EEE4227: POWER SYSTEM PROTECTION

TERM: MID-TERM

Lecture 06
Protective relays

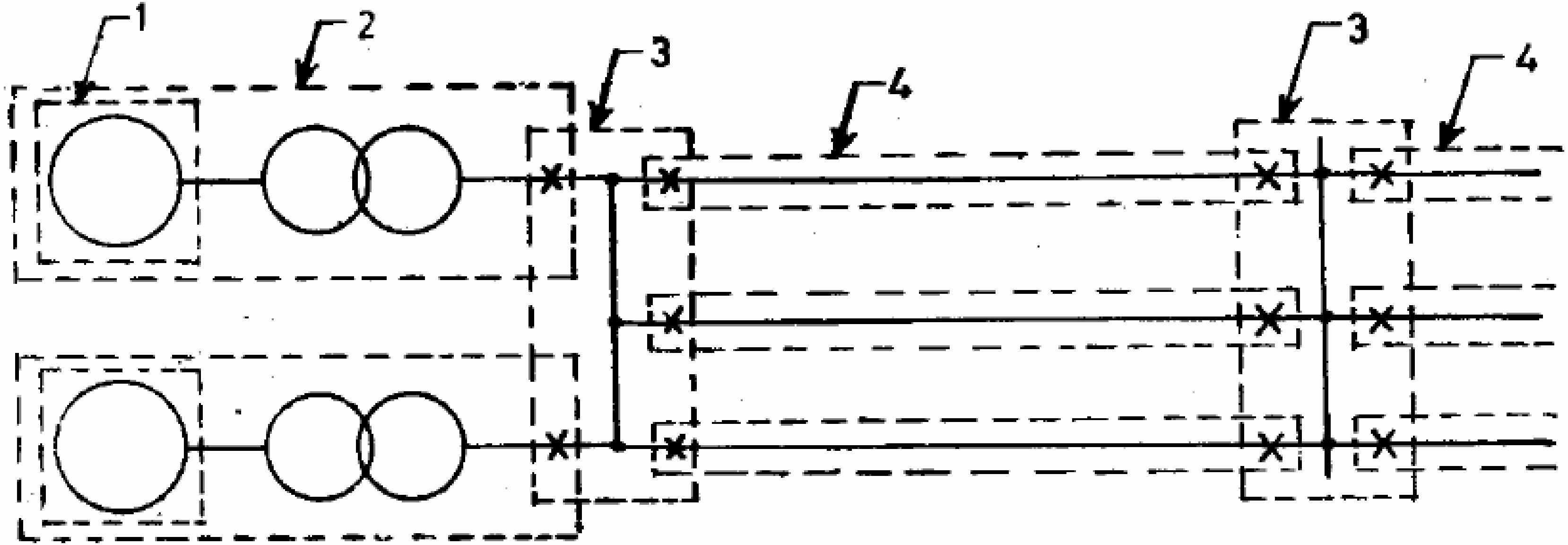
Properties of relays

- To detect any *abnormalities* in the system.
- *Isolate* the faulty section from the system as quickly as possible.
- To *limit* the damage of faulty section or element and to keep the rest of the system undistorted.
- Beside the main function to avoid damage from short circuits, relays should also take care of any *abnormal operating condition* particularly in generators or motors.
- The secondary function of relay is to *provide an indication* of location of fault and type of failure which is helpful for maintenance people.

Types of fault in a power system

Equipment	*Cause of fault*	*% of Total Faults*
1. Overhead lines	1. Lightning strokes, 30—40 2. Storms, earthquakes, icing, 3. Birds, trees, kites, aeroplanes, snakes, etc., 4. Internal over-voltages.	
2. Underground cables	1. Damage during digging 2. Insulation failure due to temperature rise, 3. Failure of joints,	8—10
3. Alternators (Generator)	1. Stator faults 2. Rotor faults, 3. Abnormal conditions, 4. Faults in associated equipment, 5. Faults in protective system.	6—8
4. Transformers	1. Insulation failure (Re. Sec. 12.4) 2. Faults in tap-changer, 3. Faults in bushing, 4. Faults in protection circuit, 5. Inadequate protection, 6. Overloading, Over voltage.	10—12
5. CT, PT	1. Over-voltages 2. Insulation failures, 3. Breaking of conductors, 4. Wrong connections.	15—20
6. Switchgear	1. Insulation failure 2. Mechanical defect, 3. Leakage of air/oil/gas, 4. Inadequate rating, 5. lack of maintenance.	10—12

