Q3) www.sayedsaad.com

Classification of relays

General function

1) Auxiliary
2) protection
3) Monitoring
4) Control

Construction (*)

1) Electrical magnetic
   L Attraction, Induction, Shaded pole
2) Non Electrical
   (Thermal, pressure, etc)
3) Microprocessor

Operating Signal

Voltage
Current
frequency
Temperature
velocity etc

Type of protection

Overcurrent
Directional Overcurrent
Distance
Over voltage
Differential
Reverse power

Special

1) Notching relay: operates in response to a specific no. of in pulses.
2) Time delay relay: intentionally induced time relay.
3) Device nos.

2	Time delay relay.
21	Distance relay
27	under voltage relay
32	Directional power relay
37	under Current
40	field failure relay
46	Reverse phase

(*) **Const.**

Attraction
1) Solenoid
2) Armature
3) balanced beam

Induction
Disc
Cup

Directional
reverse current
reverse power

Timing
Instantaneous
Definite lag
Inverse time lag

Distance
Impedance
Reactance
Admittance

Differential
Current
Voltage.

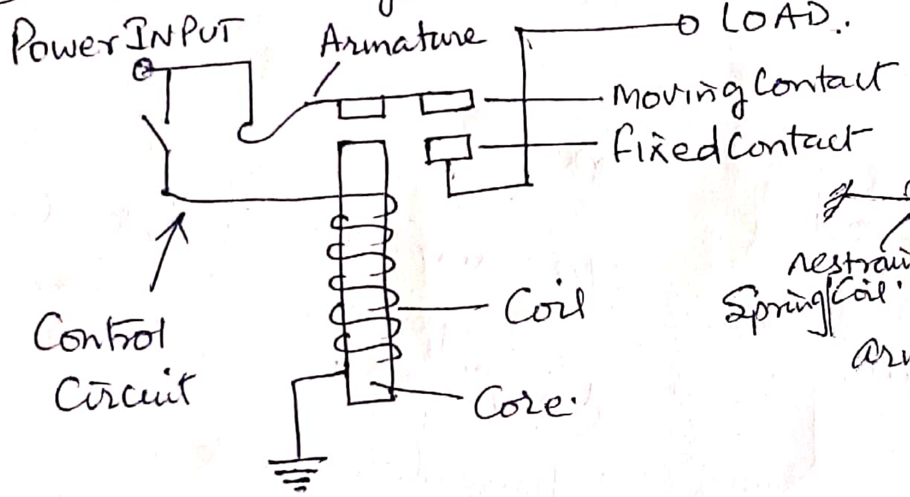
Others
O/C
U/V
Thermal
Rectifier
Static
[illegible]

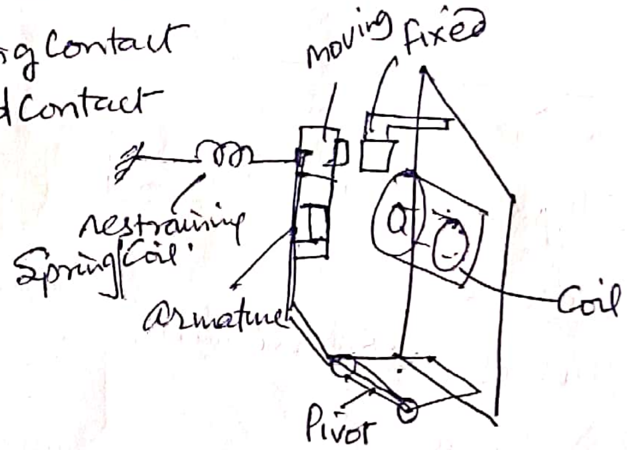
50 – Inst. over current
51 – AC over current relay
55 – powerfactor relay.
59 – Over voltage relay
67 – AC directional overcurrent relay

— x —

Construction & Principle of operation

① Armature type – ⓐ Attracted Armature type relay.

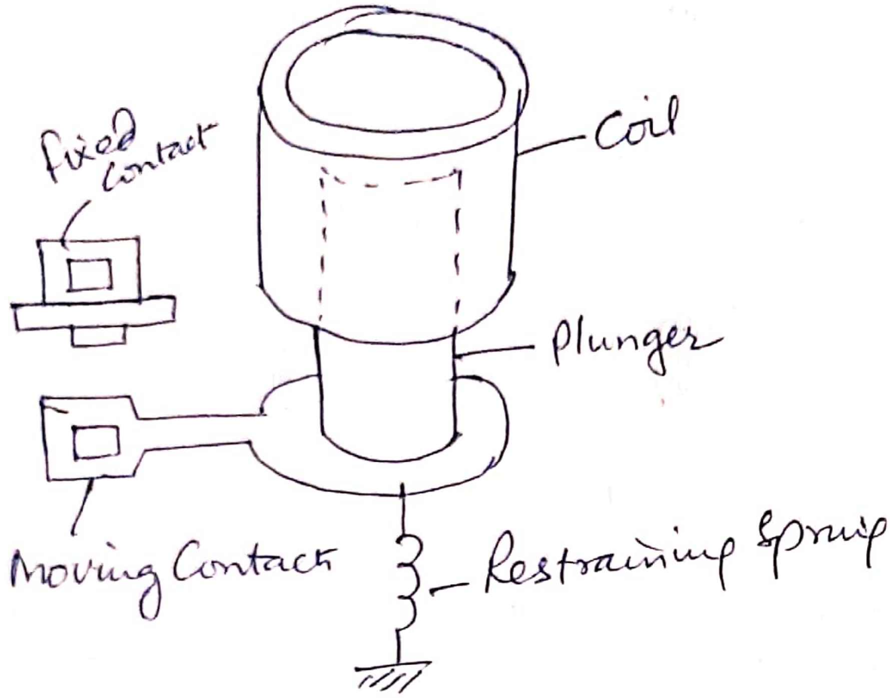




⊛ Relays work on both ac & dc. the circuit, from source to load is 'made' or 'broken' by means of a moving contact getting in contact with the fixed one, because of attraction of armature to the core.

* No time delay, hence instantaneous type.

(b) <u>Solenoid type</u> or Plunger type



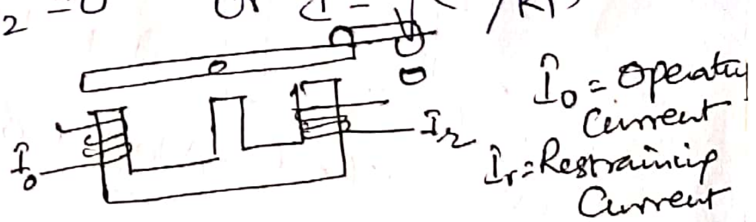
General eq^n:

force of attraction $= K_1 I^2 - K_2$

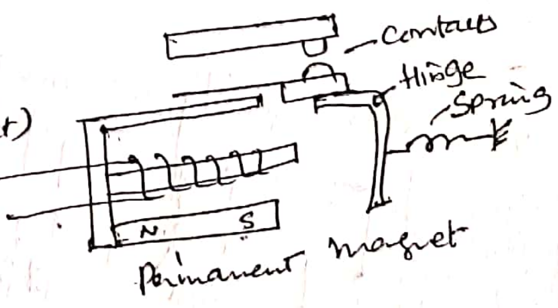
Where K_1 is the Constant depending on the Coil / armature parameters, K_2 is the restraining force.

