1 (i) Summarize the importance of protective schemes employed in power system

The protective schemes are necessary in power system deal with the co-ordination of different protective relaying equipments which includes protective current transformers, Voltage transformers, protective relays, circuit breakers, etc.

Need for protective schemes.

1. To generate an alarm signal or to close the trip circuit of Circuit breaker in order to isolate the faulty element as quick as possible.

2. To prevent the subsequent faults by disconnecting the faulty section.

3. To improve continuity of service and system stability by maintaining continuity of supply of healthy sections during fault.

4. To isolate the faulty section as fast as possible in order to reduce further damage to the faulty section.

5. To limit the fault effects by disconnecting the faulty section, causing least interference to the healthy section.

6. To avoid damage to highly expensive components of power system against commonly occuring faults like lightning surges, switching overvoltage, short circuits.

7. To prevent flow of fault current in devices as fault current may lead to insulation failure, deviation of voltage and current values from their normal ranges.

ii) What are the essential qualities of protective relay?. Explain in detail.

The following are essential qualities of protection in relays.

1. Sensitivity
2. Reliability
3. Stability
4. Selectivity
5. Fast operation
6. Economical.

1. Sensitivity.

It is the ability of a power system to operate for minimum level of fault current. A protective relay should be sensitive to operate accurately under fault conditions.

The equipments of protective systems with high sensitivity are able to sense the faults of different types, different locations and also different fault resistance within the protected zone.

Sensitivity of the system is determined by sensitivity factor.

$$K_s = I_s / I_o$$

K_s = Sensitivity factor

I_s = Minimum fault current

I_o = Minimum operating current.

Reliability

The reliability of a protective system must be good enough to operate when a fault occurs within the protected zone. The desired reliability of the system is 95%. In order to achieve desired reliability all the elements of protective system such as relays, Circuit breaker potential transformer, current transformer etc. should function properly without failure when fault occurs.

a) Security

This factor is provided to avoid the incorrect operation in between the faulty of the system

b) Dependability

It is probability of relay operation during abnormal conditions.

3. Stability.

This is the property by which protective relay is able to distinguish between the fault in the protected zone and the normal condition.

It should be able to discriminate between fault and transient condition.

Only fault element should be isolated and healthy sections are to be left unaffected.

4 Selectivity.

A protective system must be strong enough to withstand a large current flow through its protective zone during external faults taking place in other zone.

If the relay of other zone where fault has occured fails to operate then the protective system should operate and trip the breaker after a preset delay.

To achieve better stability during disturbances the design of protective system requires certain modifications like providing electrical and mechanical bias, time delays and filter circuits in protective system.

5. Speed of Operation

A protective system should be fast enough to disconnect the faulty section from the healthier section in order to minimize the further damage to the equipment and to maintain system stability.

Critical clearing time should be fast less than the operating time of relay

It is also be taken care that the operating time should not be less than 10ms to prevent unnecessary operation at transient conditions.

6. Economical

Economic aspect plays an important role in the choice of particular protection scheme. As per the rules, a relay should not cost more than 5% of total cost of equipment protected by the relay.

A relay is expected to provide maximum protection at minimum cost.

2. Explain how fault current is calculated using symmetrical components

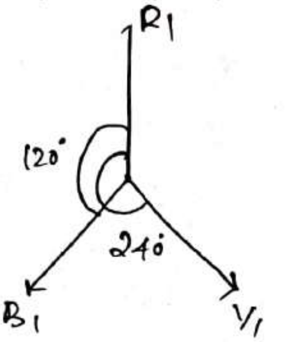
According to Fortescue's theorem, any unbalanced three phase system of sinusoidal quantities (Voltages, currents, etc) can be resolved into three quantities balanced systems of phasors which are called as symmetrical components and differ in phase sequence.

The three balanced set of components are positive, negative and zero sequence components, which give three balanced system namely positive, negative and zero sequence network.

positive sequence network is a system in which the phase (or line) quantities attain a maximum value in same cyclic order as that of original quantity

All three phasors are equal in magnitude and shifted in phase by 120°.

They are represented as R_1, Y_1 and B_1.

