UNIT – 2

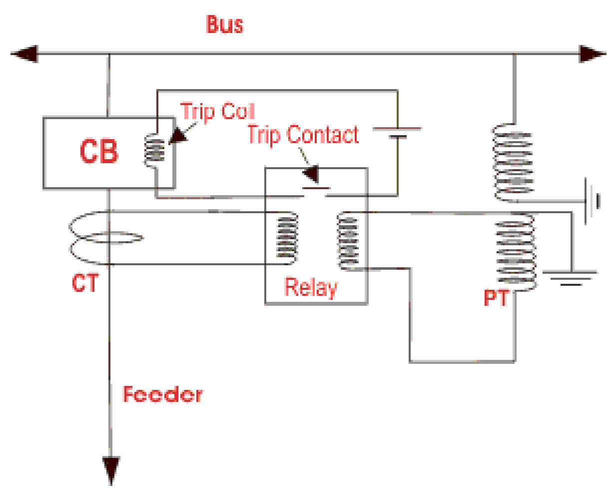
PROTECTIVE RELAY

Unit-02 /Lecture-01

Introduction About Relay

RELAY:

A relay is an electrically operated switch. Many relays use an electromagnet to operate a switching mechanism mechanically, but other operating principles are also used. Relays are used where it is necessary to control circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal.



Basic connection diagram of protection relay

In the picture the basic connection of protection relay has been shown. It is quite simple. The secondary of current transformer is connected to the current coil of relay. And secondary of voltage transformer is connected to the voltage coil of the relay. Whenever any fault occurs in the feeder circuit, proportionate secondary current of the CT will flow through the current coil of the relay due to which mmf of that coil is increased. This increased mmf is sufficient to mechanically close the normally open contact of the relay. This relay contact actually closes and completes the DC trip coil circuit and hence the trip coil is energized. The mmf of the trip coil initiates the mechanical movement of the tripping mechanism of the circuit breaker and ultimately the circuit breaker is tripped to isolate the fault.

RGPV/ June 2014, June 2013

THE FUNCTIONAL REQUIREMENTS OF PROTECTION RELAY

RELIABILITY

The most important requisite of protective relay is reliability. They remain inoperative for a long time before a fault occurs; but if a fault occurs, the relays must respond instantly and correctly.

SELECTIVITY

The relay must be operated in only those conditions for which relays are commissioned in the electrical power system. There may be some typical condition during fault for which some relays should not be operated or operated after some definite time delay hence protection relay must be sufficiently capable to select appropriate condition for which it would be operated.

SENSITIVITY

The relaying equipment must be sufficiently sensitive so that it can be operated reliably when level of fault condition just crosses the predefined limit.

SPEED

The protective relays must operate at the required speed. There must be a correct coordination provided in various power system protection relays in such a way that for fault at one portion of the system should not disturb other healthy portion.

Examples of various type of relay

OVER CURRENT RELAY :

The name 'over current relay' implies that this is a special type of protection which is used to protect the costly apparatus from the effect of huge current flow. Over current relays are those relays which operates during the excess current flow through the network and trips the circuit of circuit breaker, which isolates the faulty part of the network from the healthy part.

***BUCHHOLZ RELAY** :*

In the field of electric power distribution and transmission, a Buchholz relay is a safety device mounted on some oil-filled power transformers and reactors, equipped with an external overhead oil reservoir called a *conservator*. The Buchholz Relay is used as a protective device sensitive to the effects of dielectric failure inside the equipment.

***STATIC RELAYS** :*

The conventional relay type of electromagnet relays can be replaced by static relays which essentially consist of electronic circuitry to develop all those characteristics which are achieved by moving parts in an electromagnetic relay.

OBJECTIVE OF POWER SYSTEM PROTECTION

The objective of **power system protection** is to isolate a faulty section of electrical power system from rest of the live system so that the rest portion can function satisfactorily without any severer damage due to fault current.

What is a Relay?

Formally, a relay is a logical element which processes the inputs (mostly voltages and currents) from the system/apparatus and issues a trip decision if a fault within the relay's jurisdiction is detected. Formally, a relay is a logical element which processes the inputs (mostly voltages and currents) from the system/apparatus and issues a trip decision if a fault within the relay's jurisdiction is detected.