Protective zones



...Boundary of protective zones decided by location of CT's

x—Circuit-breaker plus Isolators

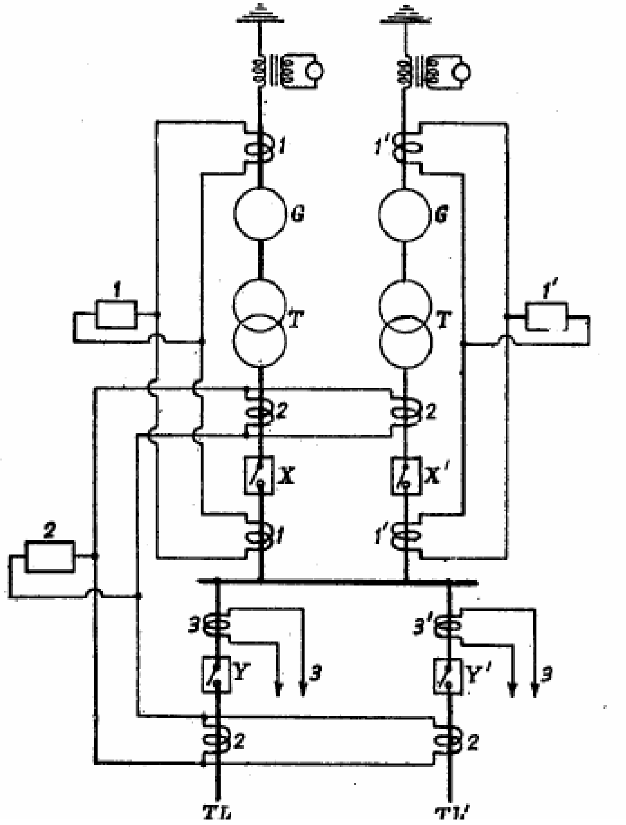
1—Generator p.zone

2—Generator transformer unit protective zone

3—Bus bar p.zone

4—Tr. line p.zone.

Protective zones



G Generator

T Main transformer of unit

TL Transformer Lines

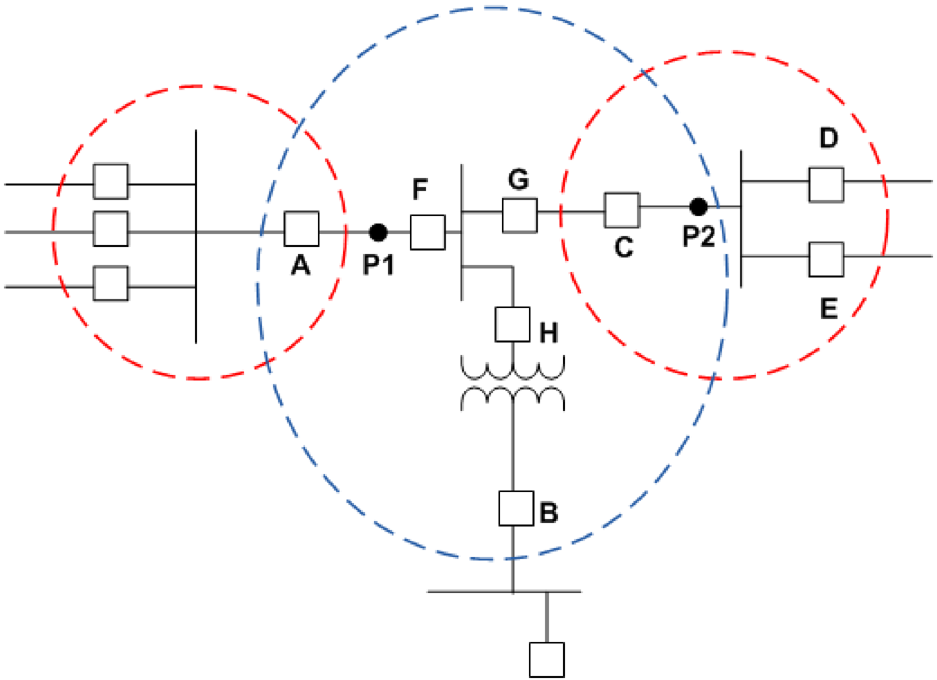
1,1′ Subscript for generator-transformer unit protection system covering circuit-breakers *X*, *X*′ respectively

2 Subscript for Main Bus Protecting System covering circuit- breaker *X*, *X*′ and also *Y*, *Y*′

3.3′ Subscript for transmission line protection systems Covering circuit-breakers *Y*, *Y*′

Necessity of more overlapped protective zones

Case 1 - *Less Overlapped*



For Fault at P1:

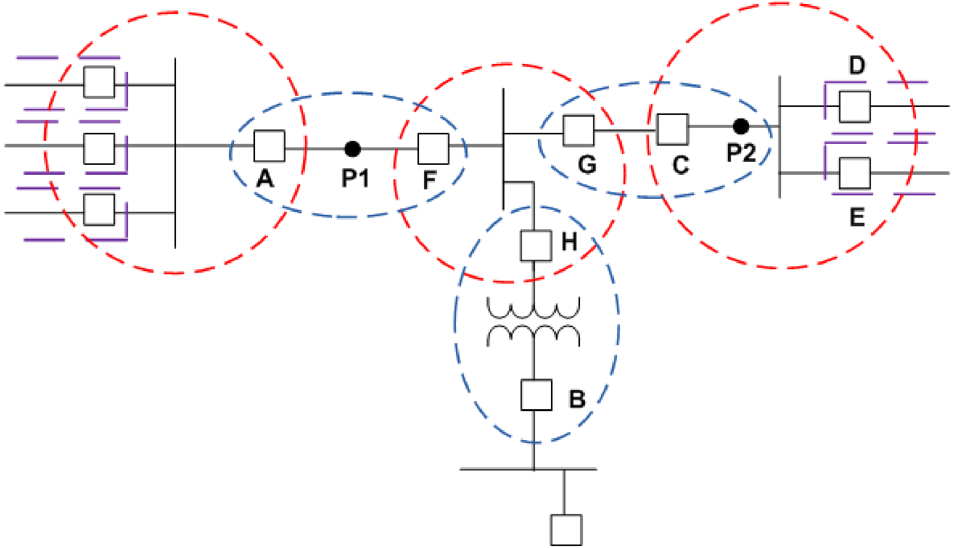
Fault under blue zone only. All the CBs in the blue zone i.e A, B, C, F, G, H will trip to isolate the fault.