<u>at balance</u> $K_1 I^2 - K_2 = 0$ or $I = \sqrt{(K_2/K_1)}$

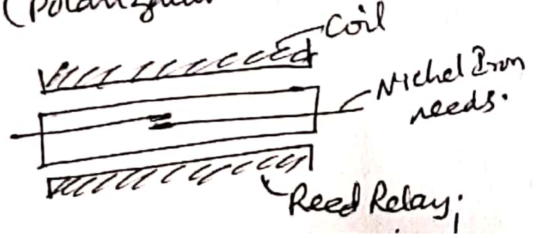
(c) balanced beam relay



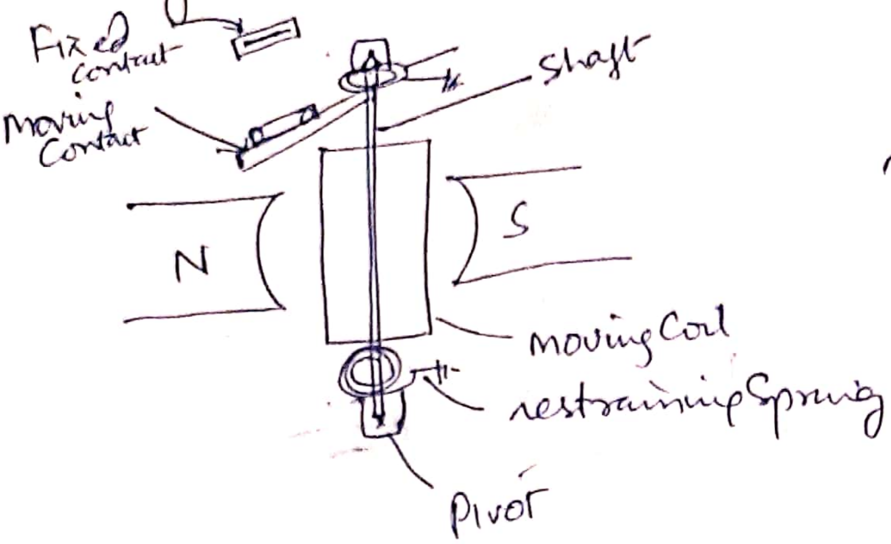
(d) Polarized moving Iron relay.
(Polarization because of Permanent magnet)



(e)



2) Relay with movable coil

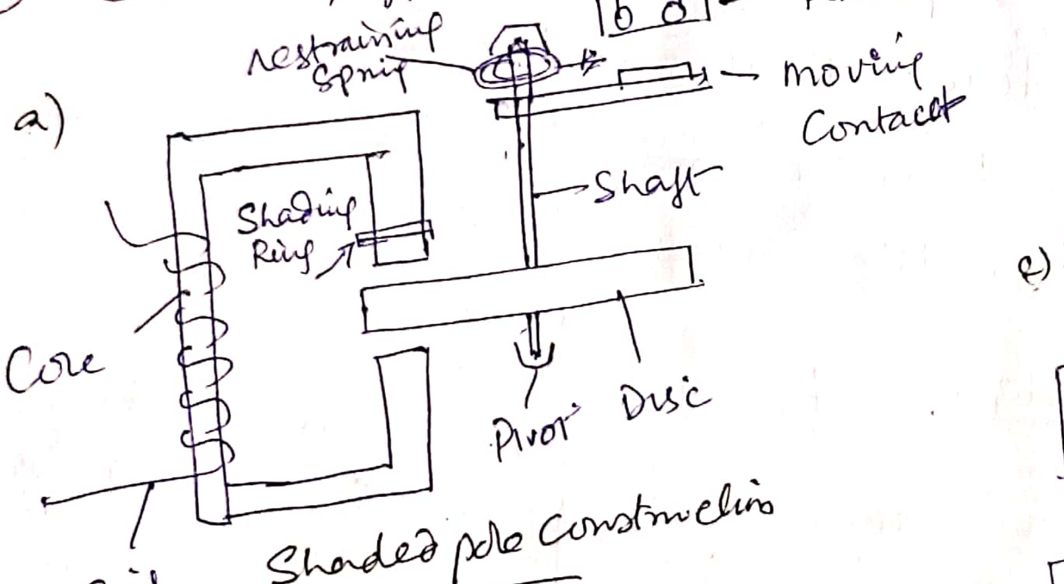


$T = BliaN$

B = Flux density
l = length of coil
i = Current through coil
a = width of coil
N = No. of turns.

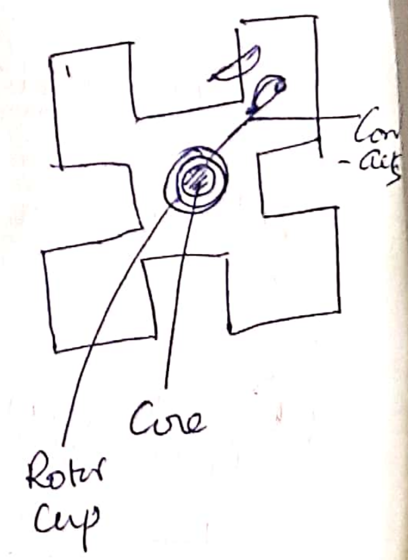
3) Induction Disc type relay

a)