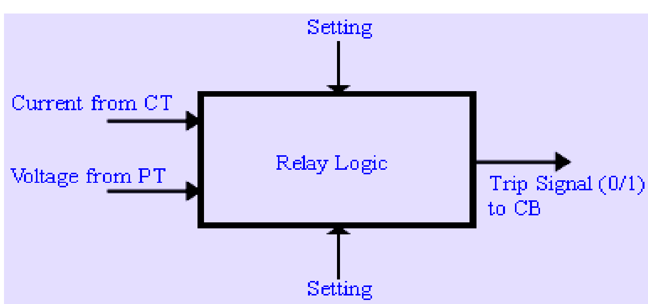


Fig 1 Concept of Relay

To monitor the health of the apparatus, relay senses current through a current transformer (CT) voltage through a voltage transformer (VT). VT is also known as Potential Transformer (PT).

The relay element analyzes these inputs and decides whether (a) there is a abnormality or a fault and (b) if yes, whether it is within jurisdiction of the relay. The jurisdiction of relay R_1 is restricted to bus B where the transmission line terminates. If the fault is in it's jurisdiction, relay sends a tripping signal to circuit breaker(CB) which opens the circuit. A real life analogy of the jurisdiction of the relay can be thought by considering transmission lines as highways on which traffic (current/power) flows.

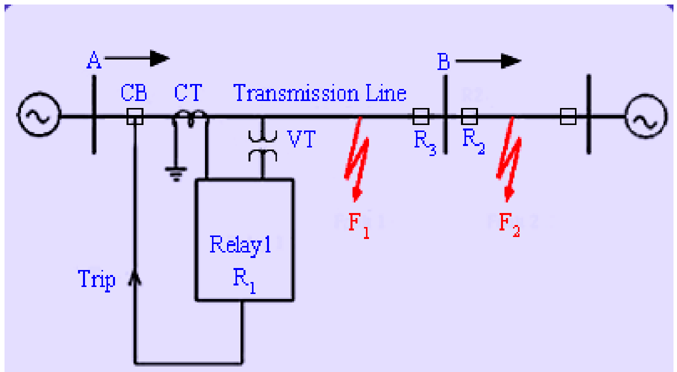


Fig 2 Typical relay scheme

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Explain the functional characteristics of a protective relay.	**RGPV/ June 2013**	7
Q.2	Explain the fundamental requirement of a protective relaying.	**RGPV/ June 2011**	7

Unit-02 /Lecture-02

Why do we need Protection-

Electrical power system operates at various voltage levels from 415 V to 400 kV or even more. Electrical apparatus used may be enclosed (e.g., motors) or placed in open (e.g., transmission lines). All such equipment undergo abnormalities in their life time due to various reasons.

For example,

- a worn out bearing may cause overloading of a motor. A tree falling or touching an overhead line may cause a fault.
- A lightning strike (classified as an act of God!) can cause insulation failure.
- Pollution may result in degradation in performance of insulators which may lead to breakdown. Under frequency or over frequency of a generator may result in mechanical damage to it's turbine requiring tripping of an alternator. Even otherwise, low frequency operation will reduce the life of a turbine and henc it should be avoided.

It is necessary to avoid these abnormal operating regions for safety of the equipment. Even more important is safety of the human personnel which may be endangered due to exposure to live parts under fault or abnormal operating conditions.

Small current of the order of 50 mA is sufficient to be fatal! Whenever human security is sacrificed or there exists possibility of equipment damage, it is necessary to isolate and de-energize the equipment. Designing electrical equipment from safety perspective is also a crucial design issue which will not be addressed here.

To conclude, every electrical equipment has to be monitored to protect it and provide human safety under abnormal operating conditions. This job is assigned to electrical protection systems. It encompasses apparatus protection and system protection

Classification of Relay

1. Electromechanical Relays
2. Solid State Relays
3. Numerical Relays

Definition of Protective Relay

A relay is automatic device which senses an abnormal condition of electrical circuit and closes its contacts. These contacts in turns close and complete the circuit breaker trip coil circuit hence make the circuit breaker tripped for disconnecting the faulty portion of the electrical circuit from rest of the healthy circuit.

Now let's have a discussion on some terms related to protective relay.

Pickup level of actuating signal: The value of actuating quantity (voltage or current) which is on threshold above which the relay initiates to be operated.

If the value of actuating quantity is increased, the electromagnetic effect of the relay coil is increased and above a certain level of actuating quantity the moving mechanism of the relay just starts to move.

Reset level: The value of current or voltage below which a relay opens its contacts and comes in original position.