For Fault at P2:

Fault has taken place in an overlapped zone , i.e at intersection of zones. All the CBs in the blue and red zone i.e A, B, C, D, E, F, G, H will trip will trip to isolate the fault.

Necessity of more overlapped protective zones

Case 1 - *More Overlapped*



For Fault at P1:

Fault under blue zone only. The CBs in the blue zone i.e **A and F only** will trip.

For Fault at P2:

Fault has taken place in an overlapped zone , i.e at intersection of zones. All the CBs in the blue and red zone i.e **G, C, D and E only** will trip.

Summary of having more protective zones

- In order to provide *service continuity* to as many areas as possible under fault condition, the power system should be divided into as many zones as possible.
- As a result, the protective scheme of only the affected zone can isolate the fault, which is also known as *selectivity.*
- Comparing the case 1 and 2, it is observed that with more number of protective zones, better service continuity can be achieved. Less consumers will also be affected.

Relaying type

- Primary relaying (first line of defense)
- Backup relaying (functions when the primary relay fails)

Necessity of back up protection

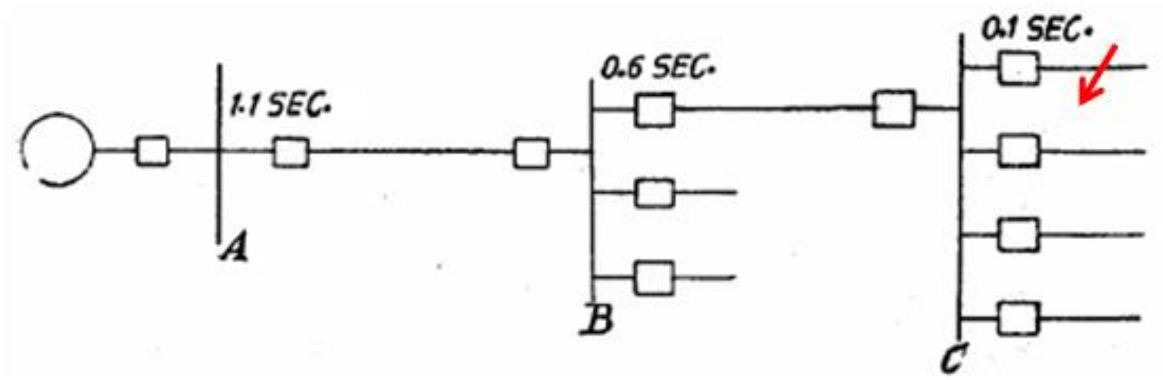
- If due to some reason, the main protection fails, the back-up protection serves the purpose of protection.
- Main protection can fail due to failure of one of the components in protective system such as relay, CT, PT, trip circuit, CB e.t.c.
- When main protection is made inoperative for the purpose of maintenance, testing, e.t.c, the backup protection acts like main protection.
- Due to economical reasons, back-up protection is given against short circuit protection only rather than other abnormal conditions.

Back up protection schemes

- Back up protection can be provided by-
  - Time graded scheme
  - Current graded scheme
  - By combination of time and current graded scheme

Back up protection schemes

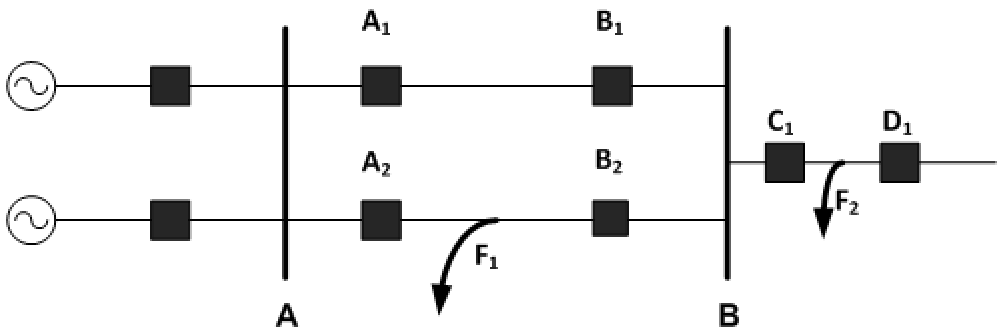
❖ Back up protection by time graded scheme-



Requirements of a relay for proper functioning

- Selectivity or discrimination
- Speed of operation
- Sensitivity
- Reliability
- Simplicity
- Economy

Selectivity



For fault at F_2, the breakers C_1 and D_1 should be tripped

For fault at F_1 , the breaker A_2 and B_2 should be tripped

Speed of operation

- Electrical apparatus may be damaged if they are made to carry the fault currents for a long time.
- If the faulty section is not disconnected quickly, then the low voltage created by the fault may shut down consumers' motors and the generators on the system may become unstable.
- The high speed relay system decreases the possibility of development of one type of fault into the other more severe type.