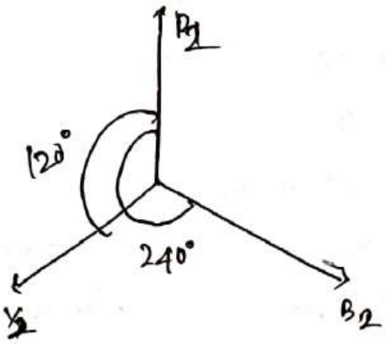


$Y_1 = R_1 \angle -120°$

$B_1 = R_1 \angle 120°$

Negative sequence network is a system in which the phasor still rotates in anti-clockwise direction but attains a maximum value in reverse order to the original quantity.

Similar to positive sequence system, all three phasors here are equal in magnitude and shifted in phase by 120°



$Y_2 = R_2 \angle 120°$

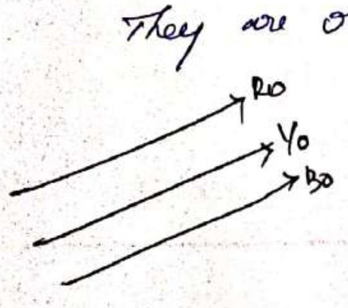
$B_2 = R_2 \angle -120°$

They are represented by R_2, Y_2 and B_2.

Zero sequence network is a system which combines three phasors equal in phase.

It represents the residual current or voltage present during fault in a 3 phase system with fourth or earth wire.

They are represented as R_0, Y_0, B_0.



$R_0 = Y_0$

$R_0 = B_0$

Basically a is defined as a complex number.

i) Magnitude is unity
ii) phase angle is 120°

$$a = 1\angle 120^\circ$$

$$a^2 = 1\angle -120^\circ$$

$$Y_1 = a^2 R_1$$

$$Y_2 = a R_2$$

$$B_1 = a R_1$$

$$B_2 = a^2 R_2$$

Consider three phasors R, Y and B of an unbalanced 3φ system which can be expressed in terms of their symmetrical components.

$$R = R_1 + R_2 + R_0 \rightarrow (1)$$

$$Y = Y_1 + Y_2 + Y_0 \rightarrow (2)$$

$$B = B_1 + B_2 + B_0 \rightarrow (3)$$

equation (2) and (3) can be written as.

$$Y = a^2 R_1 + a R_2 + R_0 \rightarrow (4)$$

$$B = a R_1 + a^2 R_2 + R_0. \rightarrow (5)$$

Equations (1), (4), (5) can be expressed in matrix.

$$\begin{bmatrix} R \\ Y \\ B \end{bmatrix} = \begin{vmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{vmatrix} \begin{vmatrix} R_0 \\ R_1 \\ R_2 \end{vmatrix}$$

Similarly phase current (I_a, I_b and I_c) can be expressed in terms of symmetrical components (I_{a0}, I_{a1} & I_{a2})

$$\begin{vmatrix} I_a \\ I_b \\ I_c \end{vmatrix} = \begin{vmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{vmatrix} \begin{vmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{vmatrix}$$

3. Discuss about 3ϕ symmetrical fault. Also discuss the different types of unsymmetrical fault that can occur on a 3ϕ system.

Symmetrical fault.

The fault which involve all the 3ϕ is known as Symmetrical fault.

Such types of fault remain balanced even after the fault.

The Symmetrical faults mainly occur at the terminal of generators.

Types of symmetrical faults.

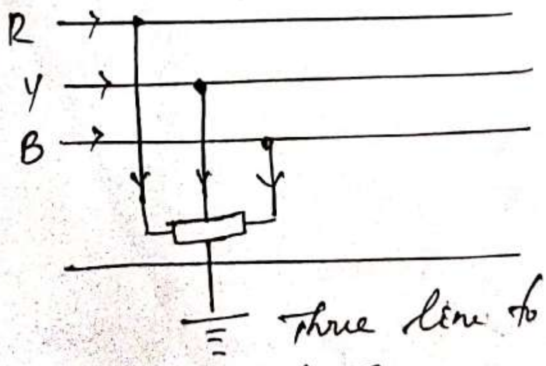
a) Line - Line - Line fault.

b) L - L - L - G fault.

a) Line - Line - Line fault.

Such type of faults are balanced, ie the system remains symmetrical even after the fault. The L - L - L - fault occurs rarely, but it is the most severe type of fault which involves the larger current.

This larger current is used of determing the rating of circuit breaker.