Operating time of relay -Just after exceeding pickup level of actuating quantity the moving mechanism (for example rotating disc) of relay starts moving and it ultimately close the relay contacts at the end of its journey. The time which elapses between the instant when actuating quantity exceeds the pickup value to the instant when the relay contacts close.

Reset time of relay – The time which elapses between the instant when the actuating quantity becomes less than the reset value to the instant when the relay contacts returns to its normal position.

Reach of relay – A distance relay operates whenever the distance seen by the relay is less than the pre-specified impedance. The actuating impedance in the relay is the function of distance in a distance protection relay. This impedance or corresponding distance is called reach of the relay.

During study of electrical protective relays, some special terms are frequently used

1. Pick up current.
2. Current setting.
3. Plug setting multiplier (PSM).
4. Time setting multiplier (TSM).

Pick Up Current of Relay

In all electrical relays, the moving contacts are not free to move. All the contacts remain in their respective normal position by some force applied on them continuously. This force is called controlling force of the relay. This controlling force may be gravitational force, may be spring force, may be magnetic force. The force applied on the relay's moving parts for changing the normal position of the contacts, is called deflecting force. This deflecting force is always in opposition of controlling force and presents always in the relay. Although the deflecting force always presents in the relay directly connected to live line, but as the magnitude of this force is less than controlling force in normal condition, the relay does not operate. If the actuating current in the relay coil increases gradually, the deflecting force in electro mechanical relay, is also increased. Once, the deflecting force crosses the controlling force, the moving parts of the relay initiate to move to change the position of the contacts in the relay. The current for which the relay initiates it operation is called **pick up current of relay**.

Current Setting of Relay

The minimum pick up value of the deflecting force of an electrical relay is constant. Again the deflecting force of the coil is proportional to its number of turns and current flowing through the coil.

$$Current\ setting\ =\ \frac{Pick\ up\ current}{Rated\ secondary\ current\ of\ CT} \times 100\%$$

Now, if we can change the number of active turns of any coil, the required current to reach at minimum pick value of the deflecting force, in the coil also changes. That means if active turns of the relay coil is reduced, then proportionately more current is required to produce desired relay actuating force. Similarly if active turns of the relay coil is increased, then proportionately reduced current is required to produce same desired deflecting force.

$$Current\ setting\ =\ \frac{1.25}{1}\ \times\ 100\%\ =\ 125\%$$

Practically same model relays may be used in different systems. As per these systems requirement the pick up current of relay is adjusted. This is known as current setting of relay. This is achieved by providing required number of tapping in the coil. These taps are brought out to a plug bridge. The number of active turns in the coil can be changed by inserting plug in different points in the bridge.

The **current setting of relay** is expressed in percentage ratio of relay pick up current to rated secondary current of CT.That means,

For example, suppose, you want that, an over current relay should operate when the system current just crosses 125% of rated current. If the relay is rated with 1 A, the normal pick up current of the relay is 1 A and it should be equal to secondary rated current of current transformer connected to the relay.

Then, the relay will be operated when the current of CT secondary becomes more than or equal 1.25 A.

As per definition,

$$PSM = \frac{Relay\ fault\ current}{Pick\ up\ current} = \frac{15}{1.5} = 10$$

The current setting is sometimes referred as current plug setting.

The current setting of over current relay is generally ranged from 50% to 200%, in steps of 25%. For earth fault relay it is from 10% to 70% in steps of 10%.

Plug Setting Multiplier of Relay

Plug setting multiplier of relay is referred as ratio of fault current in the relay to its pick up

$$PSM = \frac{Fault\ current\ in\ relay\ coil}{Pick\ up\ current}$$

$$= \frac{Fault\ current\ in\ relay\ coil}{Rated\ CT\ secondary\ current \times Current\ setting}$$

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Suppose we have connected on protection CT of ratio 200/1 A and current setting is 150%.

Hence, pick up current of the relay is, 1 × 150 % = 1.5 A

Now, suppose fault current in the CT primary is 1000 A. Hence, fault current in the CT secondary i.e. in the relay coil is, 1000 × 1/200 = 5 A

Therefore PSM of the relay is, 5 / 1.5 =3.33

Time Setting Multiplier of Relay

The operating time of an electrical relay mainly depends upon two factors :

1. How long distance to be traveled by the moving parts of the relay for closing relay contacts and
2. How fast the moving parts of the relay cover this distance.

So far adjusting relay operating time, both of the factors to be adjusted.

The adjustment of travelling distance of an electromechanical relay is commonly known as time setting. This adjustment is commonly known as **time setting multiplier of relay**. The time setting dial is calibrated from 0 to 1 in steps 0.05 sec.