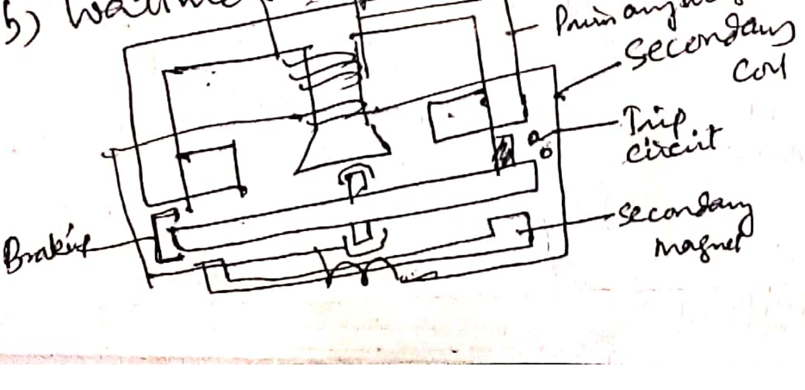


Shaded pole construction

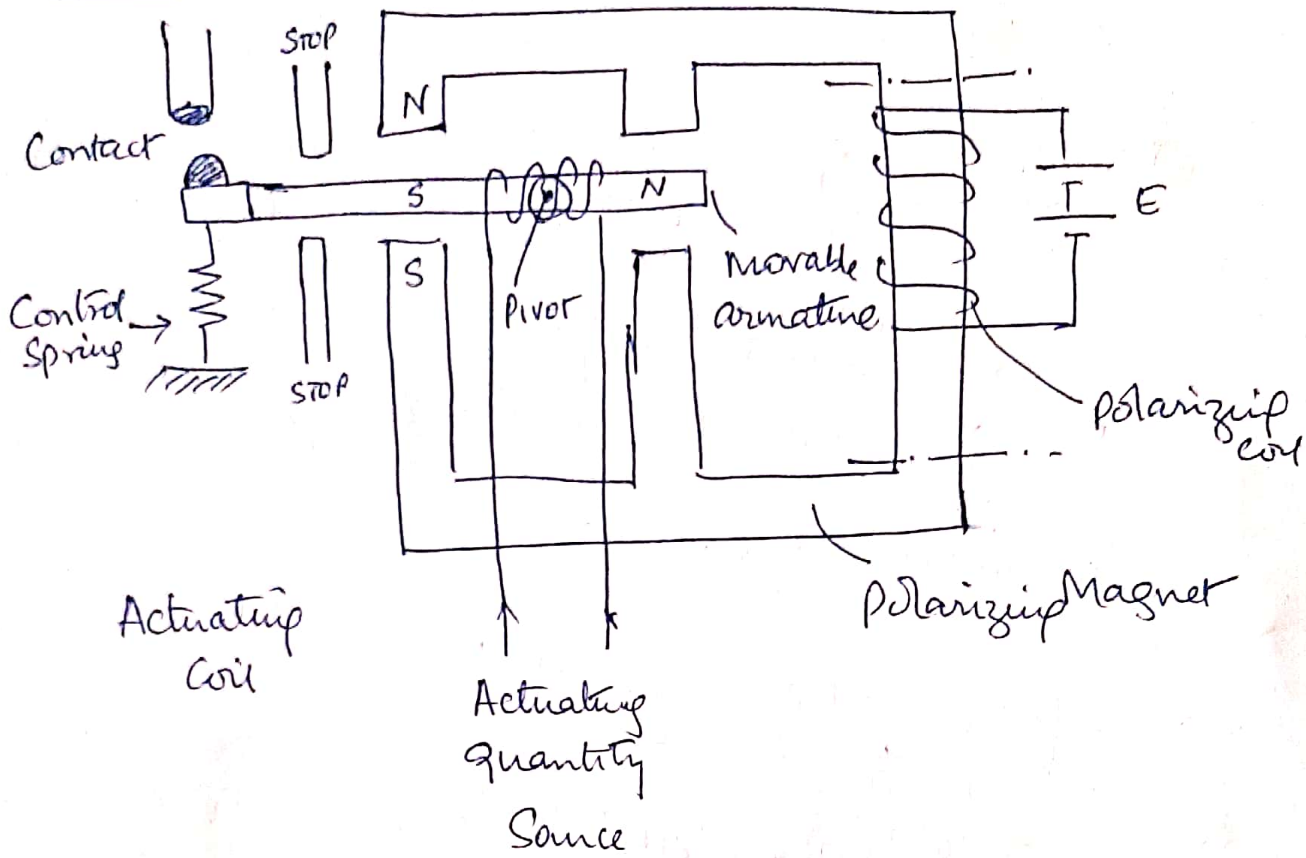
c) Induction Cup



b) Wattmeter type Constructions.



(4) Directional Relay:



Directional relay of the electromagnetic attraction type

$$F = K_1 I_p I_a - K_2$$

Net force Constant K_1,

I_p – Current in polarizing Coil

I_a – Current in actuating coil

K_2 – restraining force.

At balance $F = 0$ $K_1 I_p I_a = K_2$

$$I_p I_a = \frac{K_2}{K_1}$$

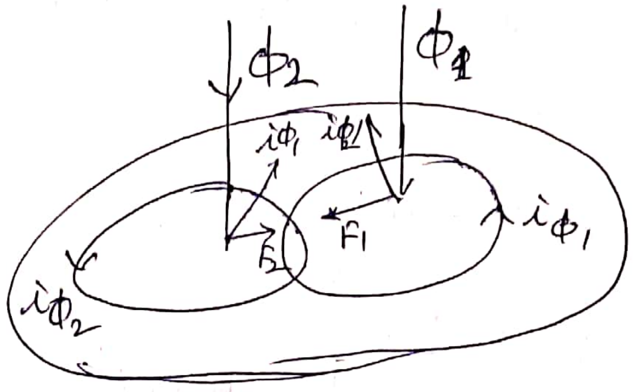
Technical aspects of attraction type of relays. (18)

1) Tendency of Vibration: the relays reset at every "zero" of the applied voltage/current, Causing chattering of the Contacts. this Can be eliminated by having a Shaded pole Construction.

2) effected by transients

3) Time characteristics :- fast action, not inherent for time delay..

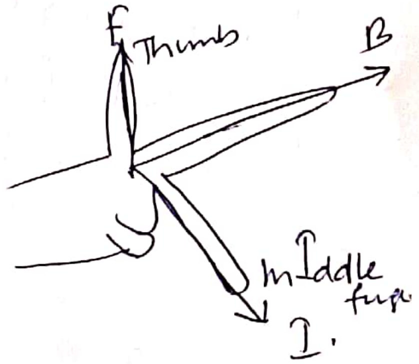
Induction Disc



$\phi_1 = \phi_{m_1} \sin \omega t$

$\phi_2 = \phi_{m_2} \sin(\omega t + \theta)$

Flemings Left hand rule



$i\phi_1 \propto \frac{d\phi_1}{dt} = \omega \phi_{m_1} \cos \omega t$

$i\phi_2 \propto \frac{d\phi_2}{dt} = \omega \phi_{m_2} \cos(\omega t + \theta).$

Force is due to $\phi_1 \, i\phi_2$, $\phi_2 \, i\phi_1$

ie $F_1 \propto \phi_1 \, \omega \phi_{m_2} \cos(\omega t + \theta)$

$F_2 \propto \phi_2 \, \omega \phi_{m_1} \cos \omega t$

when ω is constant,

Net force $F_2 - F_1 \propto \phi_{m_1} \phi_{m_2} \left[\sin(\omega t + \theta) \cos \omega t - \cos(\omega t + \theta) \sin \omega t \right]$

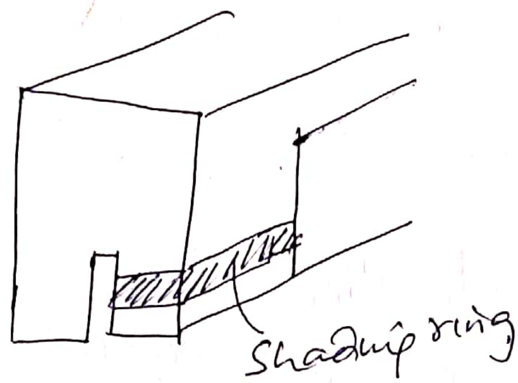
ie $F_2 - F_1 \propto \phi_{m_1} \phi_{m_2} \sin \theta.$

Conclusion

① To produce torque, alternating fluxes should be differing in phase, by 90° for max. Torque.

② Resultant torque is not a pulsating torque.

To produce a rotating field, two methods are adopted:-



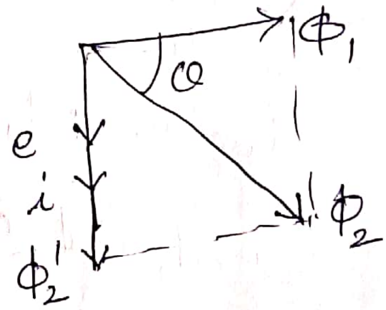
① pole shading

main flux ϕ_1

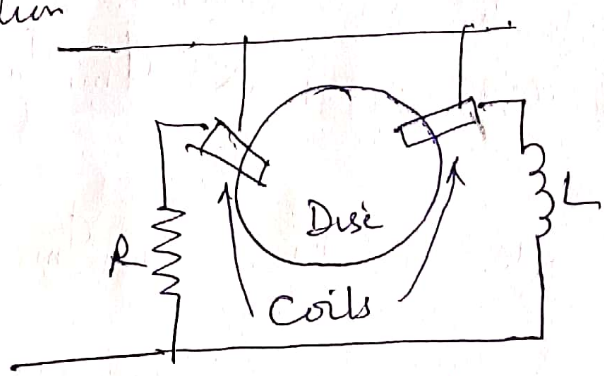
shaded pole flux lags ϕ_1 by 90°

$= -\frac{d\phi_1}{dt}$

Current in shaded pole lags by 90° from ϕ_1 and produces flux ϕ_2'.