For all the above mentioned reasons, relay system should disconnect the faulty section as fast as possible

Sensitivity

Ability of the relay system to operate with low value of actuating quantity.

- It is desirable that relay system should be sensitive so that it operates with low values of volt-ampere input.
- The smaller the volt-ampere input required to cause relay operation, the more sensitive is the relay.
- 1 VA relay is more sensitive than a 3 VA relay.

Reliability & Simplicity

- It is the ability of the relay system to operate under the pre-determined conditions.
- Without reliability, the protection would be rendered largely ineffective and could even become a liability.
- Reliability is closely related to simplicity.
- The simpler the protection scheme, the greater will be its reliability.

Economy

- The most important factor in the choice of a particular protection scheme is the economic aspect.
- The protective gear should not cost more than 5% of total cost.
- when the apparatus to be protected is of utmost importance (*e.g.* generator, main transmission line etc.), economic considerations are often subordinated to reliability.

Classification of relay

Primarily three types-

- Electro mechanical relay
- Static relay/ Solid State Relay
- Microprocessor based relay

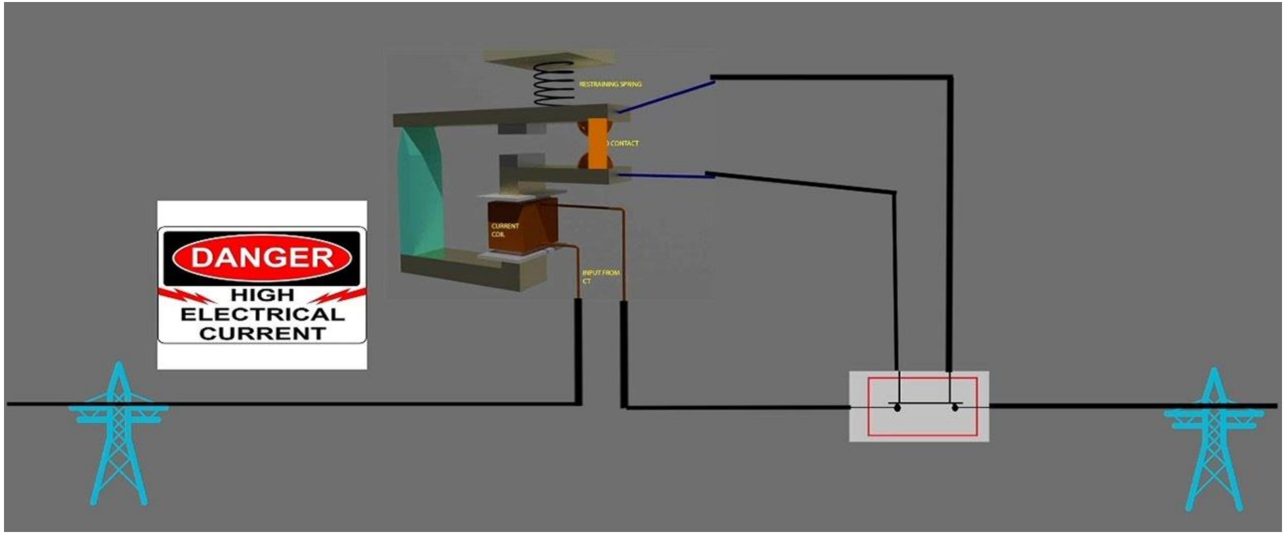
Classification of Electro mechanical relay

- Electro mechanical relay
  - Electromagnetic attraction
    - Hinged attracted armature type
    - Plunger type attraction relay
    - Balanced beam relay
  - Electromagnetic induction
    - Shaded pole type
    - Watt-hour meter type
    - Induction cup type

Actuating quantity

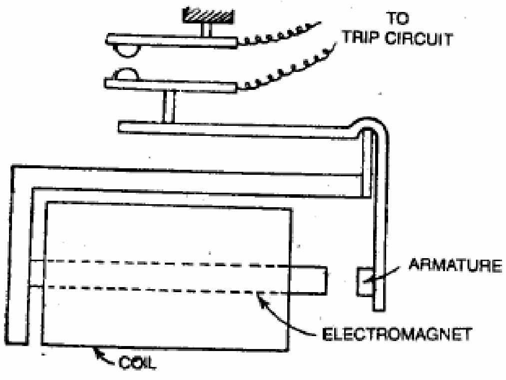
- Actuating quantity can be either *current* or *voltage* or both *voltage and current.*
- Depending on actuating quantity relay can be classified as following-
- Single actuating quantity based relay
  - Hinged attracted armature type
  - Plunger type attraction relay
  - Shaded pole type
  - Watt-hour meter type
  - Induction cup type
- Double actuating quantity based relay
  - Balanced beam relay
  - Watt-hour meter type
  - Induction cup type