But by adjusting only time setting multiplier, we can not set the actual time of operation of an electrical relay. As we already said, the time of operation also depends upon the speed of operation. The speed of moving parts of relay depends upon the force due to current in the relay coil. Hence it is clear that, speed of operation of an electrical relay depends upon the level of fault current. In other words, time of operation of relay depends upon plug setting multiplier. The relation between time of operation and plug setting multiplier is plotted on a graph paper and this is known as time / PSM graph. From this graph one can determine, the total time taken by the moving parts of an electromechanical relay, to complete its total travelling distance for different PSM. In time setting multiplier, this total travelling distance is divided and calibrated from 0 to 1 in steps of 0.05.

So when time setting is 0.1, the moving parts of the relay has to travel only 0.1 times of the total travelling distance, to close the contact of the relay. So, if we get total operating time of the relay for a particular PSM from time / PSM graph and if we multiply that time with the time setting multiplier, we will get, actual time of operation of relay for said PSM and TSM.

For getting clear idea, let us have a practical example. Say a relay has time setting 0.1 and you have to calculate actual time of operation for PSM 10.

From time / PSM graph of the relay as shown below, we can see the total operating time of the relay is 3 seconds. That means, the moving parts of the relay take total 3 seconds to travel 100% travelling distance. As the time setting multiplier is 0.1 here, actually the moving parts of the relay have to travel only 0.1 × 100% or 10% of the total travel distance, to close the relay contacts.

Hence, actual operating time of the relay is 3 × 0.1 = 0.3 sec. i.e. 10% of 3 sec.

Time vs PSM Curve of Relay

This is relation curve between operating time and plug setting multiplier of an electrical relay. The x-axis or horizontal axis of the Time / PSM graph represents, PSM and Y-axis or vertical axis represents time of operation of the relay. The time of operation represents in this graph is that, which required to operate the relay when time setting multiplier set at 1.

From the Time / PSM curve of a typical relay shown below, it is seen that, if PSM is 10, the time of operation of relay is 3 sec. That means, the relay will take 3 seconds to complete its operation, with time setting 1.

It is also seen from the curve that, for lower value of plug setting multiplier, i.e. for lower value of fault current, the time of operation of the relay is inversely proportional to the fault current.

But when PSM becomes more than 20, the operating time of relay becomes almost constant. This feature is necessary in order to ensure discrimination on very heavy fault current flowing through sound feeders.

Calculation of Relay Operation Time

For calculating actual relay operating time, we need to know these following operation.

1. Current setting.
2. Fault current level.
3. Ratio of current transformer.
4. Time / PSM curve.
5. Time setting.

Step – 1

From CT ratio, we first see the rated secondary current of CT. Say the CT ratio is 100 / 1 A, i.e. secondary current of CT is 1 A.

Step – 2

From current setting we calculate the trick current of the relay. Say current setting of the relay is 150% therefore pick up current of the relay is 1 × 150% = 1.5 A.

Step – 3

Now we have to calculate PSM for the specified faulty current level. For that, we have to first divide primary faulty current by CT ratio to get relay faulty current. Say the faulty current level is 1500 A, in the CT primary, hence secondary equivalent of faulty current is 1500/(100/1) = 15 A

$$PSM = \frac{Relay\ fault\ current}{Pick\ up\ current} = \frac{15}{1.5} = 10$$

Step – 4

Now, after calculating PSM, we have to find out the total time of operation of the relay from Time / PSM curve. From the curve, say we found the time of operation of relay is 3 second for PSM = 10.

NO	RGPV QUESTIONS	Year	Marks
Q.1	Discuss classification of relay.	**RGPV/ June 2014**	7
Q.2	Discuss briefly about following (i) Pickup, reset and drop-off (ii) Reset of relay and burden of relay (iii) operating time (iv) seal in relay	**RGPV/ June 2011, Dec 2013,2012,2011**	7
Q.3	Explain the following terms Selectivity, PSM, TSM, Protective zone, primary and back up relay, quality of relay.	**RGPV/ June 2012**	7
Q.4	Numerical on PSM and Time of operation of relay.	**RGPV/ Dec 2012**	7

Unit-02 /Lecture-03

Types of Relays

Power system protection relays can be categorized into different types of relays.

Types of protection relays are mainly based on their characteristic, logic, on actuating parameter and operation mechanism.