② Two pole Construction



Comparison of Relays

	Ele/mech.	Static	Digital	Numerical
Tech. Standard	1st gen	2nd gen	Current generation	
Principle	Electro magnetic	Transistors & ICs.	← builtin Microprocessors with Software. →	
Measuring element/ hardware.	Induction disc, electromagnet Induction Cup	R,L,C Transistors analogue ICs Comparators.	← μP., digital ICs, DSP →	
Measuring method	Electrical Quantity Converted to mech, Torque, force.	level detection/ Comparison in Comparator	← A/D Conversion → Numerical algorithm	
Relay Size	Bulky	Small	Small	Compact
Speed of response	Slow	fast	fast	very fast
Timing functn	Mech Clock Dashpot	Static timers	Counter	Counter
Accuracy	Temp. dependant	Temp. dependant	Stable	Stable

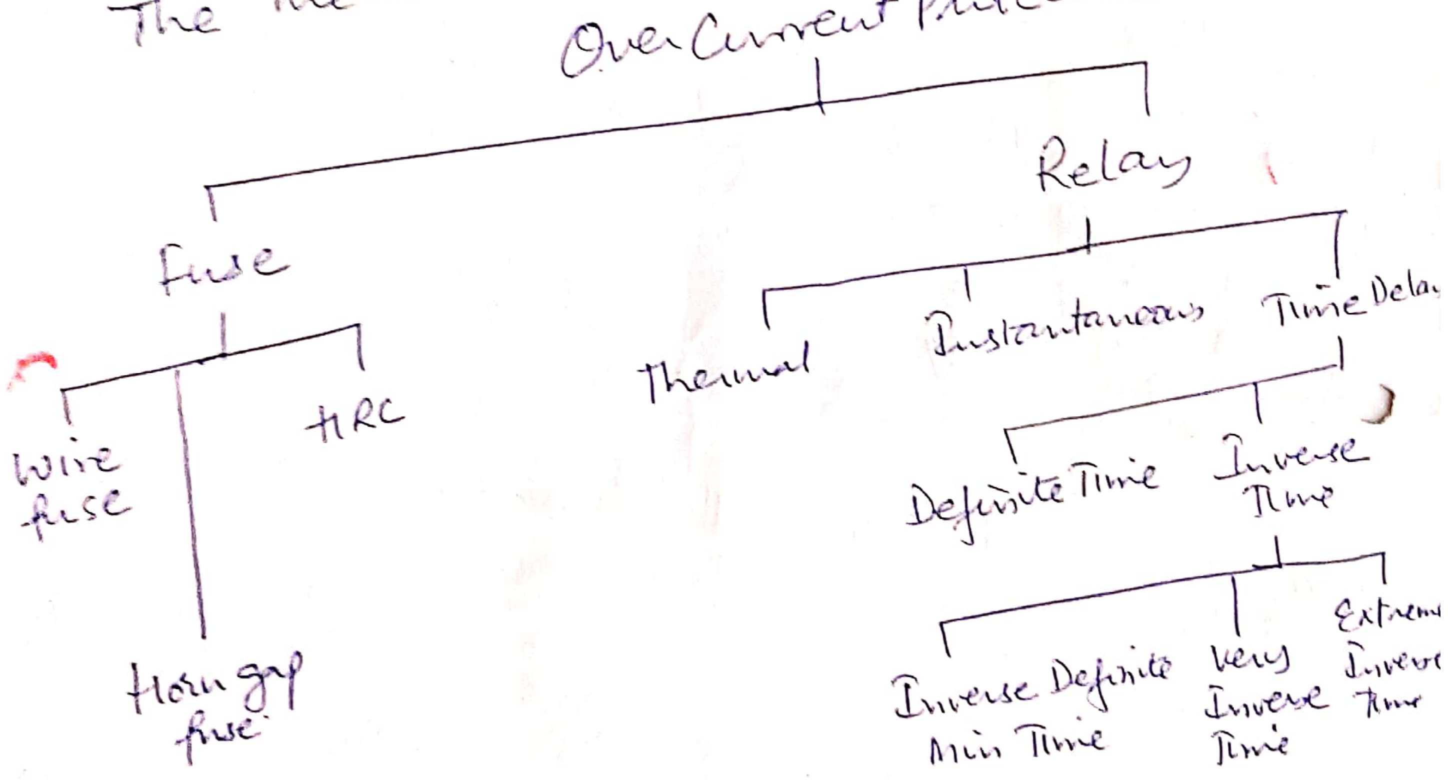
Characteristic	Electromechanical	Static	Digital	Numerical
Reliability	High	low	High	High
Vibration proof	NO	yes	Yes	Yes
Characteristics	Ltd	wide	wide	wide
Requirement of Drawout	required	required	← NOT required →	
CT burden	8-10VA	1VA	<0.5VA	<0.5VA
Reset time	Very high	Less	Less	Less
Aux. Supply	required	required	required	required
Range of Settings	Limited	wide	wide	wide.
Isolation voltage	low	High	High	High
Function	Single	Single	→ Multifunction →	
Maintenance	Frequent	Frequent	low	Very low

Charact	Elec. Mech.	Static	Digital	Numerical
Deterioration due to op.	Yes	Y. NO	NO	NO
Relay Prog.	No	partial	Programmable —	
SCADA compatible	NO	NO	Possible	Yes
Operation value Indication	Not Possible	Possible	possible	possible
Visual Indication	Flags, Targets	LEDs.	LEDs, LCDs	LEDs, LCDs
Self monitoring	NO	Yes	Yes	Yes
Parameter Setting	Plug of Dial setting	Thumbwheel Dual Switches	← Keypad for Numeric values through Computer →	
Fault disturbance recording	← Not possible	→	← Possible →	

OVER CURRENT PROTECTION

Normal Current is the rated Current in the Circuit for which it is designed.
Excess flow of Current results, when there is a fault in the system. this magnitude is Called Over Current and the system is to be protected against such Over Currents. This is done by means of Over Current Protection Schemes:-

The methods adopted are



—————— x ——————

Fuse law heat Produced $= I^2R = I^2 \cdot \rho \frac{l}{a} = I^2 \cdot \rho \cdot \frac{l}{\frac{\pi}{4}d^2} = K_1 \frac{I^2}{d^2}$

heat dissipated $\propto$ Surface area $\propto \pi \cdot d \cdot l = K_2 dl$

$\therefore$ Heat produced = Heat dissipated ie $K_1 \frac{I^2}{d^2} = K_2 dl$. or $\left(\frac{K_1}{K_2}\right) I^2 = d^3 l$

l of the fuse is Constant $\therefore \left(\frac{K_1}{K_2 l}\right) = K$. $\therefore I^2 K = d^3$. or $\boxed{I = \left(\frac{1}{K}\right) d^{3/2}}$

Fuses. — Tinned wire
— High rupturing capacity

Fuse is the weakest link in the circuit and the simplest protective device.

