



R. C. Patel College of Engineering & Polytechnic, Shirpur



Department of Electrical Engineering

Name of Subject: - **SWITCHGEAR AND PROTECTION (SGP)**

Course Code: - **315334**

Scheme:- **EE-5K**

Semester:- **Fifth**

Unit No. 03- Protective Relays

CO1 - Select the suitable switchgears for different applications.

Unit	Title	COs	Learning hours	R Level	U Level	A Level	Total Marks
III	Protective Relays	CO3	12	4	4	10	18

THEORY SYLLABUS CONTENT

- 3.1 Protective Relay: Fundamental quality requirements (Selectivity, Speed, Sensitivity, Reliability, Simplicity, Economy)
- 3.2 Basic relay terminology- Protective relay, Relay time, Pick up, Reset current, current setting, Plug setting multiplier, Time setting multiplier.
- 3.3 Electromagnetic disc relay, Thermal relay, over voltage relay, Over current, Earth fault relay: Operation and its characteristics.
- 3.4 Static, Digital Relay (Microprocessor based): Block diagram, working, advantages and limitations. Numerical relay: Introduction
- 3.5 Distance relaying- Principle
- 3.6 Directional relay: Need and operation with block diagram.
- 3.7 Current and Voltage differential relay: Operation

Subject Incharge
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protective Relays

* Relay: The purpose of protective relay is to operate the correct C.B. so as to disconnect the faulty part from the system as quickly as possible.

* function of Protective Relay:

- To sound an alarm or to close the trip circuit of C.B. ~~as~~ so as to disconnect circuit during an abnormal condition
- To disconnect the faulty part from system.
- To localise the effect of fault by disconnecting the faulty part.
- To disconnect faulty part quickly to maintain stability.

* Qualities of protective Relay:

1) selectivity: It is ability of protective system to select correct part of the system in fault condition and disconnect faulty part without disturbing the rest system.

2) speed: The relay system should disconnect the faulty part as early as possible.

3) Sensitivity: It is ability of relay system to operate with lower value of actuating quantity.

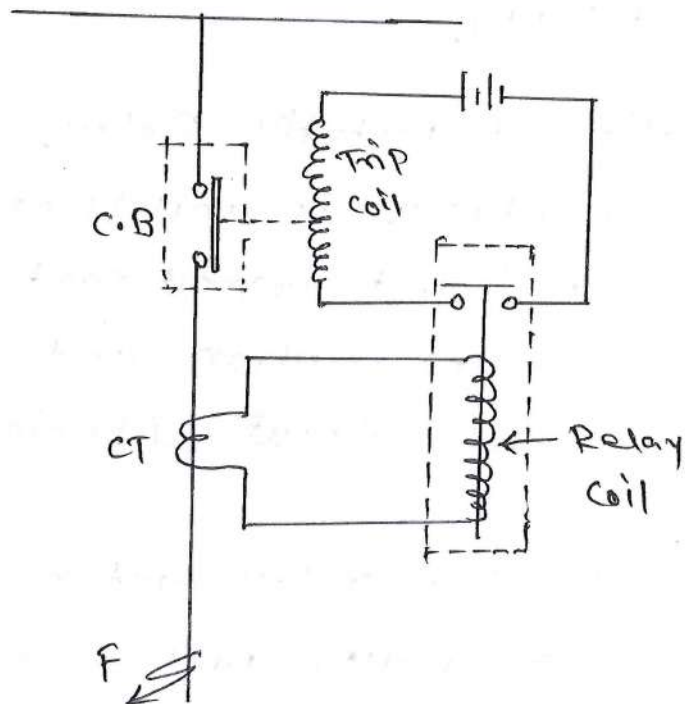
4) Reliability: It is ability of relay system to operate under predetermined conditions.

5) Simplicity: The relaying system should be simple so that it can be easily maintained.

- simpler the protective scheme, greater it's reliability.

6) Economy ; The cost of protective gear should not be more than 5% of total equipment cost.

* Basic connection of trip circuit.



* Basic Relay Terminology:

1) Relay Time: It is time interval between the occurrence of fault and ~~to~~ closure of relay contact.

2) pick-up current; It is value of operating quantity above which relay operates and closes its contacts.

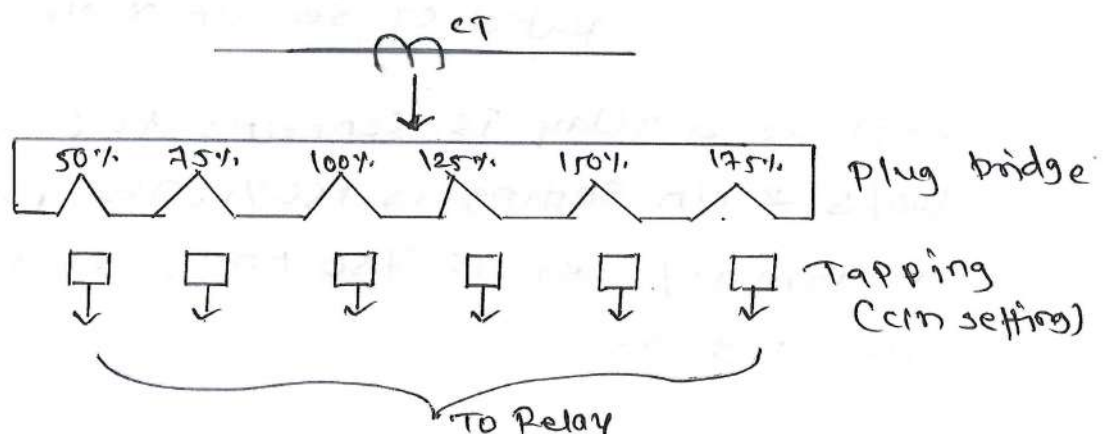
oe It is the minimum current in relay coil at which relay starts to operate.

3) Reset : The value of current & voltage below which relay reset & come back to original position.

oe The value of operating quantity at which the relay starts opening and coming to original state (i.e., open)

4) current setting :

- The relays are used to protect devices with different rating.
- So pick up current of relay will be different. The process of adjusting pickup current to required value is known as current setting.



- by selecting appropriate tap, the required pickup current can be selected.
- The relay ckt is connected to secondary side of C.T. The CT secondary output is given to plug bridge where tapings are provided.
- In above case, if CT ratio is 100/5 and current setting is 150%, then pickup current is

$$\text{Pickup current} = \frac{\text{Rated CT sec. c/n}}{\text{current setting}} \times \text{current setting}$$

$$= 5 \times 1.5$$

$$\therefore \text{pickup current} = 7.5 \text{ Amp.}$$

- The steps of current setting range from 50% to 200% in steps of 25% for over c/n relays.