Electromagnetic attraction type relay

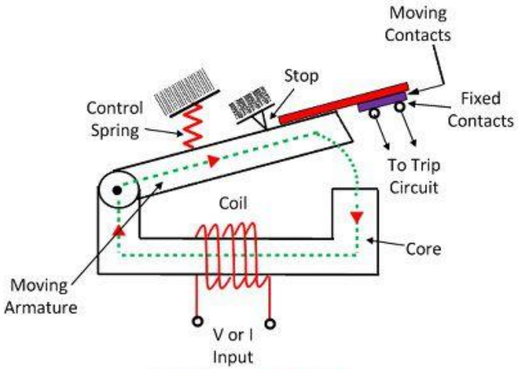


Hinged attracted armature type

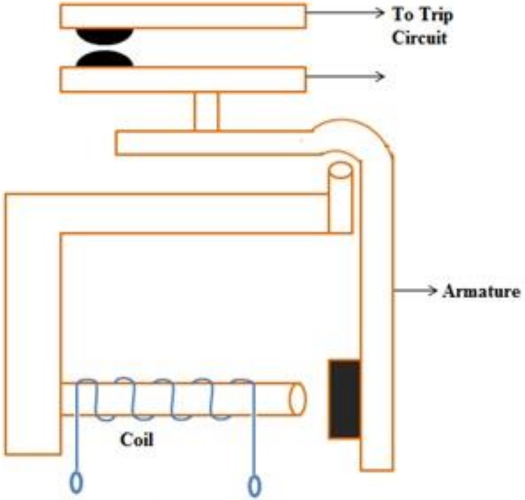
Also known as attracted armature type electromechanical relay.



(a) Hinged armature type relay.



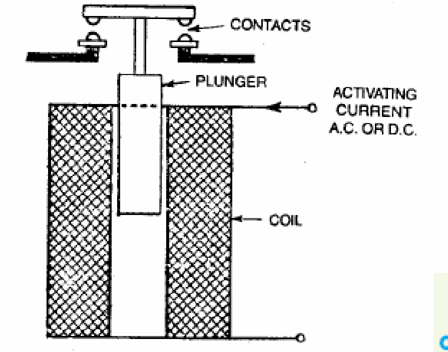
Hinged Armature Type



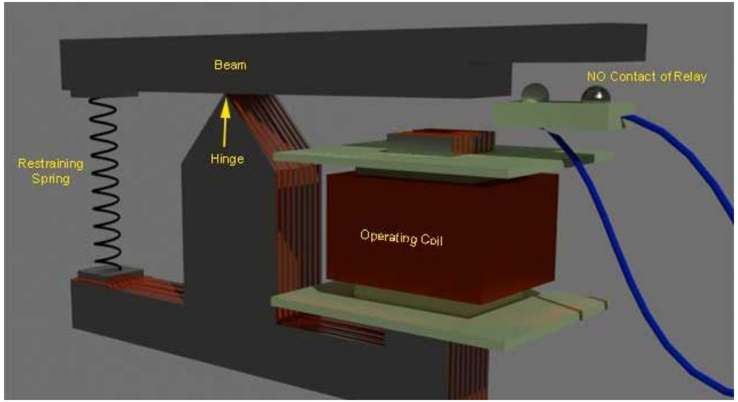
Hinged Armature type (A)

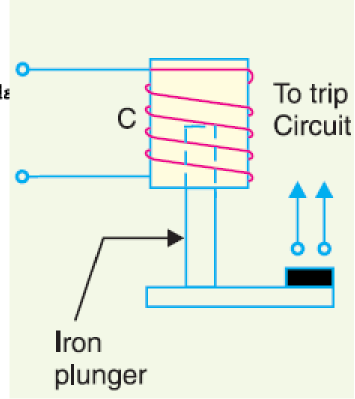
Plunger type attraction relay

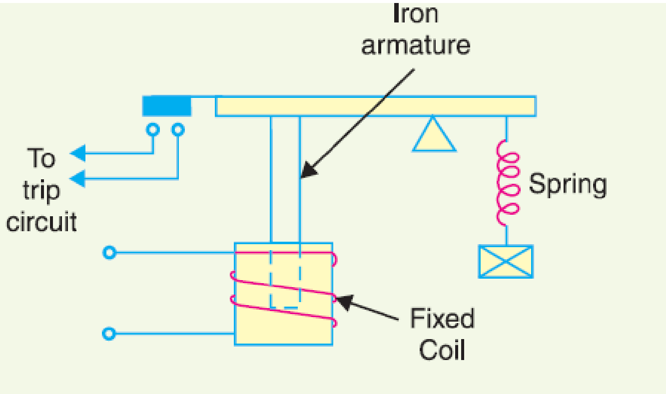
Also known as solenoid type electromechanical relay.