- Based on operation mechanism protection relay can be categorized as electromagnetic relay, static relay and mechanical relay. Actually relay is nothing but a combination of one or more open or closed contacts. These all or some specific contacts the relay change their state when actuating parameters are applied to the relay. That means open contacts become closed and closed contacts become open. In electromagnetic relay these closing and opening of relay contacts are done by electromagnetic action of a solenoid.
- In mechanical relay these closing and opening of relay contacts are done by mechanical displacement of different gear level system.
- In static relay it is mainly done by semiconductor switches like thyristor. In digital relay on and off state can be referred as 1 and 0 state.
- **Based on Characteristic the protection relay can be categorized as-**

1. Definite time relays
2. Inverse time relays with definite minimum time(IDMT)
3. Instantaneous relays.
4. IDMT with inst.
5. Stepped characteristic.
6. Programmed switches.
7. Voltage restraint over current relay.

- **Based on of logic the protection relay can be categorized as-**

1. Differential.
2. Unbalance.
3. Neutral displacement.
4. Directional.
5. Restricted earth fault.
6. Over fluxing.
7. Distance schemes.
8. Bus bar protection.
9. Reverse power relays.
10. Loss of excitation.
11. Negative phase sequence relays etc.

- **Based on actuating parameter the protection relay can be categorized as-**

1. Current relays.
2. Voltage relays.
3. Frequency relays.
4. Power relays etc.

- **Based on application the protection relay can be categorized as-**

1. Primary relay.
2. Backup relay.

Primary relay or primary protection relay is the first line of power system protection whereas backup relay is operated only when primary relay fails to be operated during fault. Hence backup relay is slower in action than primary relay. Any relay may fail to be operated due to any of the following reasons,

1. The protective relay itself is defective.
2. DC Trip voltage supply to the relay is unavailable.
3. Trip lead from relay panel to circuit breaker is disconnected.
4. Trip coil in the circuit breaker is disconnected or defective.
5. Current or voltage signals from CT or PT respectively is unavailable.

As because backup relay operates only when primary relay fails, backup protection relay should not have anything common with primary protection relay.

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Protective zone, primary and back up relay, quality of relay.	**RGPV/ June 2012**	7
Q.2	How relays are classified according to (i) Principle of operation (ii) Time of operation	**RGPV/ June 2013**	7

Unit-02 /Lecture-04

Electromechanical Relays

When the principle of electromechanical energy conversion is used for decision making, the relay is referred as an electromechanical relay. These relays represent the first generation of relays. Let us consider a simple example of an over current relay, which issues a trip signal if current in the apparatus is above a reference value. By proper geometrical placement of current carrying conductor in the magnetic field, Lorentz force is produced in the operating coil.

This force is used to create the operating torque. If constant 'B' is used (for example by a permanent magnet), then the instantaneous torque produced is proportional to instantaneous value of the current. Since the instantaneous current is sinusoidal, the instantaneous torque is also sinusoidal which has a zero average value. Thus, no net deflection of operating coil is perceived.

On the other hand, if the B is also made proportional to the instantaneous value of the current, then the instantaneous torque will be proportional to square of the instantaneous current (non-negative quantity). The average torque will be proportional to square of the rms current. Movement of the relay contact caused by the operating torque may be restrained by a spring in the over current relay. If the spring has a spring constant 'k', then the deflection is proportional to the operating torque (in this case proportional to). When the deflection exceeds a preset value, the relay contacts closes and a trip decision is issued. Electromechanical relays are known for their ruggedness and immunity to Electromagnetic Interference (EMI).