5) plug - setting Multiplier (PSM) :

- It is defined as the ratio of fault current in the relay coil to pickup current.

$$\text{PSM} = \frac{\text{fault c/n in relay coil}}{\text{pickup current.}}$$

$$= \frac{\text{fault c/n in relay coil}}{\text{Rated CT sec. c/n} \times \text{c/n setting.}}$$

- Suppose a relay is connected to CT with ratio 100/5 & c/n setting is 150%. The fault c/n in primary ckt is 750 Amp. The PSM is calculated as

Fault c/n in primary = 750 AMP

CT ratio is 100/5, therefore CT secondary c/n or fault c/n in relay coil is

$$= 750 \times \frac{5}{100}$$

$$= 37.5 \text{ AMP}$$

~~∴ PSM~~

pickup c/n = Rated CT sec c/n $\times$ c/n setting

$$= 5 \times 1.5$$

$$= 7.5 \text{ A.}$$

$$\therefore \text{PSM} = \frac{\text{Fault c/n in relay coil}}{\text{pickup c/n}}$$

$$= \frac{37.5}{7.5} = 5.$$

6) Time setting Multiplier (TSM):

- A relay is generally provided with control to adjust the time of operation, this adjustment is known as TSM.

or

- The operating time of relay can be adjusted by using TSM. The span is 0 to 1 in steps of 0.05.

- The relay operating time is found from time-PSM curve.

- To find actual operating time of relay,

1. Find relay operating time from time-PSM curve

2. Then multiply that time setting to get actual time

$$\therefore \text{Actual operating time of Relay} = \text{Relay operating time from time-PSM curve} \times \text{Time setting}$$

Example:-

Q Determine the time of

Important formulae:

$$1) \text{ pickup current} = \frac{\text{Rated CT sec.}}{\text{current}} \times \text{current setting}$$

$$2) \text{ fault c/n in relay coil} = \frac{\text{fault c/n in primary}}{\text{CT ratio}} \times \text{inverse of CT ratio}$$

$$3) \text{ PSM} = \frac{\text{fault c/n in relay coil}}{\text{Pickup current}}$$

$$4) \text{ Actual operating Time} = \frac{\text{operating time from curve}}{\text{Time setting}}$$

Problem 1: Determine time of operation of 5A, 3 sec over current relay having a current setting of 125% and time multiplier of 0.6 connected to supply ckt through a 400/5 current transformer, when a ckt carries a fault current of 4000A. use the curve

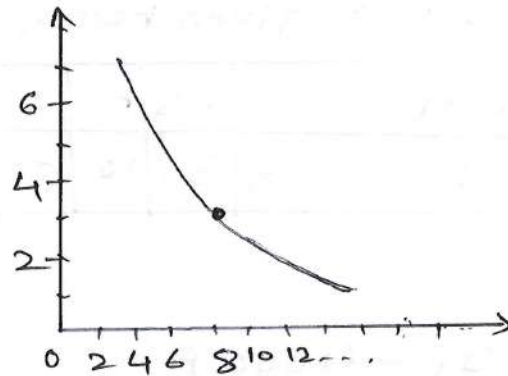


Fig: Time - PSM curve.

Solution:-

Rated CT sec. c/n = 5A

current setting = 125% = 1.25

Fault c/n in pri = 4000A

time setting = 0.6

1) pickup current = $5 \times 1.25 = 6.25 \text{ A}$

2) Fault c/n in relay = $4000 \times \frac{5}{400} = 50 \text{ A}$
coil

3) Plug setting multiplier = $\frac{\text{Fault c/n in relay (coil)}}{\text{pick-up c/n}}$
(PSM)

$$= \frac{50}{6.25} = 8$$

$\therefore$ from graph, ^{for} PSM of 8, the time of operation is 3.5 second

$\therefore$ Actual relay operating time = 3.5×0.6

$$= 2.1 \text{ Second}$$

Problem 2: Determine the time of operation of 1 Amp 3 second over current relay having PSM of 125% and time multiplier of 0.6. The supplying CT is rated 400:1 and fault c/n is 4000A. The relay characteristics is as given below:

PSM	1.3	2	4	8	10	20
Time of operation	30	10	5	3.3	3	2.2

Solution:

$$I_f = 4000 \text{ A}$$

$$\text{plug setting} = 125\% = 1.25$$

$$\text{CT, ratio} = 400:1$$

$$\begin{aligned} \Rightarrow \text{pickup c/n} &= 1 \times 1.25 \\ &= 1.25 \end{aligned}$$

$$\begin{aligned} 2) \text{ Fault c/n in relay coil} &= 4000 \times \frac{1}{400} \\ &= 10 \text{ Amp.} \end{aligned}$$

$$\begin{aligned} 3) \text{ PSM} &= \frac{\text{fault c/n in relay coil}}{\text{Pickup current}} \\ &= \frac{10}{1.25} = 8 \end{aligned}$$

4) From table, For PSM = 8, Time is 3.3 sec

$$\begin{aligned} \therefore \text{Actual operating time of relay} &= 3.3 \times 0.6 \\ &= 1.98 \text{ seconds} \end{aligned}$$

Types of Relay

1) Electrodynammic Relay :

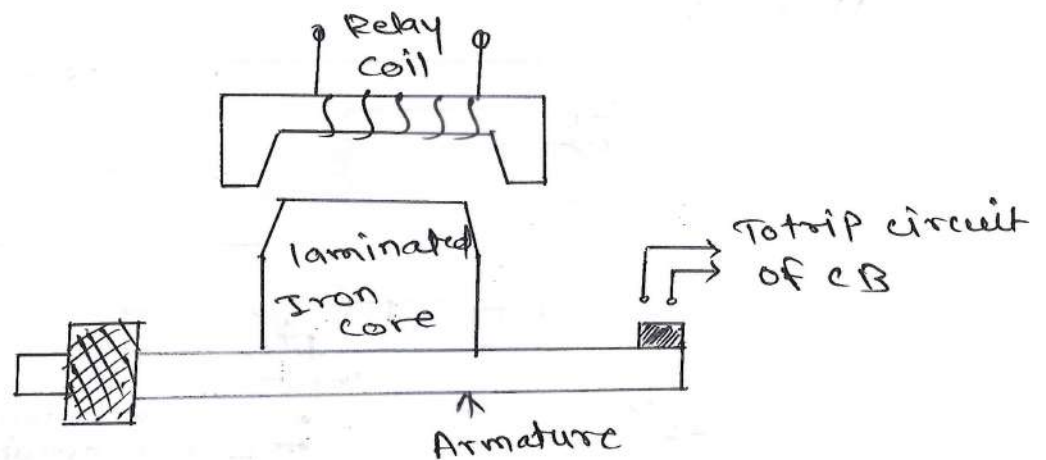
a) Electromagnetic Attraction type relay

b) Electromagnetic Induction type relay

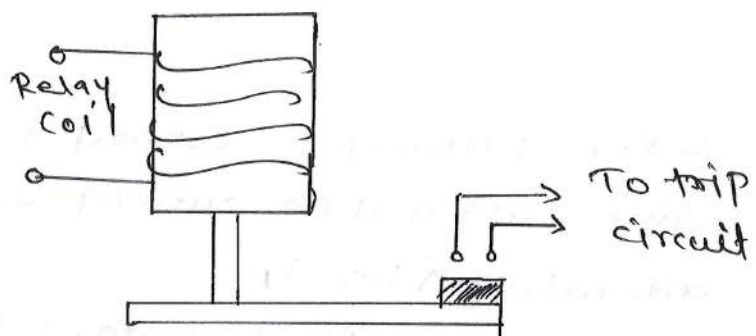
2) Static relay :

a) Electromagnetic Attraction type relay :