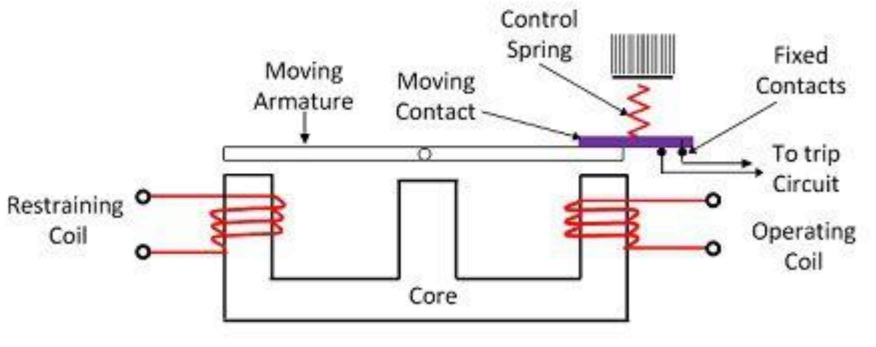
(b) Plunger type electromagnetic attraction rela



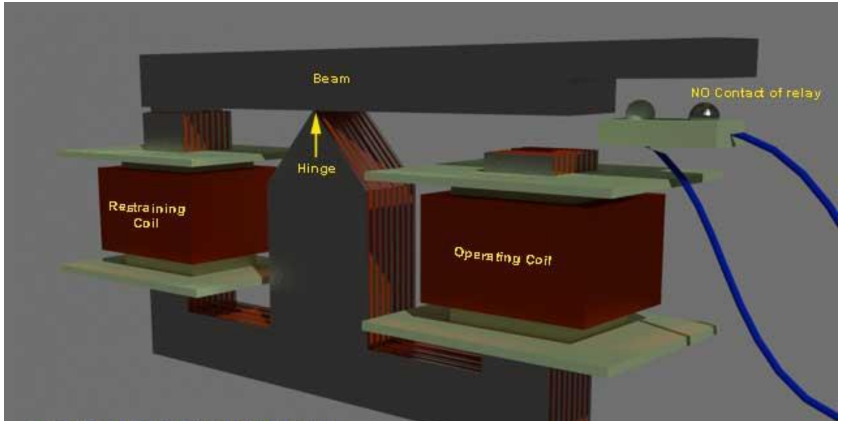




Balanced beam relay



Balanced Beam Type



Conceptual View of Balance Beam Relay

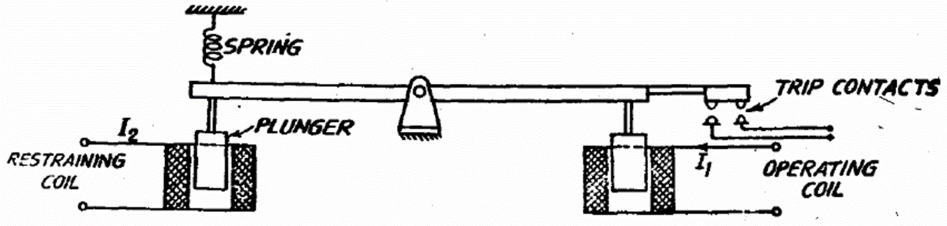


Fig. Balance beam relay of early days.

Balanced beam relay

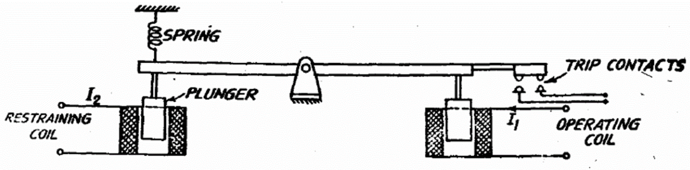


Fig. Balance beam relay of early days.

Neglecting spring effect, the net torque is given by

$$T = K_1 I_1^2 - K_2 I_2^2$$

where

T = net torque

I_1 = current in operating coil

I_2 = current in restraining coil

K_1, K_2 = constants.

