Logical design of relays:

Relay is the device which sense the fault and cause the C.B trip circuit to be energized and the breaker to open their contacts. The job of a relay is to discriminate between a fault within its zone of protection and all other system conditions. Their logical performance can be define in terms of the inputs and outputs of the relay independently. Consequently the output state of the relay will be, with its contacts closed, called trip, or with its contacts open, called block.

The most commonly relays used are:

1- Magnitude relays.
2- Directional relays.
3- Ratio relays.
4- Differential relays.
5- Pilot relays.

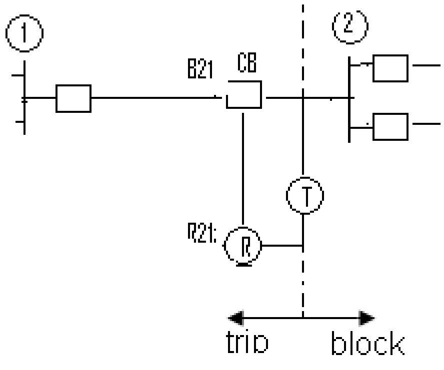
1- Magnitude relays: they respond to the magnitude of their input current, and operate to trip whenever the current magnitude exceeds a certain value which is adjustable.

$|I_f| > |I_p|$ trip

$|I_f| < |I_p|$ block

when $|I_p|$: pickup value of the relay.

2- Directional relays: they depends for its operation upon the direction of the current with respect o the voltage.



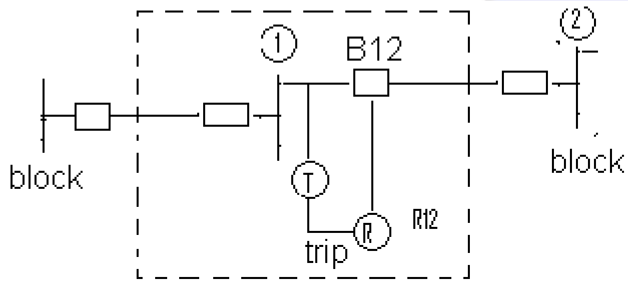
Thus the directional relays use a polarizing voltage.

$\theta_{min} > \theta_{op} > \theta_{max}$ trip

$\theta_{min} < \theta_{op} < \theta_{max}$ block

Where θ_{op}: phase angle of the operating quantity measured with the polarizing phasor as the reference, and θ_{min} and θ_{max} are the two angles defining the boundary of the operating characteristic.

3- Ratio relays:(impedance relay), (distance relay): they described by the distance along the lines, or equivalently by the impedance between bus 1 and the fault location.



Consider Z_r is the setting impedance included in the zone. The impedance is proportional to the distance. This condition can be conveniently expressed as a requirement on the ratio of the voltage and current at the location of R12. This ratio is

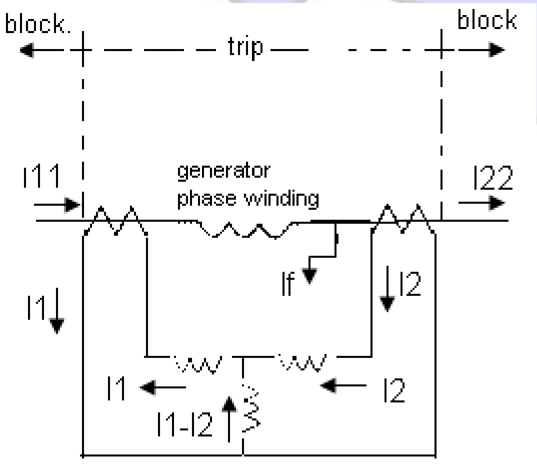
$$Z = \frac{V_1}{I_{12}}$$

the relay performance are:

$|Z| < |Z_r|$ trip

$|Z| > |Z_r|$ block

4- Differential relays:



Consider the zone of protection of one phase of a generator winding shown in figure. Two current transformers are placed at the boundaries of the zone. Then for normal conditions