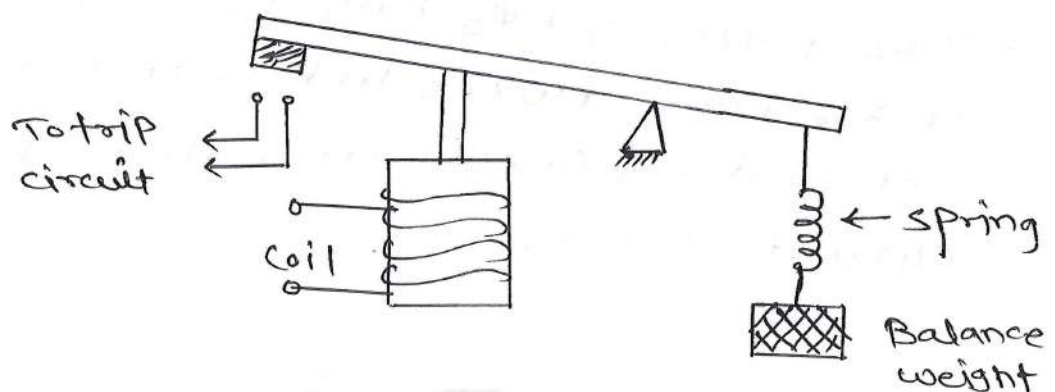
i) Attracted Armature type relay-



ii) Plunger Type Relay / Solenoid Type Relay :

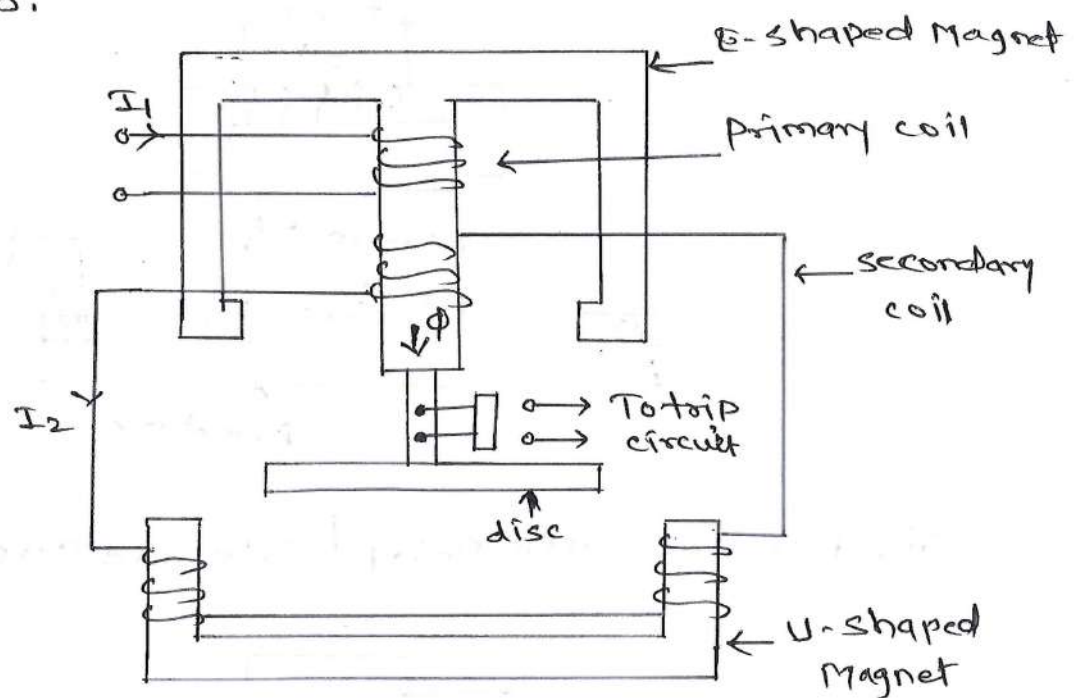


iii) Balance Beam Relay :



b) Electromagnetic Disc Type Relay / Induction relay:

- These relay operates on the principle of mutual induction.
- They are used with only AC quantity.
- It consist of aluminium disc placed in two electromagnets.
- The two electromagnets produce alternating fluxes.



- when primary is connected to AC supply, it carries alternating current I_1 , which produces alternating flux Φ_1 .
- Induce EMF in secondary coil, circulates current I_2 , which produces flux Φ_2 .
- Two fluxes Φ_1 & Φ_2 have phase difference of α , These fluxes link with disc, induces emf in disc, causes circulation of eddy current in disc.

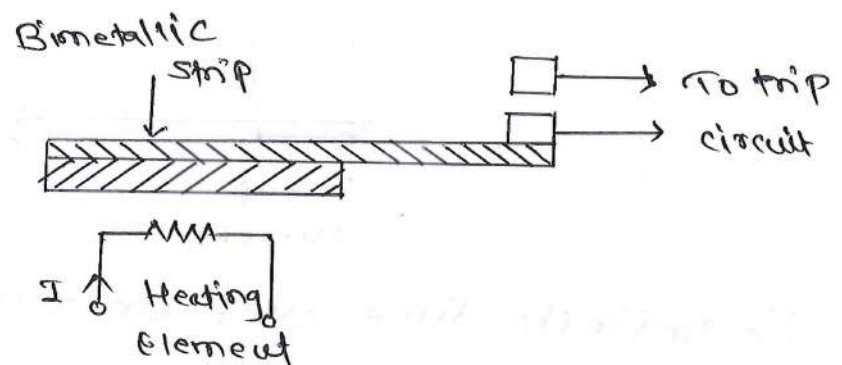
- The eddy c/n flux and ϕ_1, ϕ_2 produce resultant torque on the disc.

$$T \propto \phi_1 \phi_2 \sin \alpha$$

- The disc rotates and relay contacts are closed due to which trip signal is sent to circuit breaker. The circuit breaker operates and disconnect faulty part from the system.

* Thermal Relays :

- This relay work on the heating effect of electric current. It consist of bimetallic strip.
- Bimetallic strip consist two different metals having different coefficient of expansion.



- The relay contact are arranged on upper strip.
- A Heating element is kept near the bimetallic strip.
- At the time of fault, heating element carries abnormal or fault current, due to heating element, bimetallic strip heated and bends, which closes the relay contact and trip circuit operates, which operates CB & disconnect faulty part from system.

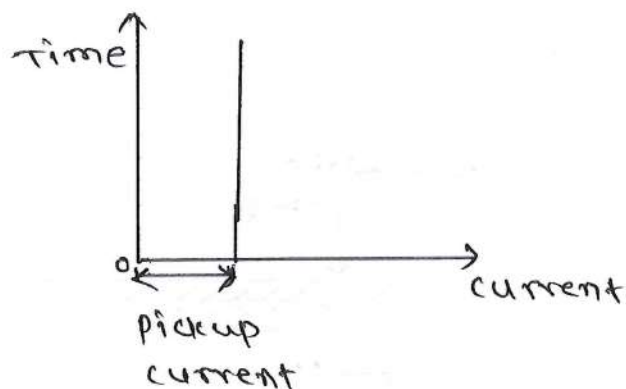
* Over current Relay:

- Over current relay classified as

- i) Instantaneous over c/n relay
- ii) Definite time over c/n relay
- iii) Inverse time over c/n relay
- iv) Inverse definite minimum time (IDMT) over c/n relay.