Fusing element is a small piece of wire connecting two mounted insulated terminals. Normal current is carried through and the heat produced does not reach the melting point.

For excess current, the melting point is reached and the wire melts causing disconnection in the circuit.

Material used for fuse wire —: Aluminium,

Metal	Melting point °C (°F)	Specific Resistance μΩ-cm.
Al.	(240) 115.6°c	2.86
Copper.	(2000) 1093.3°c	1.72
lead.	(624) 328.9°c.	21.0
Silver	(1830) 998.9°c.	1.64
Tin	(463) 239.4°c.	11.3
Zinc	(787) 419.4°c.	6.1.

Some key Terms related to a fuses

① Fuse element or wire ② Minimum Fusing Current

③ Current rating of fusing element — the value of current which the element can carry safely. this is less than min. fusing current.

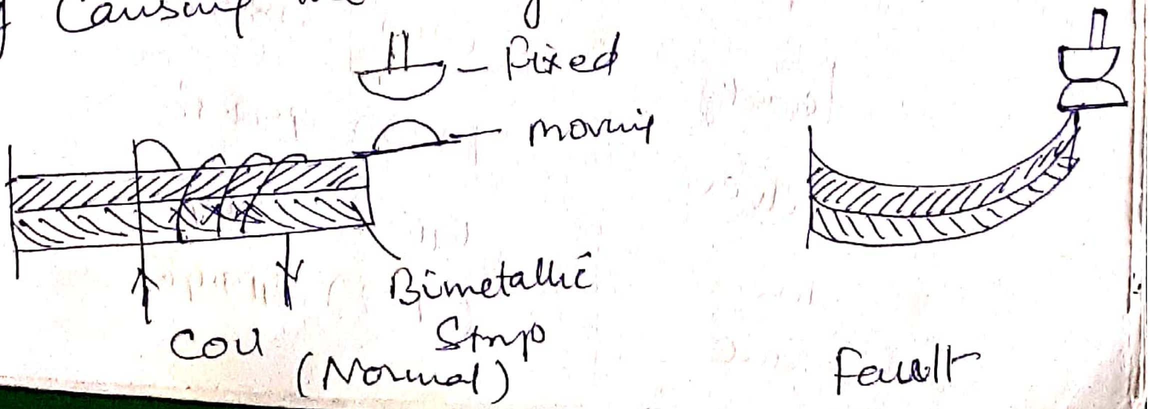
④ Fusing factor = $\frac{\text{Min fusing Current}}{\text{Current rating}}$

⑤ **Prospective Current**: that Rms value of the current, or DC current, which would flow in the circuit, immediately on short circuit,

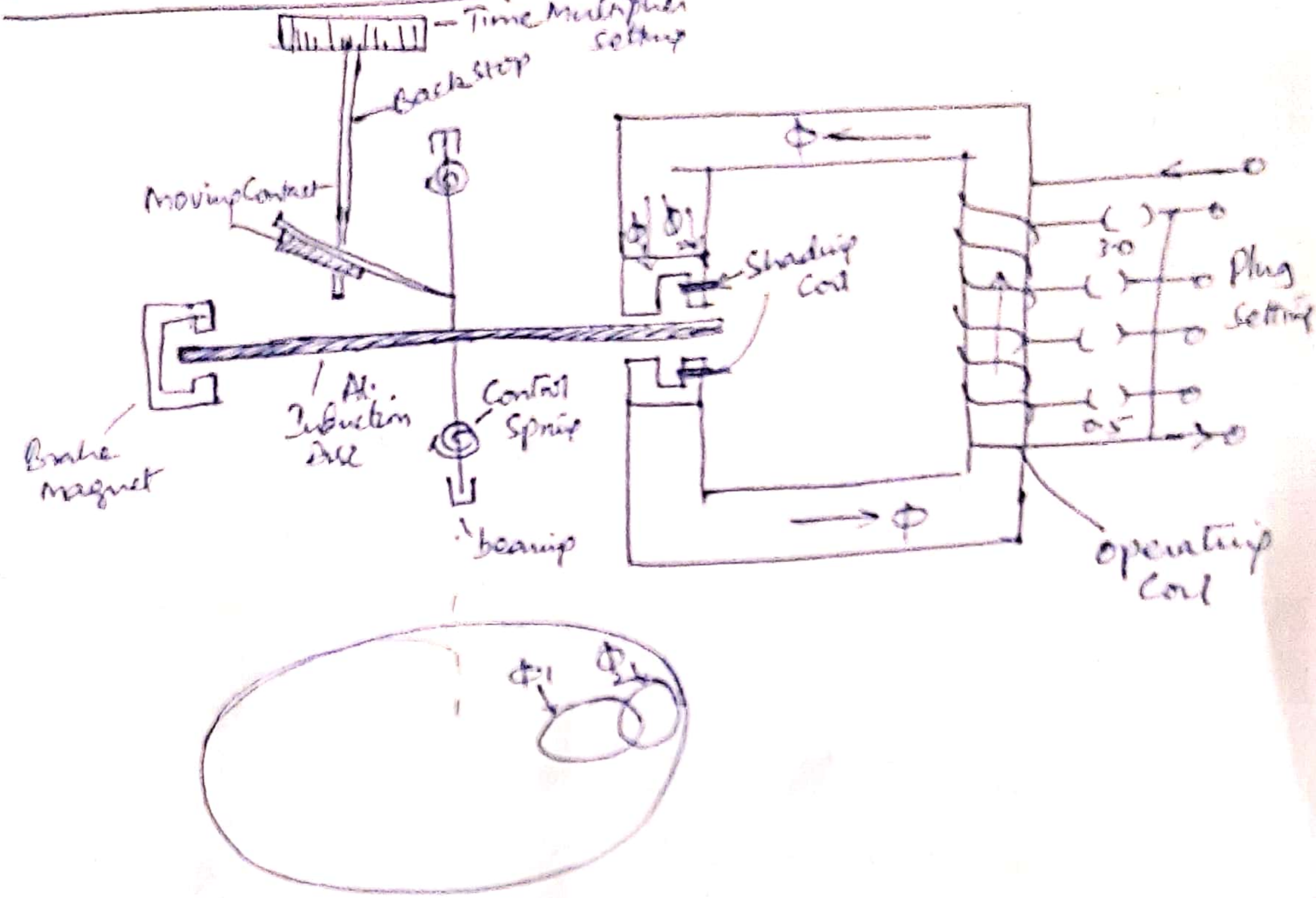
⑥ Total operating time = Melting Time or Prearcing time + Arcing time

⑦ Clearing I^2t = Prearcing I^2t + Arcing I^2t.