$I_1 - I_2 = 0$

And for a fault inside the zone

$I_1 - I_2 = I_f$

The value of adjustable current $|I_p|$ is chosen such that

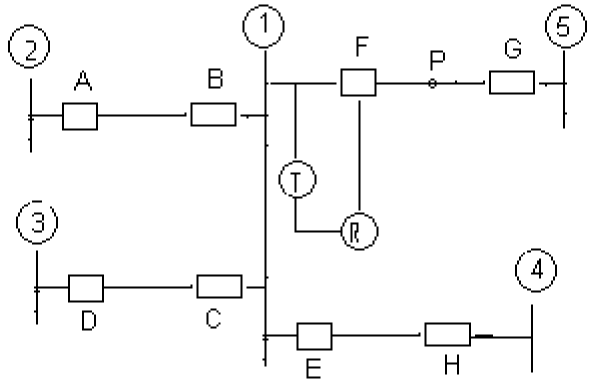
$|I_1 - I_2| > |I_p|$ trip

$|I_1 - I_2| < |I_p|$ block

5- Pilot relays: pilot relay provides a technique of communicating information from a remote zone boundary to the relay at each terminal. The physical medium used for pilot channels could be conductor of a telephone circuit, high-frequency signals coupled on to the power transmission line (known as the power-line carrier), or microwave channels.

Primary and backup protection:

It is the system which would take over the job of protection in case the appropriate primary protection system fails to clear the fault.

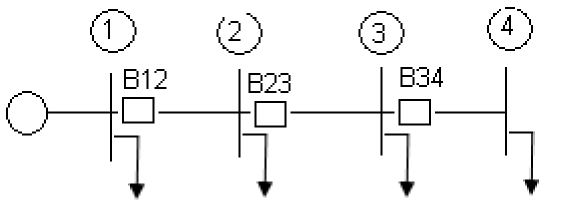


The backup system must allow a sufficient time for the primary protection system to function normally.

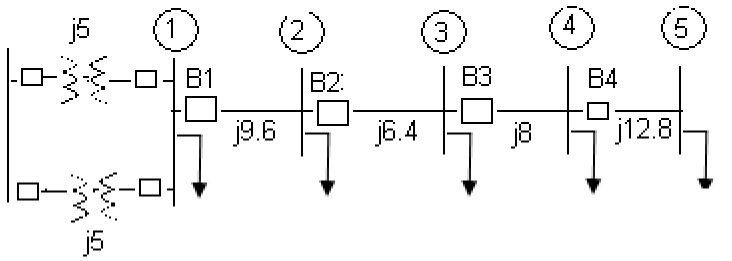
Transmission line protection:

Protection of sub transmission line :

In the figure, clearly for any fault on line 1-2, breaker B12 must be opened. In this case all the loads at buses 2, 3, and 4 downstream from breaker 1 will be interrupted. overcurrent relay can be used in this system. Fault current produced by a fault on any of the line will depend upon the fault location, and since the fault path impedance will increase with the distance to the fault from the generator, the fault current will be inversely proportional to this distance.



Example: a 13.8 kV radial system. This system can be operated with one or two transformers. Transmission line and transformer reactance in ohms are shown in figure. If protection system for line-to-line and three-phase fault is to be designed, calculate the minimum and maximum fault current for a fault at bus 5



Solution:

maximum fault current will occur for three-phase fault when the two transformers are in service. At this case at bus 5

$$I_f = \frac{13800/\sqrt{3}}{j(2.5 + 9.6 + 6.4 + 8 + 12.8)} = -j202.75$$

For a three-phase fault at bus 5 with only one transformer

$$I_f = \frac{13800/\sqrt{3}}{j(5 + 9.6 + 6.4 + 8 + 12.8)} = -j190.6$$

minimum fault current will occur when only one transformer in service for a line-to-line fault, this current is usually equal $\sqrt{3/2}$ of the three-phase fault current

$$\therefore I_f = \frac{\sqrt{3}}{2}(-j190.6) = -j165.1 \text{ A}$$