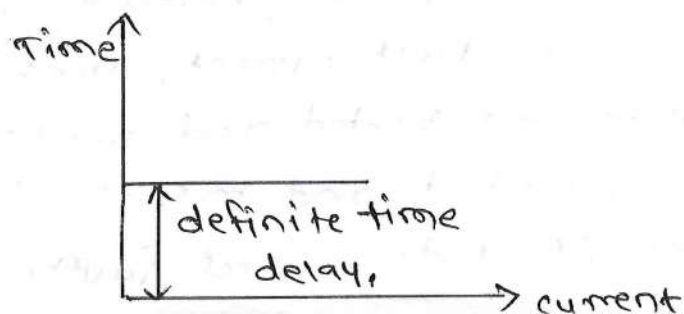
i) Instantaneous over c/n relay;

- This type of relay operates instantly, without any intentional time delay.
- It is used for rapid clearance of severe fault
- This relay trip the CB immediately when the current exceeds its pickup value.



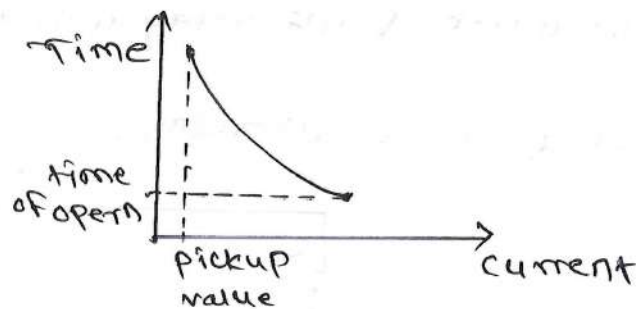
ii) Definite time over c/n relay:

- This type of relay operates after a fixed (definite) time delay.
- The operating time remains constant.
- It has fixed operating time irrespective of the magnitude of fault current.



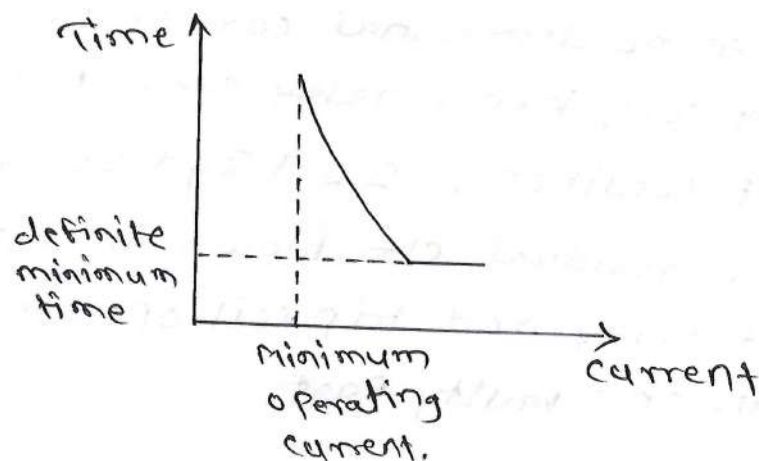
iii) Inverse time over c/n relay:

- It is a protective relay whose operating time decreases as the fault current increases.
i.e. more the fault c/n, less the operating time.
- It is the most widely used overcurrent relay.
- This relay operates with a time delay that is inversely proportional to the magnitude of the fault current.



iv) Inverse definite minimum time (IDMT) over c/n relay:

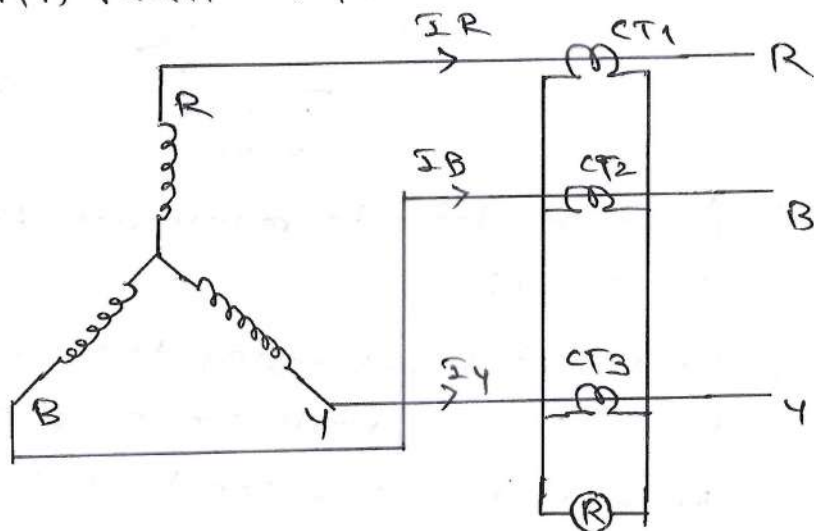
- In this type, operating time is inversely proportional to the fault c/n near pickup value and then it becomes constant, i.e. minimum definite time.
- The operating time depends on magnitude of fault current and reaches a definite minimum operating time.



* Earth Fault Relay:

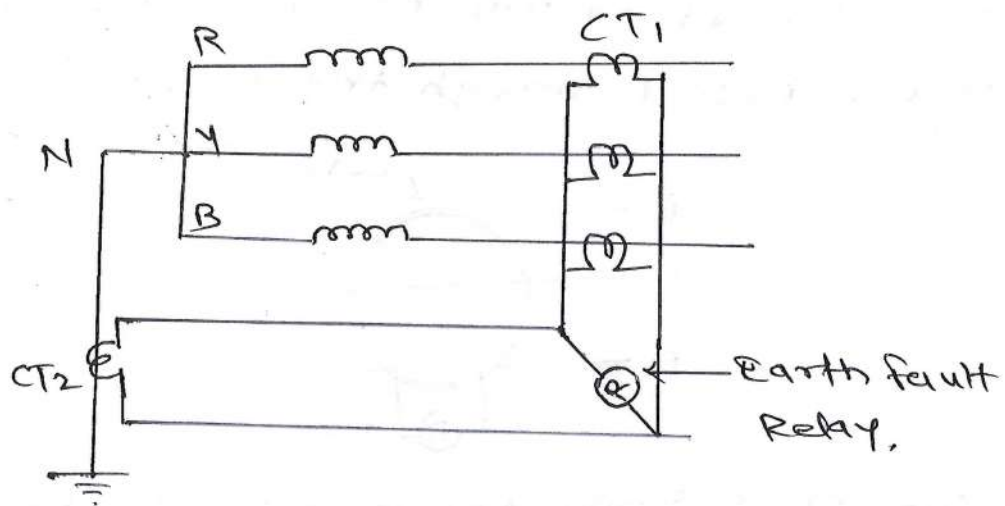
- It is a protective relay that detect earth fault or ground fault.
- It operates when leakage c/m flows from a phase conductor to earth due to insulation failure
- They classified as
 - i) Residual Earth Fault relay
 - ii) Restricted Earth fault relay
 - iii) Earth Fault-relay using core balance CT

i) Residual Earth fault relay:



- It consist 3 CT'S. The 3 CTs are connected in each phase. Earth fault relay connected in CT secondary circuit.
- At normal condition, $I_R + I_Y + I_B = 0$
Hence no differential current flows through relay coil, hence relay cannot operate
- At fault condition, $I_R + I_Y + I_B \neq 0$
Hence residual c/m flows through earth fault relay and trip coil operates and isolate the faulty part.

ii) Restricted Earth fault Relay:

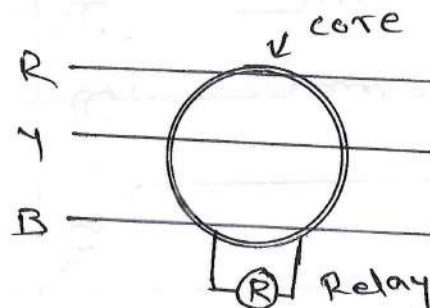


- It is highly sensitive protection relay used to detect earth / ground fault within a specific protected zone.
- It compares vector sum of current from the phase CTs and neutral CT current.
- Under normal condition, the algebraic sum of these current is zero. No current flows through the relay, so it remain inactive.
- For an internal earth fault within protected zone, the differential current flows through the relay coil.
- The relay operates and trip the circuit breaker.

iii) Earth Fault relay using core balance CT:

- A core balance CT earth fault relay is a protection scheme used to detect earth leakage (ground fault) by measuring residual (Zero sequence) current in 3-phase system.

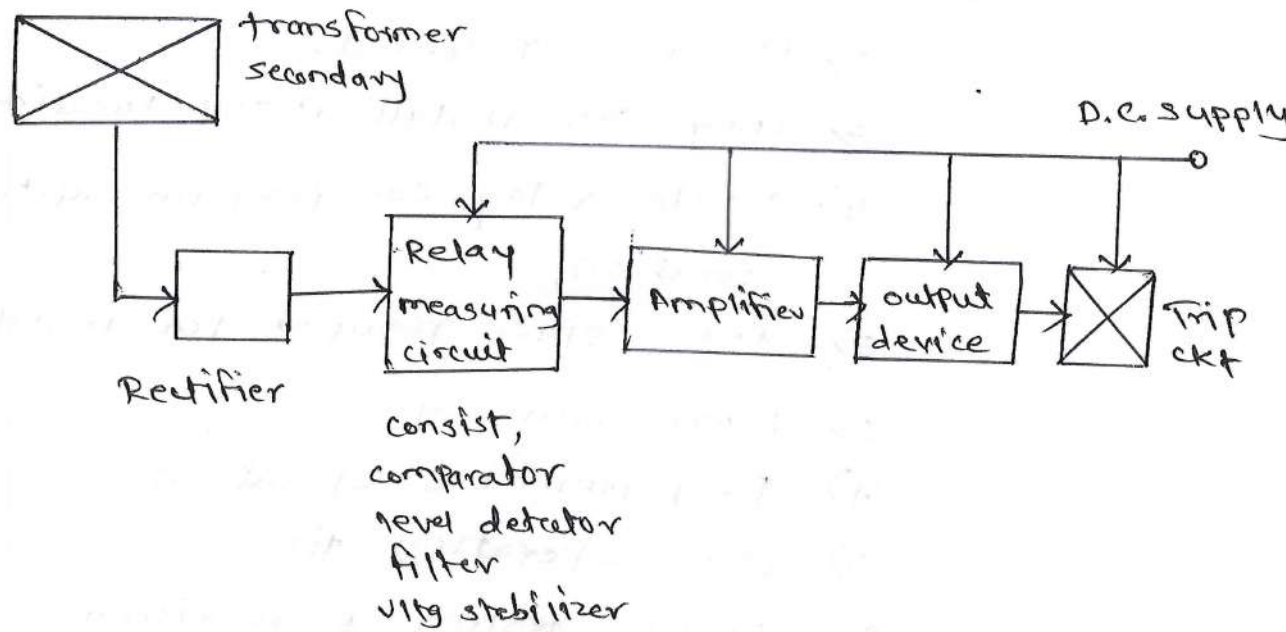
- A CBCT is installed around all three phase conductor. If system has neutral conductor, it is also passed through the CBCT.



- Current entering the load equals the current returning.
- The vector sum of all current is zero.

$$I_R + I_Y + I_B (+ I_N) = 0$$
- No magnetic flux is produced in CBCT
- the earth fault relay does not operate.
- If insulation fails & current leaks to earth
- The vector sum of current is no longer zero.
- The CBCT senses the residual current.
- The earth fault relay trips the CB.

* Static Relay:



- The static relay means, it consist of solid state components like, transistor, rectifier, Amplifier for measurement & comparison of electrical quantity.
- static relay is the relay in which there is no moving part.
- fig. shows essential components of static relay.
- In static relay, the o/p of CT & PT is rectified in rectifier.
- Rectified o/p is given to the measuring ckt which consist of comparator, level detector filter & logic circuit.
- The o/p is generate when i/p reaches to it's threshold value.
- Amplifier amplifies the o/p of measuring unit.
- o/p of amplifier is given to the o/p unit which energize the trip coil & relay is operate.

Advantages: 1) low power consumption

2) No moving contacts

3) They can install at any location.

4) single relay can perform multiple operation.

5) less space required for installation.

6) More accuracy

7) programmable operation

8) Less operating time.

9) simple testing & servicing

10) It can be used for repeated operation.

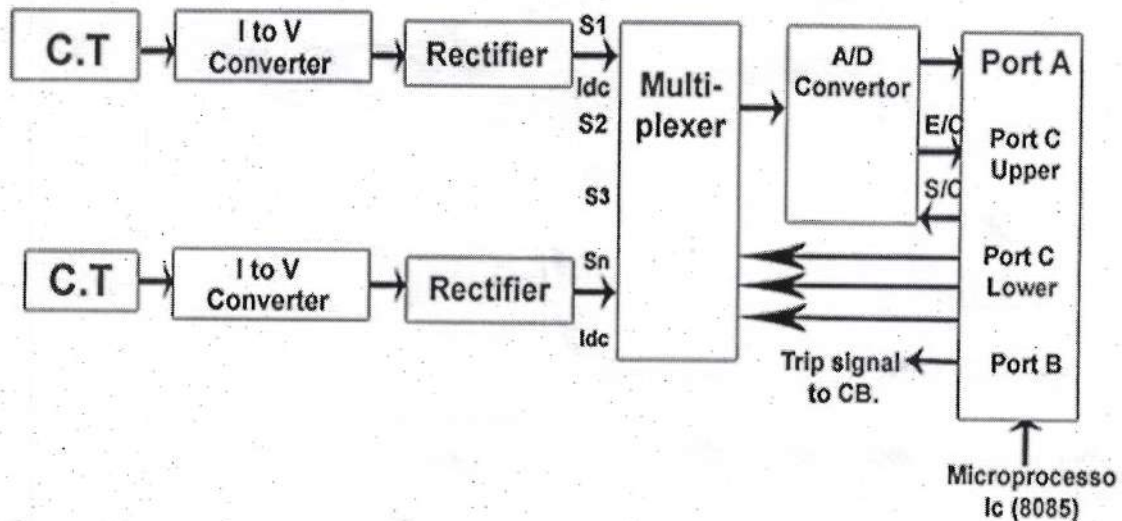
Disadvantages: 1) Required external power supply for operation.