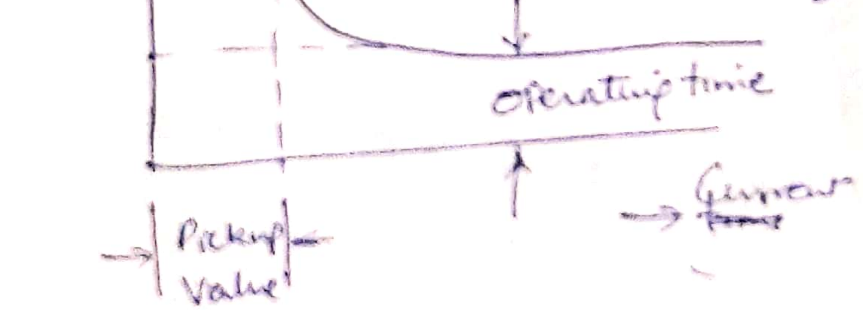
Thermal Relay: Bimetallic strip expands unevenly causing the relay to act

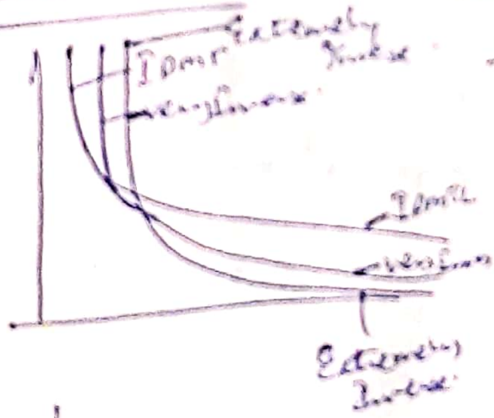


Overcurrent Relay



Definite Time OC Relay





IDMTL

$$t_{op} = \frac{0.14(TMS)}{(PSM)^{0.02} - 1}$$

Very Inverse time

$$t_{op} = \frac{13.5(TMS)}{PSM - 1}$$

Extremely Inverse

$$t_{op} = \frac{80.0(TMS)}{(PSM)^2 - 1}$$

Key terms

(1) Pick up Current (2) Current Setting

(3) plug setting Multiplier (PSM) (4) Time setting Multiplier (TSM)

(1) **Pickup Current** : Moving Contacts are under Constant restraining force (T_R), so that an additional force is required to overcome the restraining force. this additional force is called the deflecting force. (T_d)

$$T_d = -T_R.$$ ie T_d opposes T_R.

the value of Current for which the relay initiates its operation is called pickup Current of the relay

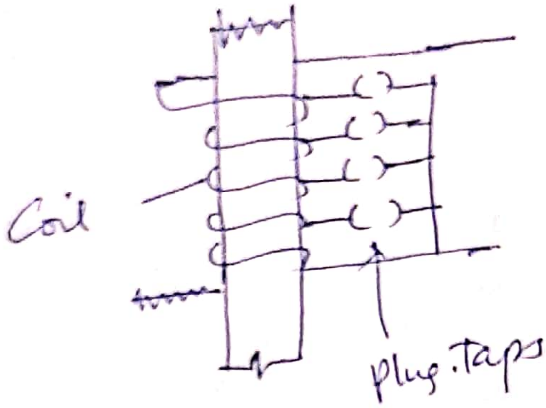
(2) **Current Setting**

For a required T_d, the force created by the coil depends on no. of Turns of the coil of Current through it.

$$T_d \propto N_c I_c$$

Hence if Turns are reduced More Current is required.

Same model of relay can be used for multiple requirements by having a no. of Tappings of the coil.



$$\text{Current setting or Current plug setting} = \frac{\text{Pickup Current}}{\text{Rated Secondary CT Current}} \times 100\%$$

O/c relay plug setting range → 50% to 200% in steps of 25%

E/F relay ——— 10% to 70% in steps of 10%

Plug setting Multiplier

$$PSM = \frac{\text{fault Current in relay}}{\text{Pickup current}}$$

$$= \frac{\text{fault current}}{\text{Rated Secondary CT} \times \text{Current setting}}$$

CT of ratio 200/1A.

Fault Current = 1000A.

Current setting 150%.

Relay rating = 1A.

Pickup current = relay rating × Current setting

= 1 × 150% = 1.5A.

fault current in CT secondary = $\frac{1000}{(200/1)}$ = 5 A.

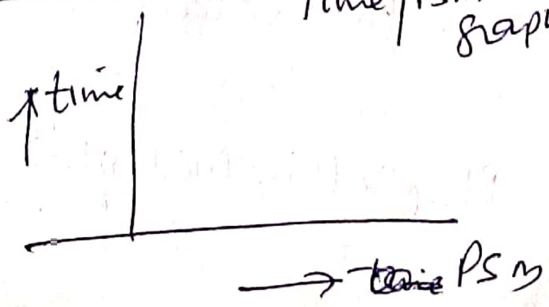
∴ PSM = $\frac{\text{fault current in Relay}}{\text{Rated Secondary CT} \times \text{Current Setting}}$

= $\frac{5}{1 \times 1.5}$ = 3.33.

Time Setting Multiplier (TSM): dial calibrated 0 to 1 in steps of 0.05 sec

Time Vs PSM Curve

Time/PSM graph



Steps to Calculate the Relay Operation Time

(1) Current Setting (2) Fault Current Value.

(3) Ratio of Current Transformer. (4) Time/PSM Curve.

(5) Time Setting

Step (1). Determine the rated Secondary Current of CT.

(2) From Current Setting, Calculate the ~~Trip~~ Pickup Current

Pickup Current = Current Setting × rated Secondary of CT

(3) To Calculate PSM for the Specified fault Current level –

$$\frac{\text{Primary fault Current}}{\text{CT ratio}} = \text{relay fault Current}$$

$$PSM = \frac{\text{Relay fault Current}}{\text{Pickup Current}}$$

(4) for the PSM – find the total operating time from Time/PSM Curve.

(5) operating time of relay × TSM = actual time of Operation

The induction relay can be modified to give different characteristics / operating features such as :-

1) <u>Directional or reverse current relay</u> :- Operates when applied voltage or current attains a specific phase displacement. An undervoltage compensation is provided.

2) <u>Directional or reverse power relay</u> :- the relay is actuated when the phase angle between voltage and current exceeds a set limit. No undervoltage compensation is provided.

3) Overvoltage, or over power relay :- principle is similar to above and actuates when the power or voltage or current exceeds the set limit.

(4) Differential relay :- operation depends on the difference in phase or magnitude.

(5) Distance Relay :- operation depends on voltage to current ratio.

Radial and Parallel Feeder

Over Current protection

feeder → Line to transfer power from Source to load end

To achieve uninterrupted power Supply, feeder Protection is required

- ~~Types~~ Reasons which Contribute to a fault:-

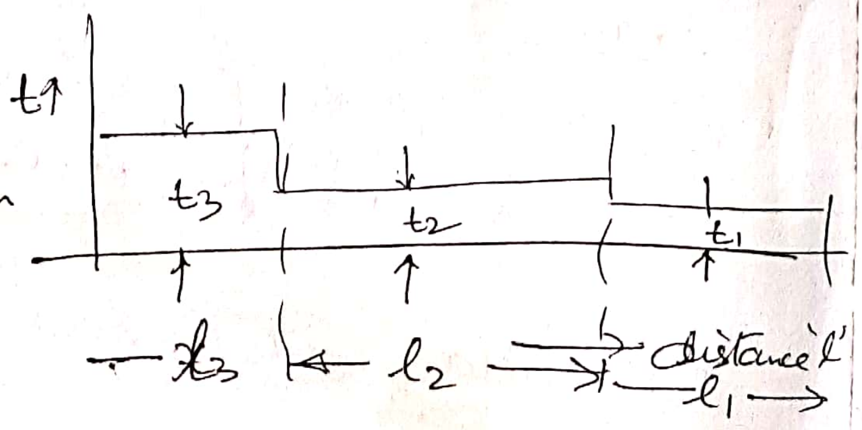
over loading, Over voltage, under frequency, power swing, Transient faults, Temperature and Lightning.