At the verge of operation, net torque is zero, therefore,

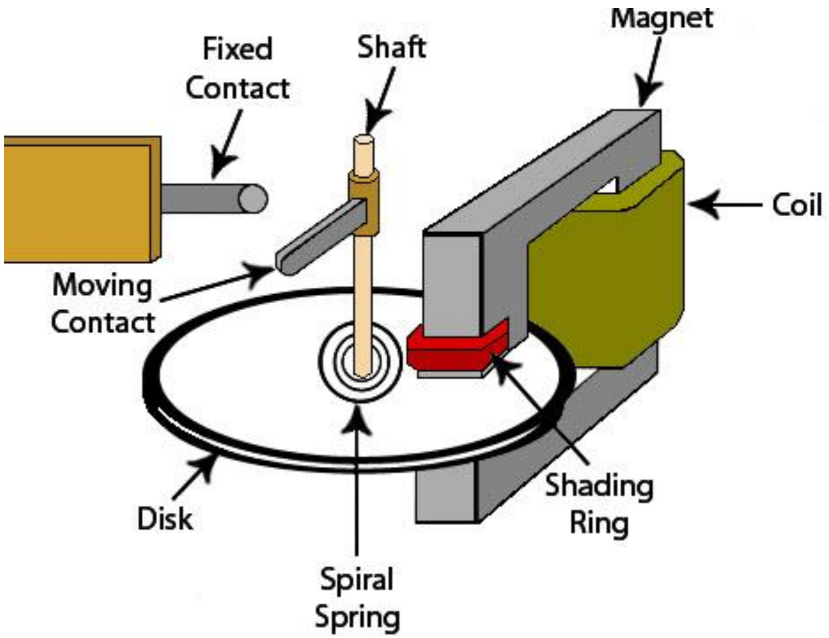
$$K_1 I_1^2 = K_2 I_2^2$$

$$\frac{I_1}{I_2} = \sqrt{\frac{K_2}{K_1}} = \text{constant.}$$

If the actuating quantity is V_1 instead of current I_1, Then,

$$\frac{V_1}{I_2} = \sqrt{\frac{K_2}{K_1}}$$

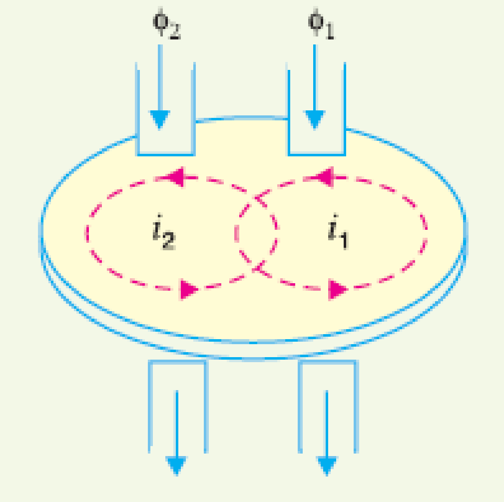
Electromagnetic induction type relay



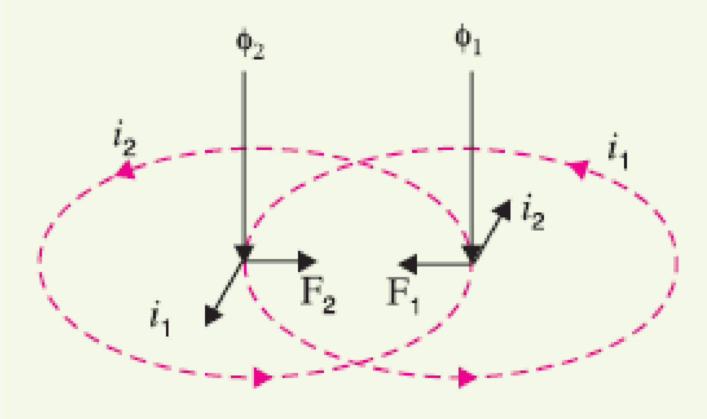
- ❖ Electromagnetic induction relays operate on the principle of induction motor.
- ❖ Induction relays are widely used with ac quantities not with dc owing to the principle of operation.
- ❖ consists of a pivoted aluminium disc placed in two alternating magnetic fields of the same frequency but displaced in time and space.
- ❖ The torque is produced in the disc by the interaction of one of the magnetic fields with the currents induced in the disc by the other.

Principle of operation of Electromagnetic induction type relay

❖ Generation of torque in electromagnetic induction type relay-



The two ac fluxes ϕ2 and ϕ1 differing in phase by an angle α induce e.m.f.s in the disc and cause the circulation of eddy currents *i*2 and *i*1 respectively. These currents lag behind their respective fluxes by 90o.



$$\phi_1 = \phi_{1max} \sin \omega t$$
$$\phi_2 = \phi_{2max} \sin (\omega t + \alpha)$$

where ϕ_1 and ϕ_2 are the instantaneous values of fluxes and ϕ_2 leads ϕ_1 by an angle α.

Principle of operation of Electromagnetic induction type relay

Assuming that the paths through which the rotor currents flow have negligible self-inductance, the rotor currents will be in phase with their voltages.

$$i_1 \propto \frac{d\phi_1}{dt} \propto \frac{d}{dt}(\phi_{1max} \sin \omega t)$$

$$\propto \phi_{1max} \cos \omega t$$

$$i_2 \propto \frac{d\phi_2}{dt} \propto \phi_{2max} \cos(\omega t + \alpha)$$

Now, $F_1 \propto \phi_1 i_2$ and $F_2 \propto \phi_2 i_1$

From the figure it is clear that two forces are in opposite direction, i.e. net force will be F=F2-F1

$$F \propto F_2 - F_1$$

$$\propto \phi_2 i_1 - \phi_1 i_2$$

$$\propto \phi_{2max} \sin(\omega t + \alpha) \phi_{1max} \cos \omega t - \phi_{1max} \sin \omega t \, \phi_{2max} \cos(\omega t + \alpha)$$

$$\propto \phi_{1max} \phi_{2max} [\sin(\omega t + \alpha) \cos \omega t - \sin \omega t \cos(\omega t + \alpha)]$$