2) very sensitive to voltage transient

3) characteristics affected by temp.

4) cost is high.

* Digital Relay / Microprocessor based Relay:



- This type of relaying system is used in the industrial motors / equipment and also in distribution lines.
- They consist of CTs, current to voltage converter, rectifier, multiplexer, A/D converter microprocessor kit.
- The A.C voltage proportional to the load current is converted to D.C. by rectifier. Thus the up accept D.C. voltage proportional to load current.
- The o/p rectifier is fed to multiplexer.
- The o/p of multiplexer is fed to A/D converter to obtain signal in digital form.
- Up send signal to ADC for starting conversion.

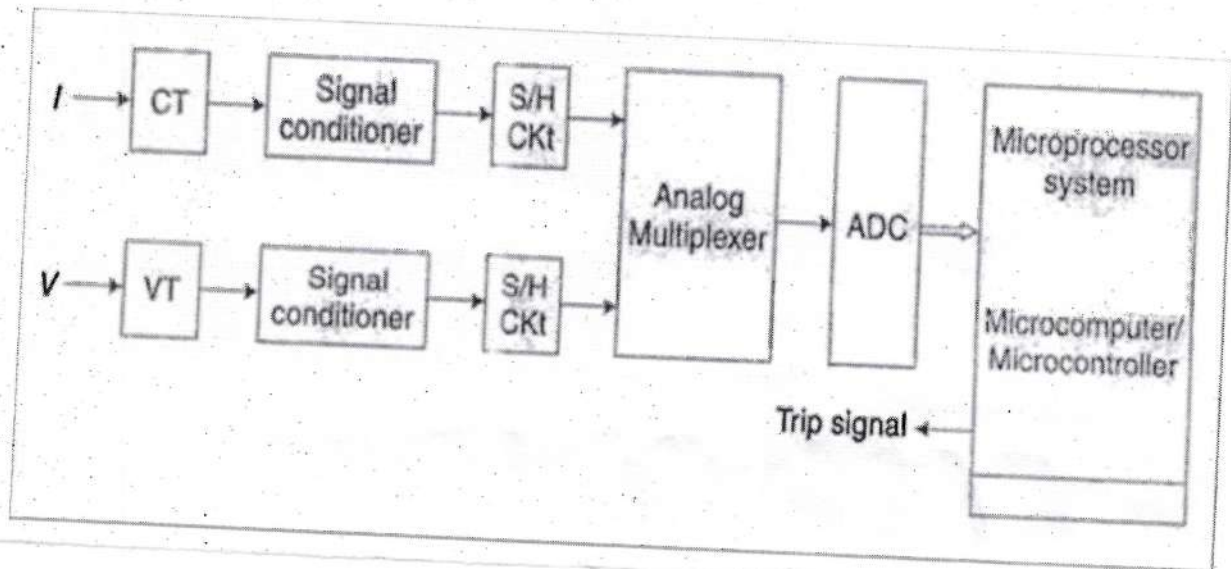
- Microprocessor can sense the fault current of number of circuits.
- If the measured values exceed preset limit or indicate a fault, the relay trip.
- which operates a CB, and isolating the faulty section.

- + Advantages:
- 1) High accuracy & flexibility
 - 2) Multi functionality
 - 3) can detect internal hardware/software errors, self monitoring function.
 - 4) can interface with SCADA system
 - 5) setting & logic can be easily modify.
 - 6) Easy to operate & use.
 - 7) High speed of operation.

- * Disadvantages:
- 1) High initial cost
 - 2) complexity in installation and programming.
 - 3) affected by electromagnetic interference
 - 4) Required external power supply
 - 5) required trained person to operate.

* Numerical Relay:

- The μ p based relay works on number, it is known as numerical relay.
- It is also known as μ p based relay or computer based relay or digital relay.



- Construction and working same as micro-processor based relay.
- It offers multi-function & multiple characteristics.
- Advantages & disadvantage same as μ p based relay.

* comparison

Feature	Electromechanical Relay	Static Relay	Numerical Relay
Technology	Electromagnetic	Electronic	Microprocessor Digital signal processing.
speed	slow	Fast	very fast
Accuracy	Moderate	High	very High
Maintenance	High	Moderate	Low
self-diagnostic	No	No	yes
Event Recording	No	No	yes
Multifunction	No	limited	yes

$$Z = \frac{V}{I}$$

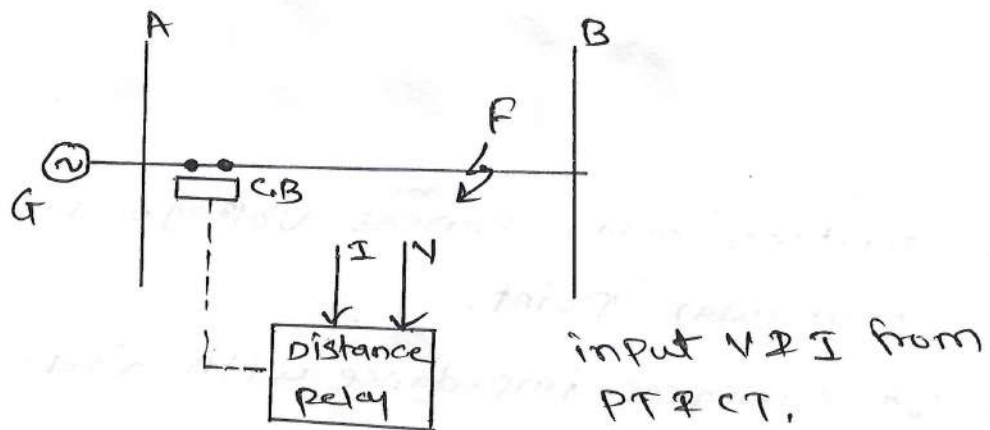
* Distance Relay:

- A distance relay is a protective relay that measures the impedance (distance) between the relay location & fault point.
- Impedance of transmission line is proportional to it's length, the relay estimates the distance to the fault & trips the CB if the fault lies within it's preset protection zone.
- The measured impedance is