Feeder protection

- Unit Type
  - Differential
  - Carrier Current
- Non Unit Type
  - Time graded O/C
  - Current graded O/C
  - Distance protection

Non Unit Type

(A) Time graded protection

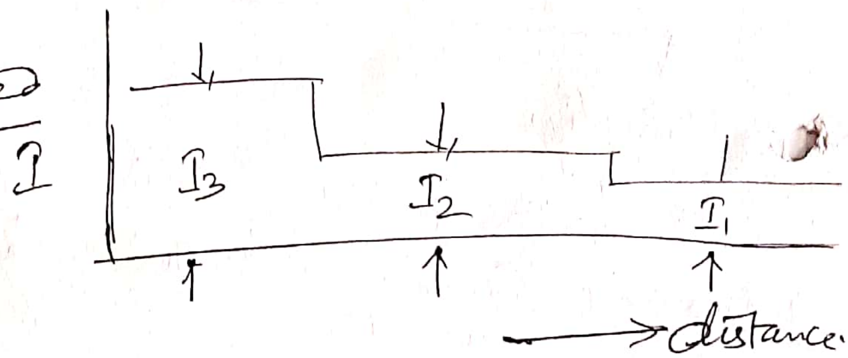


Suitable distances of the feeders, l_1, l_2, l_3 etc are provided with time graded protection such that the feeder element nearer to the ~~relay~~ fault, will have relay to act in shorter time interval.

Drawbacks

1) Time lag is not desirable in terms of short circuits
2) Suitable for unidirectional radial supply
3) with changes in load, the settings are to be changed.

(B) Current graded

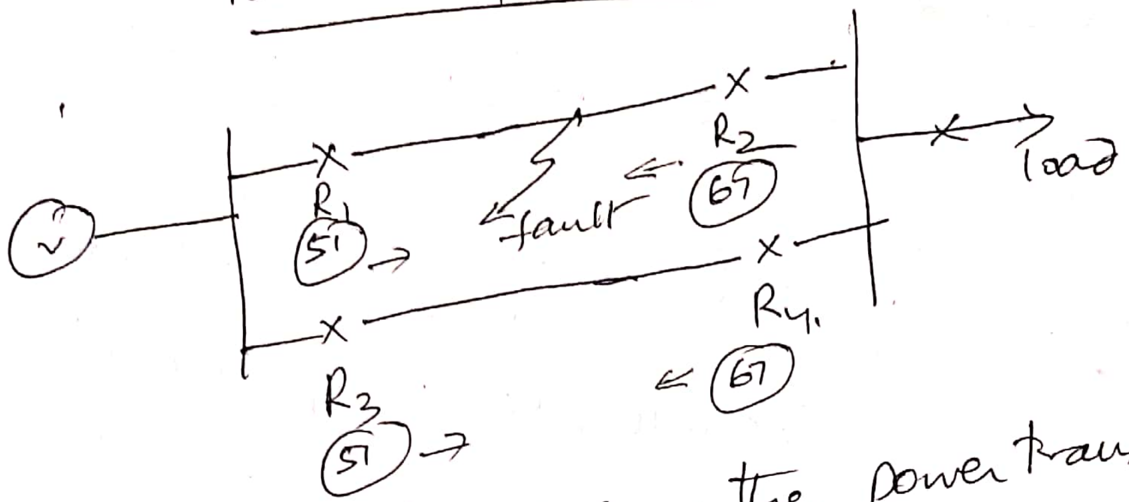


Drawbacks

the zone of fault cannot be clearly identified, because of low magnitude.

IDMT relay with current grading is used

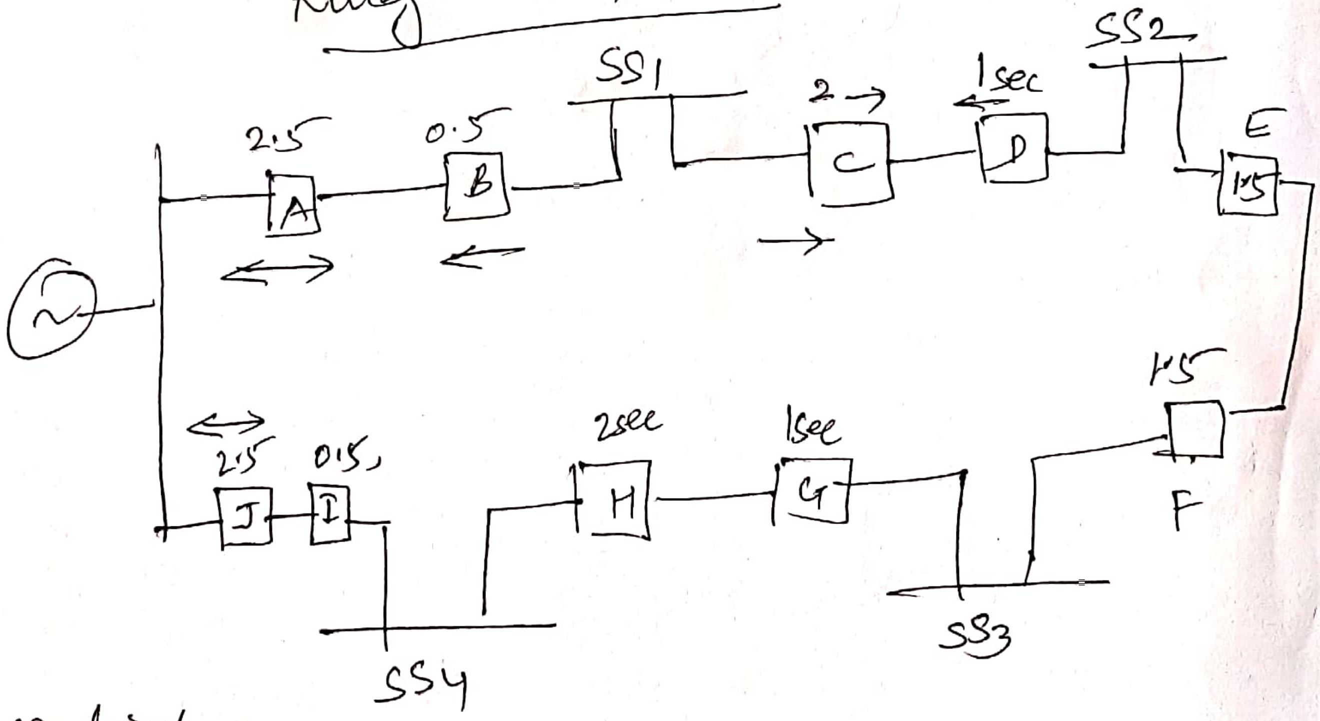
Parallel feeders



Parallel feeders, to overcome the power transfer capability of a single feeder.

During fault power may flow in opposite direction hence, Directional relays are used

Ring main feeder



A,J - Nondirection

BC, DE, FG, H, I reverse power relays.

around the loop

$G - SS_1 - SS_2 - SS_3 - SS_4 - G$

the outgoing relays A, C, E, G, I

are set with decreasing time limits.

