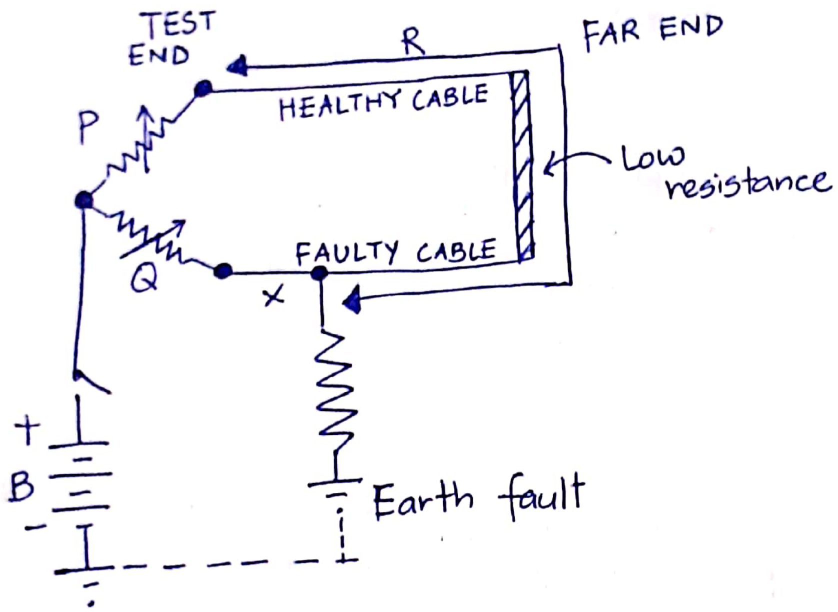


$$\frac{P}{Q} = \frac{R}{S}$$

(Wheatstone Bridge)

Murray Loop Test :

1) method of locating fault or short circuit



$$\frac{P}{Q} = \frac{R}{X}$$

$$\Rightarrow \frac{P}{Q} + 1 = \frac{R}{X} + 1$$

$$\Rightarrow \frac{P+Q}{Q} = \frac{R+X}{X}$$

r : resistance of individual cable

$$\Rightarrow \frac{P+Q}{Q} = \frac{2r}{X}$$

$$\Rightarrow X = \frac{Q}{P+Q} \times 2r$$

if l is the length of individual cable, then resistance per meter length of cable $= \frac{r}{l}$

. Distance of fault point from test end is

$$d = \frac{x}{(r/l)}$$

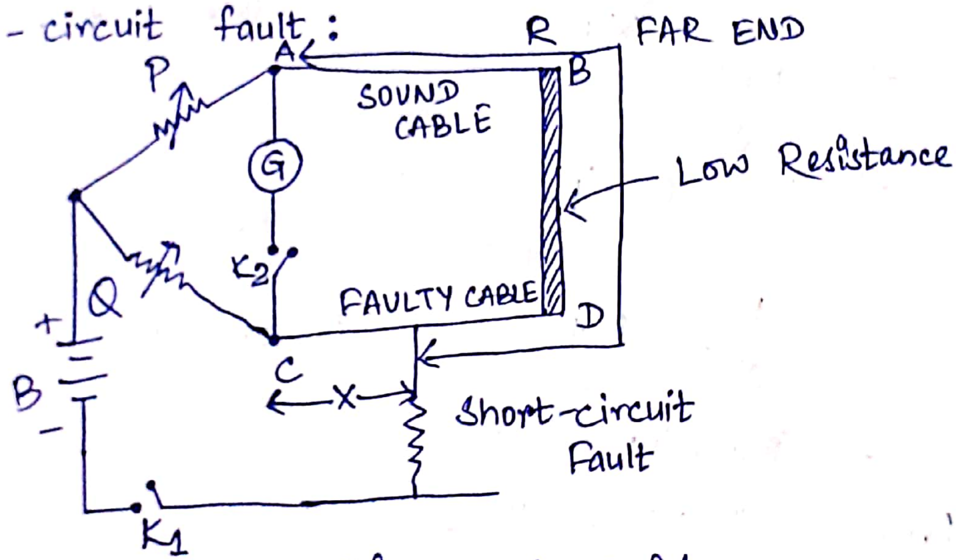
$$= \frac{\frac{Q}{(P+Q)} \times 2r}{(r/l)}$$

$$= \frac{Q}{(P+Q)} \times 2r \times \frac{l}{r}$$

$$= \frac{Q}{(P+Q)} \times 2l$$

$$= \frac{Q}{(P+Q)} \times (\text{loop length}) \text{ (in m)}$$

(ii) Short-circuit fault :