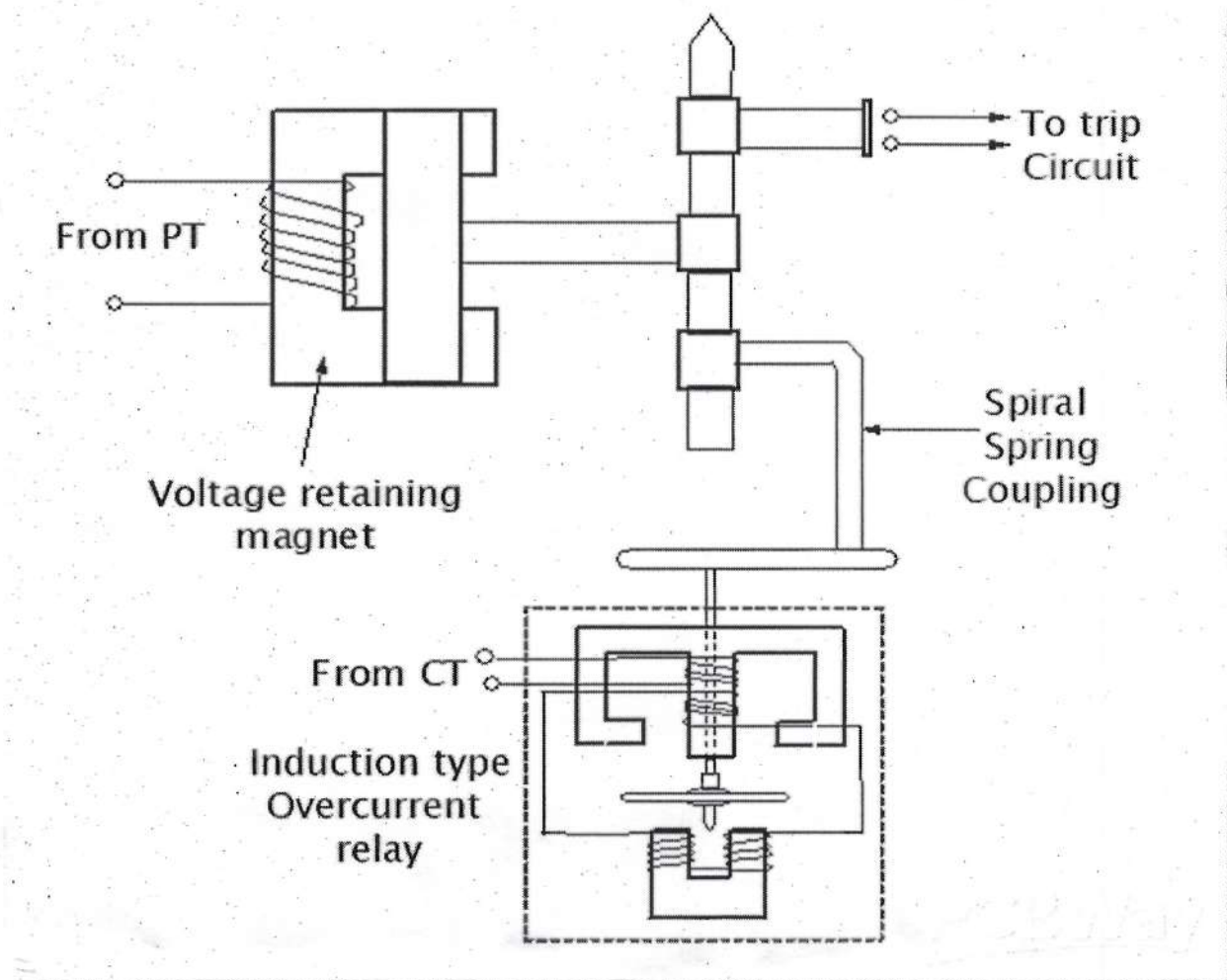
$$Z = \frac{V}{I}$$

where V - voltage measured by PT

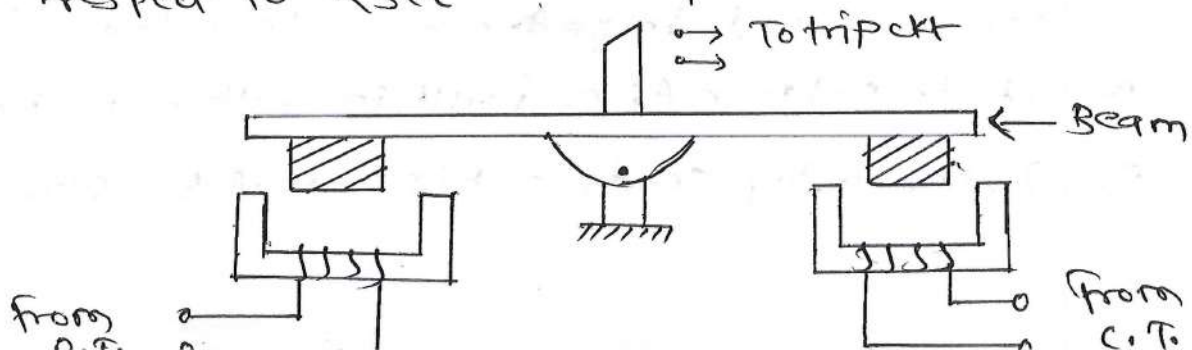
I - current measured by CT.



- During a fault, the line voltage decreases and the current increases, causing the measured impedance to decrease.
- If the measured impedance is less than the preset impedance (i.e. fault in within protected zone), the relay sends a trip signal to C.B.

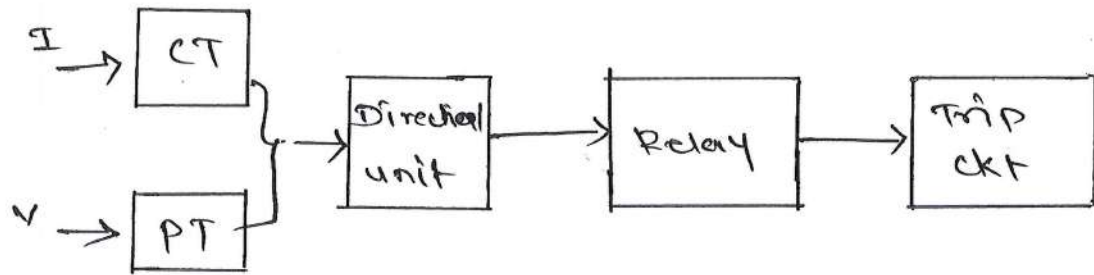


- Distance relay senses voltage & current at particular point.
- It compares impedance with Z_{set} .
- current coil of relay produces operating torque
- voltage coil of relay produces restraining torque
- If impedance sensed by relay changes with respect to Z_{set} and relay operates.