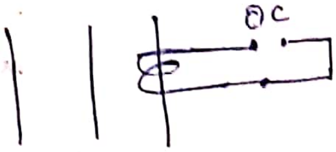
In the opp direction

$G - S_4 - S_3 - S_2 - S_2 - S_1 - G$ the outgoing

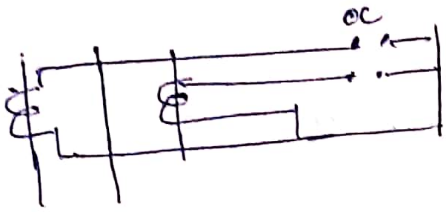
relays J, H, F, D, B. are also set in

the decreasing time limit

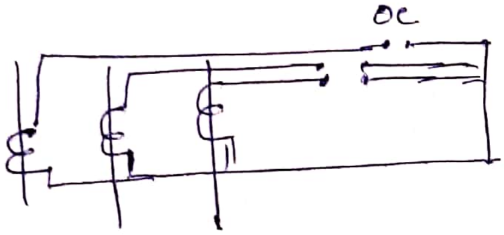
Over Current protection.

1. 

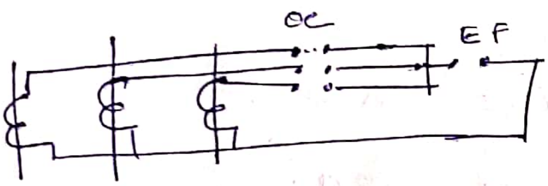
one CT for overload protection — for balanced load

2. 

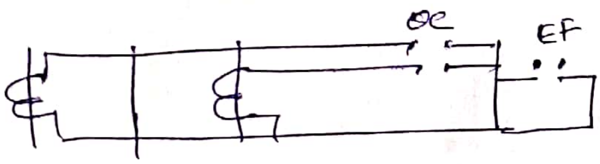
Two relays with 2 CTs for L-L fault and O/c protection — CTs must be in same phase in every station

3. 

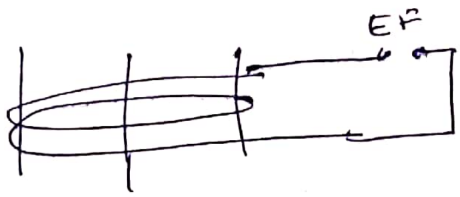
3 O/c relays with 3 CTs for L-L fault protection — EF setting less than phase fault setting

4. 

3 O/c, 1 E/F for L-L and L-E protection

5. 

2 O/c, 1 E/F for L-L prot.

6. 

E/F relay with Core balance CT.

Inverse Overcurrent relay coordination

Operating time

$$T_A = T_B + CB_B + O_A + F$$

T_A = operating time of relay at Station A

T_B = operating time of relay at Station B

CB_B = operating time of circuit breaker at Station B

O_A = Overtravel time of relay at Station A

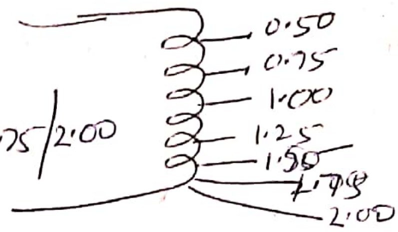
F = Factor of safety

Overtravel is the travel time of relay moving elements after the actuating force is removed.

Relay Settings

Plug Setting:- of the relay changes the no of turns of the exciting coil.

Seven taps — 0.50/0.75/1.00/1.25/1.50/1.75/2.00



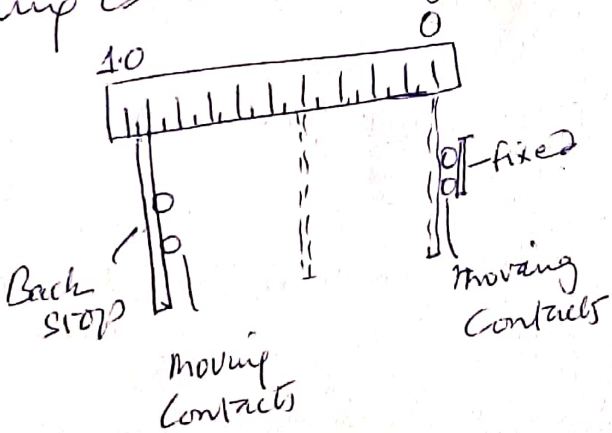
for 0.50 tap the Complete coil is utilized.

for 2.00 tap only a $\frac{1}{4}$ th of coil is utilized hence the Current should be 4 times to operate the relay.

for no plug the relay automatically sets to 2.00 tap

For a given Current, the greater the plug setting, the longer is the time for operation of the relay.

TIME multiplier Setting the relay's "backstop" of the rotating disc is adjusted.



with TSM = 1.0 the back stop is 180° away from Fixed Contacts

for TSM = 0 the back stop shorts the

<u>Pickup Current</u> : the Current at which relays initiates action

Min. deflecting force $\propto$ Current through Coil of No of Turns

$\propto I \cdot N_c$

for $N_c \downarrow$ $I \uparrow$ and for $I \downarrow$ $N_c \uparrow$.

<u>Current setting of relay</u> to use same relay for different locations by changing the settings

$$\text{Current setting} = \left(\frac{\text{Pickup Current}}{\text{Rated Secondary Current of CT}}\right) \times 100\%$$

$$\text{Pickup Current} = \text{Current Setting} \times \text{Rated Secondary of CT}$$

Normal Current 100A

Fault Current 125% ie 125 A.

CT ratio 100/1

Normal Relay Current = 1 A

fault Current in relay pickup = 125% of Normal = 1.25 A

$$\therefore \text{Current Setting} = \left(\frac{1.25}{1}\right) 100\% = \underline{125\%}$$

O/c relays — 50 to 200% in steps of 25%.

E/F relay 10% to 70% in steps of 10%.

Plug Setting Multiplier

- PSM is ratio of fault Current in the relay to Pickup Current

$$PSM = \frac{\text{fault Current}}{\text{Pickup Current}}$$

$$= \frac{\text{fault Current}}{\text{Current Setting} \times \text{Rated Secondary of CT}}$$

eg:- CT ratio 200/1   Current Setting = 150%

Pickup of Relay = 1 × 150% = 1.5A

∴ Let fault Current be 1200A

~~fault Current in CT secondary = $\frac{1200}{150 \times 1}$~~

1200 — 200
200 — 1200
1 — ?
$\frac{1 \times 1200}{200}$

200 — 1200
1 — ?
$\frac{1 \times 1200}{200}$ = 6

$$PSM = \frac{\text{fault Current in relay}}{\text{Pickup Current}} = \frac{6A}{1.5 \times 1}$$

$$= 4.0$$

Function of a Protective Relay is to detect / locate a fault, transmit a signal to isolate the fault, through the Connected switchgear.

Basic electrical quantities which are measured / monitored are Current, Voltage, phase and frequency.

Faults
- Symmetrical faults
- Unsymmetrical Faults
  - Single phase to ground (L-G)
  - Two phase to ground (2L-G)
  - Phase to phase (L-L)
  - Three phase
  - Open circuits

Faults Can occur Simultaneously too.

Overhead faults	50%	Line-Line	8%
Underground Cable	9%	Line-Ground	85%
Transformers	10%	Double Line To ground	5%
Generators	7%	Three phase	2%
Switchgear	12%		
CTs, VTs, Relays, Control equipment	12%		