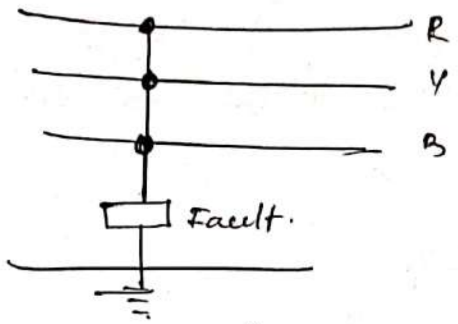
Three line to ground.

b) L - L - L - G. [Three phase line to ground fault.].

The 3ϕ line to ground fault includes all the 3ϕ of system.

The L-L-L-G fault occurs between the 3 phases and ground of the system.

The probability of occurence of such type of fault is nearly 2 to 3 percent.



Unsymmetrical fault.

The fault gives rise to unsymmetrical current. that is current is differing in magnitude and phases in 3ϕ of the power system are known a unsymmetrical fault.

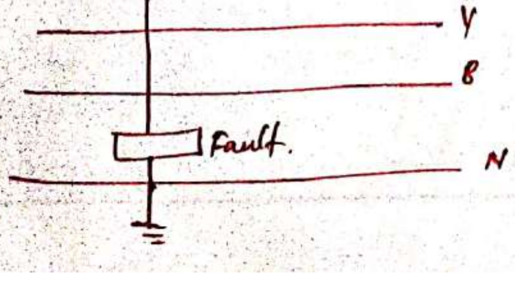
It is also defined as the fault which involves the one or two phases such as L-G, L-L, L-L-G faults.

The unsymmetrical faults make the system unbalanced.

1. Single Line-ground (L-G) fault.
2. Line to Line fault (L-L)
3. Double line to ground fault (L-L-G).

1. Single Line to Ground fault

The single line of ground fault occurs when one conductor falls to the ground or contact the neutral conductor. The 70-80 percent of the fault in the power system is single line to ground fault.

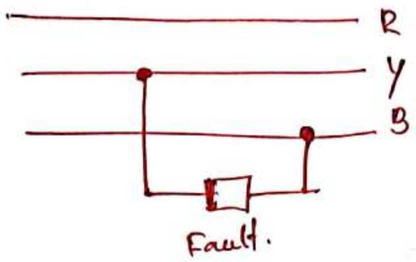


2. Line-to-Line fault.

A line-to-Line fault occurs when two conductors are short circuited. The major cause of this type of fault is the heavy wind.

The heavy wind swinging the line conductors which may touch together and hence cause short circuit.

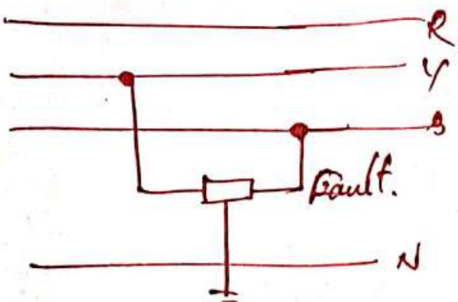
The percentage of such faults is approximately 15 - 20%.



3. Double line - line ground fault.

In double line-to-ground fault, the two lines come in contact with each other along with the ground.

The probability of such types of faults is nearly 10%.



4) In a 3-phase 4 wire system, the current R, Y and B under abnormal condition of loading are as under $I_R = 100\angle 30^\circ A$, $I_Y = 50\angle 300^\circ A$, $I_B = 30\angle 180^\circ A$. Calculate the positive, negative and zero sequence currents in R line and return current in the neutral wire.

Let $\vec{I_0}$, $\vec{I_1}$ and $\vec{I_2}$ be the zero, positive and negative sequence current respectively.

Of the line current in R phase.

$\vec{I_0} = \frac{1}{3}\left[\vec{I_R} + \vec{I_Y} + \vec{I_B}\right]$

$= \frac{1}{3}\left[100\angle 30^\circ + 50\angle 300^\circ + 30\angle 180^\circ\right]$

$= \frac{1}{3}\left[(86.60 + j50) + (25 - j43.3) + (-30 + j0)\right]$

$= \frac{1}{3}\left[81.6 + j6.7\right]$

$= (27.2 + j2.23)$

$= 27.29\angle 4.68^\circ A.$

$\vec{I_1} = \frac{1}{3}\left[\vec{I_R} + a\vec{I_Y} + a^2\vec{I_B}\right]$

$= \frac{1}{3}\left[100\angle 30^\circ + (1\angle -120^\circ)(50\angle 300^\circ) + (1\angle -120^\circ)(30\angle 180^\circ)\right]$