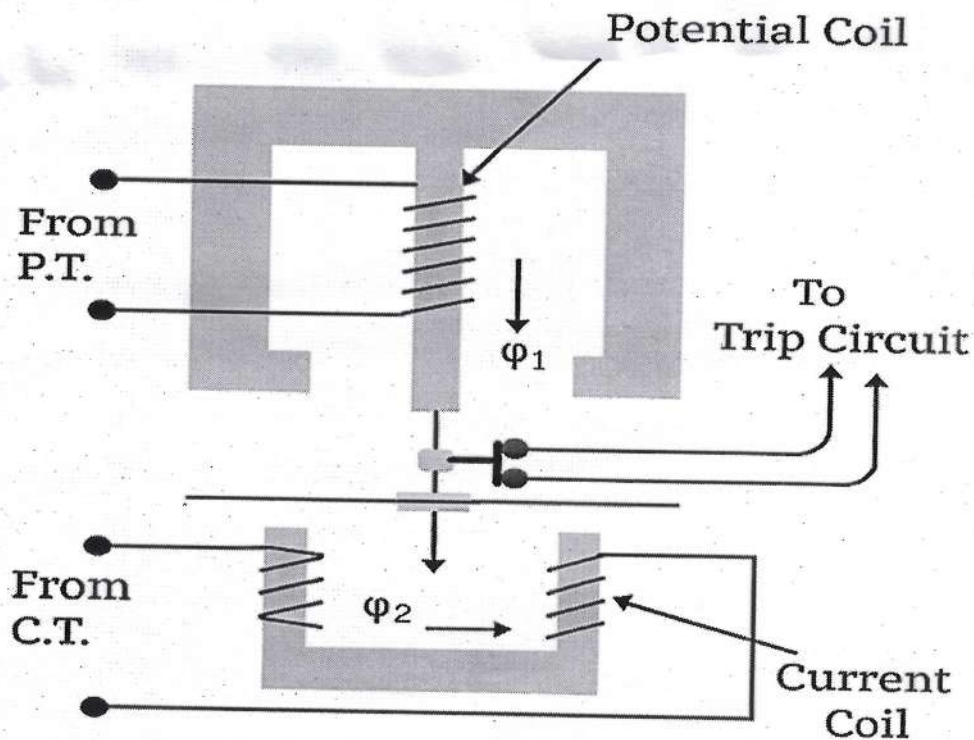
* Directional Relay:

Need: In power system, under fault condition, the power may flow in reverse direction. Hence to protect system from such reverse power flow, directional relay is used.



- It consists of CT, PT to sense current and voltage. A directional unit is added which detects the direction of power flow.
- When reverse power flow takes place the directional unit initiates relay operation. The relay operates & sends trip signal to CB.
- In induction type directional relay, it consists of two electromagnets,
 - Shunt magnet (E-shaped) which is excited by PT.
 - Series magnet (C-shaped) which is excited by C.T.
- An aluminum disc is suspended between the two electromagnets & it is supported by spindle.
- The two fluxes ϕ_1 & ϕ_2 are proportional to voltage & current respectively. Causes eddy current induced in aluminium disc.

- During normal working condition, there is no torque produced on aluminum disc.



Construction of Directional Relay

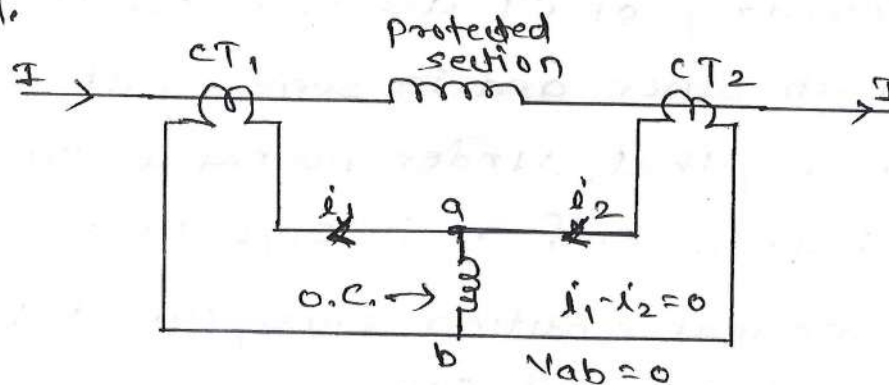
- when fault occurs, direction of power flow changes, the torque is produced on the disc and it rotates.
- Due to rotation, the trip circuit contacts are closed & relay sends trip signal to CB and circuit breaker operates.

* Differential Relay:

- It is a relay which operates when the vector difference of two or more similar electrical quantities exceeds the pre-determined value.
- There are two types of differential relay.
 - i) current differential relay
 - ii) voltage differential relay.

i] current differential relay

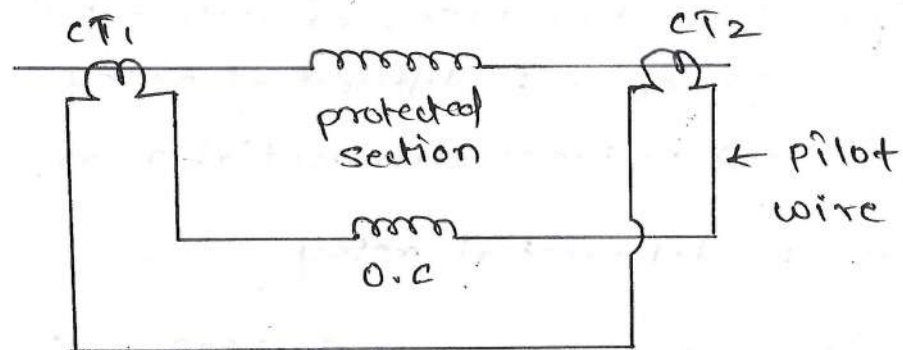
- Following fig. shows arrangement of c/n differential relay.



- Two identical CT's are fitted on either end of section to be protected.
- Secondary of CT's are connected in series to carry induced current in a same direction.
- operating coil of relay is connected across C.T. secondary circuit.
- This differential relay compares the current at two ends of protected system.
- Under normal condition, current through the secondary is equal, no current flows through operating coil.
- If fault occurs, two secondary c/n will not be equal & differential c/n flows through the operating coil of relay causes relay to operate.

ii] voltage differential Relay:

- Following fig. shows voltage differential relay, it consist two identical CT, connected at either end of protected system.



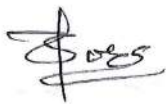
- The secondary of CT are connected in parallel with each other and in series with relay in such a way that, under normal working condition there induced emf are in opposition.
- Under normal condition, equal current flow in primary of CT₁ and CT₂.
- Secondary voltage of two transformer are balance against each other and no current will flow through pilot wire.
- In short circuit condition, current in a two primary are different from each other. Therefore secondary voltage will not same.
- This voltage difference will causes current to flow through operating coil of relay, which closes the trip circuit.
- diff

Unit - 3

Question Bank

- 1) state the term sensitivity and reliability.
- 2) state the term pickup current and current setting of protective relay
- 3) state any two limitations of differential protection
- 4) with the help of neat diagram explain the working of thermal relay.
- 5) Determine the time of operation of a 5 Amp, 3 sec over current relay having a current setting of 125%, and a TSM of 0.6 connected to supply circuit through a 400/5 CT when the circuit carries a fault current of 4000A. (From Time/PSM curve for the PSM of 8 the time of operation is 3.5 sec).
- 6) with the help of block diagrams explain operation of directional relay.
- 7) with the help of block diagram explain working of static relay.
- 8) with the help of flow chart explain the working of LFP based relay, state there any four advantages.
- 9) Name any four fundamental qualities requirement for protection relay.

- 10) state any two advantages of lvp based relay.
- 11) Define Relay time, pickup current, PSM, TSM.
- 12) Explain the principle of time graded protection of feeder using IDMT over current relay.
- 13) With the help of block diagram state the operation of lvp based over current protection.
- 14) state any two application of static relay, induction relay and MHO relay.
- 15) Define differential relay. With neat sketch explain the operation of voltage and current differential relay.



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