$$\propto \phi_{1max} \phi_{2max} \sin \alpha$$

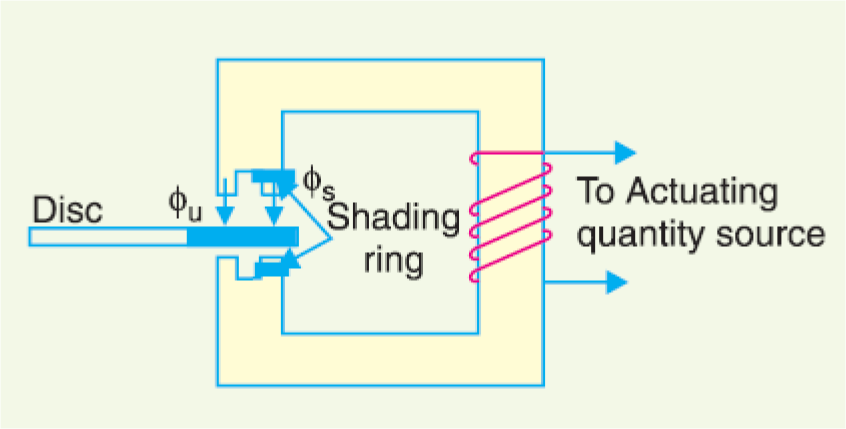
$$\propto \phi_1 \phi_2 \sin \alpha$$

Principle of operation of Electromagnetic induction type relay

Summary-

- The greater the phase angle between the fluxes, the greater is the net force applied on the disc.
- Maximum force will be obtained when the two fluxes will be 90° out of phase.

Shaded pole type induction relay



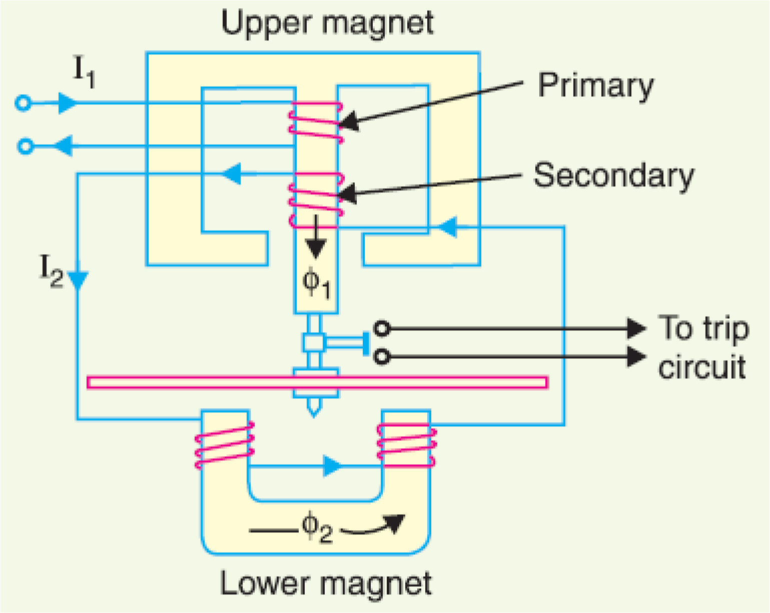
- The alternating flux Φs in the shaded portion of the pole will lag the flux in the unshaded portion of the pole will lag behind by the angle α.
- Therefore,

$$T \propto \phi_s \phi_u \sin \alpha$$

- Assuming fluxes are in proportional to the relay coil current I,

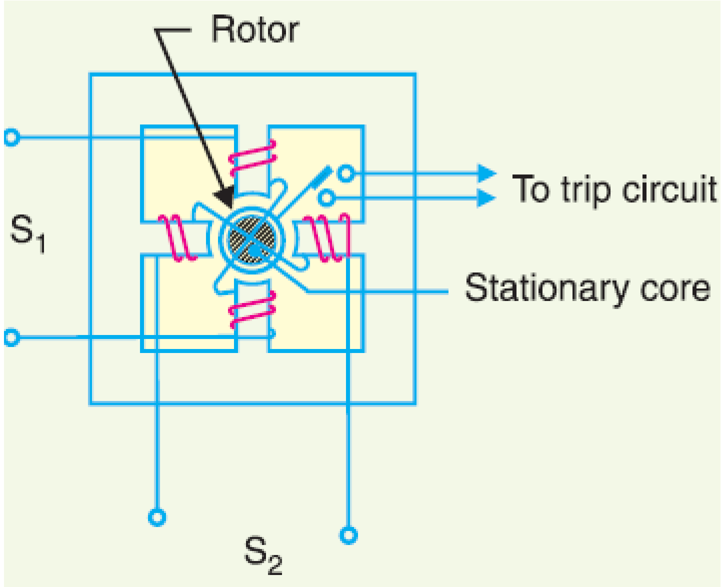
$$T \propto I^2 \sin \alpha$$

Watt-hour meter type induction relay



- This structure is used in watt-hour meters and power relays.
- Consists of pivoted aluminium disc which can rotate freely between two poles of electromagnet.
- Primary winding current I1(Φ1) induces an emf on secondary winding, so circulates a current I2(Φ2) in secondary winding.
- These two fluxes differing in phase by α will create a driving torque.

Induction cup type induction relay



- The rotating field is created by two pairs of coils wound on four poles.
- The rotating field induces currents in the cup to provide necessary driving torque.
- If Φ1 & Φ2 represent the fluxes produced by the respective pairs of poles, then torque will be proportional to ϕ1ϕ2 sin α

- Reference-
- Topics 21.2-21.5/Chapter 21/ Principles of power systems/ V.K.Mehta & Rohit Mehta.

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