In balanced position of bridge :

$$\frac{P}{Q} = \frac{R}{X}$$

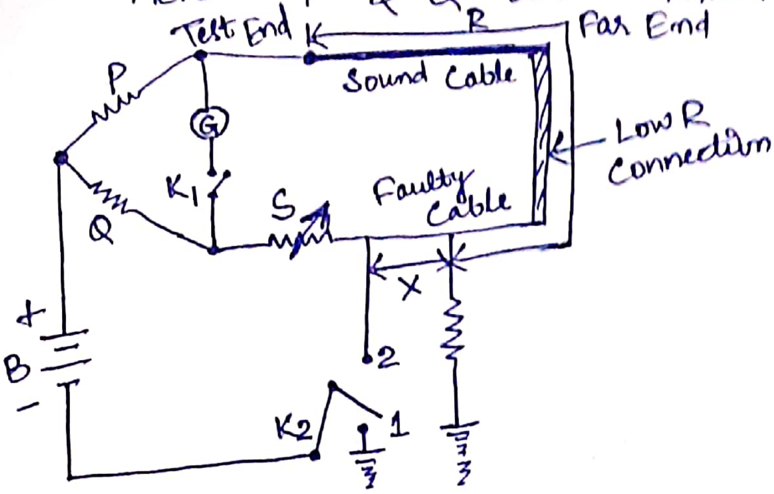
$$\Rightarrow \frac{P+Q}{Q} = \frac{R+X}{X} = \frac{2r}{X}$$

$$\Rightarrow X = \frac{Q}{P+Q} \times 2r$$

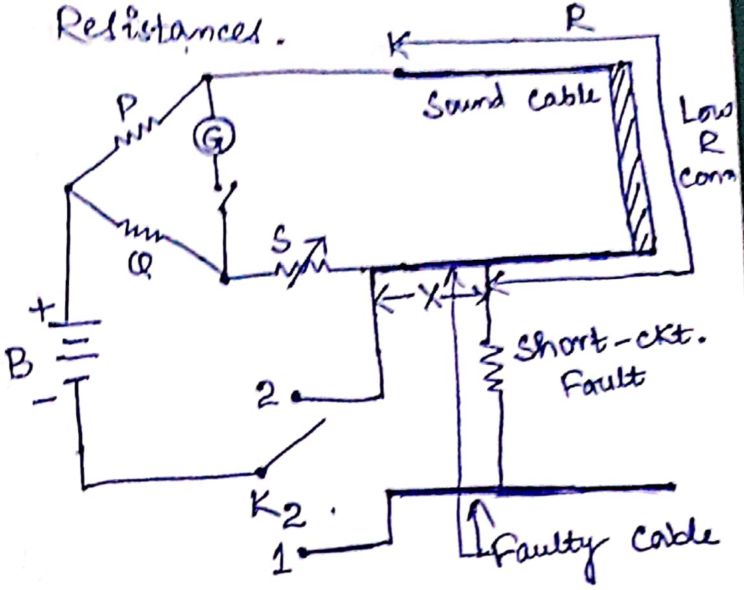
$$= \frac{Q}{P+Q} \times (\text{loop length}) \text{ (in m)}$$

Varley Loop Test :

Here P & Q are fixed Resistances.



Earth Fault



Short-Circuit Fault

For earth or short-ckt. fault, Key K_2 is thrown to position 1. Let S_1 & S_2 be two new resistance values when key K_2 is thrown to position 1 & 2 respectively.

$$\frac{P}{Q} = \frac{R}{X+S_1} \quad \text{(Position 1).}$$

$$\Rightarrow \frac{P+Q}{Q} = \frac{R+X+S_1}{X+S_1}$$

$$\Rightarrow X = \frac{Q(R+X) - PS_1}{P+Q} \quad \text{—— (1)}$$

$$\frac{P}{Q} = \frac{R+X}{S_2} \quad \text{(Position 2)}$$

$$\Rightarrow (R+X)Q = PS_2 \quad \text{—— (II)}$$

From eq^n (1) & (II),

$$X = \frac{P(S_2 - S_1)}{P+Q}$$

Loop Resistance $= R+X = \frac{P}{Q} S_2$.

Distance of fault from test end,

$d = \frac{X}{r}$ metres (r = resistance of cable per metre length)