$= \frac{1}{3}\left[100\angle 30^\circ + 50\angle 180^\circ + 30\angle 60^\circ\right]$

$= \frac{1}{3}\left[(86.6 + j50) + (-50 + j0) + (15 + j25.98)\right]$

$= \frac{1}{3}\left[126.6 + j119.28\right]$

$= 42.2 + j39.76$

$= 57.98\angle 43.3^\circ A$

$\vec{I_2} = \frac{1}{3}\left[\vec{I_R} + a^2\vec{I_Y} + a\vec{I_B}\right]$

$= \frac{1}{3}\left[(100\angle 30^\circ + (1\angle -120^\circ)(50\angle 300^\circ) + (1\angle 120^\circ)(30\angle 180^\circ)\right]$

$= \frac{1}{3}\left[100\angle 30^\circ + 50\angle 180^\circ + 3\angle 300^\circ\right]$

$= \frac{1}{3}\left[(86.6 + j50) + (-50 + j0) + (15 + j25.98)\right]$

$= \frac{1}{3}(51.6 + j24.02)$

$= (17.2 + j8).$

$= 18.96\angle 24.9^\circ A$

Current in the neutral wire

$$= \vec{I_R} + \vec{I_Y} + \vec{I_B}$$

$$= (81.6 + j6.7)$$

$$= 81.87 \angle 4.7° A.$$

7. Discuss briefly about primary protection and backup protection.

Primary protection.

Below is the power system protection scheme designed to protect power system parts and components.

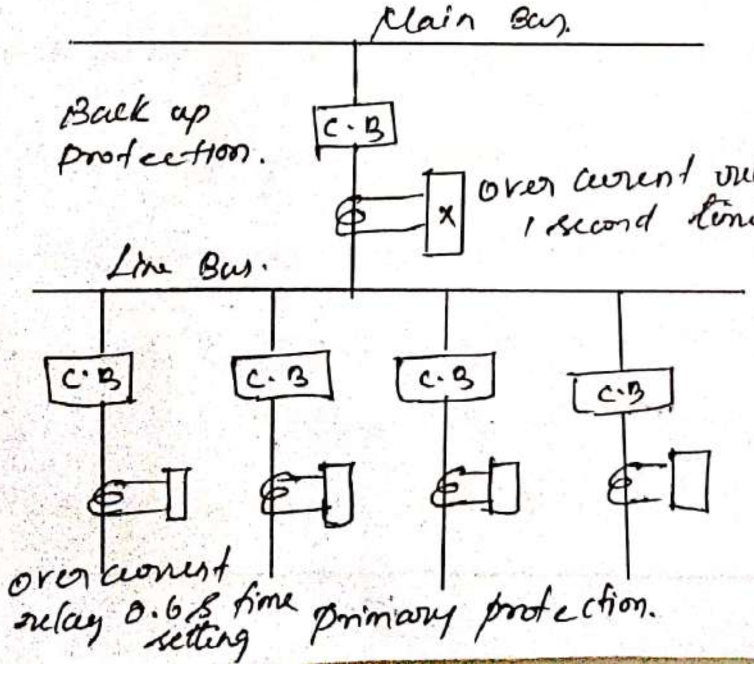
Each line is associated with over current relay that protect the lines from faults.

So if fault happens on any line, it will be clearly by its relay and circuit breaker.

This is called primary or main protection

Sometimes faults are not eliminated by the primary protection system because trouble within the relays, circuit breakers or wiring system in different conditions.

In those conditions secondary or backup protection system does the required job.



Primary protection may fail due to following reasons.

* Failure of DC supply to the tripping circuit.
* Failure in relay operating current or voltage.
* Failure in circuit breaker tripping mechanism
* Failure of main protective relay operation
* Failure in the wiring of relaying scheme
* Failure of CTs and PTs operation.

Secondary protection.

Back-up protection is very important for stable and reliable power system.

It is not possible to design a 100% secure and efficient system because there are possibilities of failure in the connected CTs, PTs circuit breaker etc. in the system.

If it happens then it will destroy our whole system.

If the primary protection operation falls into trouble, then secondary protection disconnects the faulty part from the system.

When we disconnect the faulty primary protection for testing or maintenance purpose, then secondary will act as primary protection.

The relay x (1 sec time setting) provides backup protection for each of the four connected lines to the main bus.