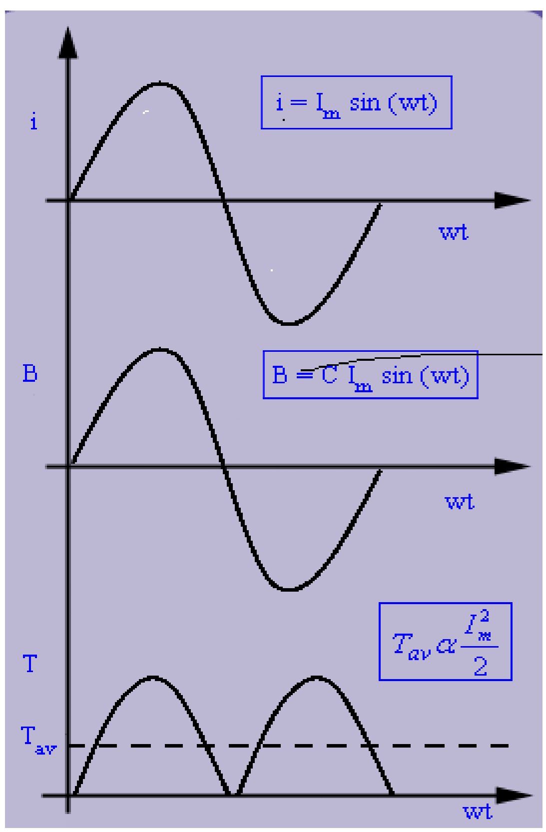


Fig Torque and Current Relation

Solid State Relays

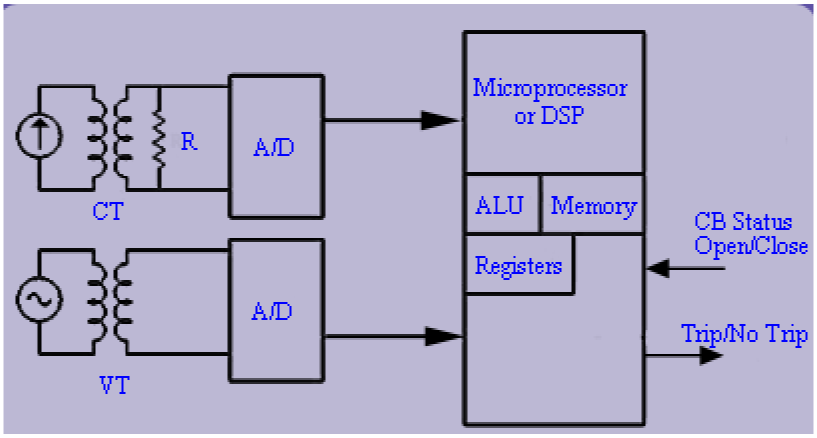
What are SSRs?

Difference between SSRs and Mechanical Relays SSRs (solid-state relays) have no movable contacts very different in general operation from mechanical relays that have movable contacts. SSRs, however, employ semiconductor switching elements, such as thyristors, triacs, diodes, and transis Furthermore, SSRs employ optical semiconductors called photocouplers to isolate input (control) and output (load) signals. Photocouplers change electric signals into optical signals and transmit the signals through space, thus fully isolating the input and output sections while transferring the signals at high speed. SSRs consist of electronic parts with no mechanical contacts. Therefore, SSRs have a variety of features that mechanical relays do not incorporate. The greatest feature of SSRs is that SSRs do not use switching contacts that will physically wear out.

Static relays with no or few moving parts became practical with the introduction of the transistor. Static relays offer the advantage of higher sensitivity than purely electromechanical relays, because power to operate output contacts is derived from a separate supply, not from the signal circuits. Static relays eliminated or reduced contact bounce, and could provide fast operation, long life and low maintenance.

Numerical Relays

The block diagram of a numerical relay is shown in fig It involves analog to digital (A/D) conversion of analog voltage and currents obtained from secondary of CTs and VTs. These current and voltage samples are fed to the microprocessor or Digital Signal Processors (DSPs) where the protection algorithms or programs process the signals and decide whether a fault exists in the apparatus under consideration or not. In case, a fault is diagnosed, a trip decision is issued. Numerical relays provide maximum flexibility in defining relaying logic.



Block diagram of Numerical Relay

The hardware comprising of numerical relay can be made scalable i.e., the maximum number of v and i input signals can be scaled up easily. A generic hardware board can be developed to provide functionality. Changing the relaying functionality is achieved by simply changing the relaying progra Also, various relaying functionalities can be multiplexed in a single relay.

- It has all the advantages of solid state relays like self checking etc.
- Enabled with communication facility, it can be treated as an Intelligent Electronic Device (IE perform both control and protection functionality. Also,
- a relay which can communicate can be made adaptive i.e. it can adjust to changing apparat conditions.

For example,

a differential protection scheme can adapt to transformer tap changes. An overcurrent relay can ad loading conditions. Numerical relays are both "the present and the future". Hence, in this course, o biased towards numerical relaying. This also gives an algorithmic flavour to the course.

The functions of electromechanical protection systems are now being replaced by microprocessor-based digital protective relays, sometimes called "numeric relays".

A microprocessor-based digital protection relay can replace the functions of many discrete electromechanical instruments

These convert voltage and currents to digital form and process the resulting measurements using a microprocessor. The digital relay can emulate functions of many discrete electromechanical relays in one device, simplifying protection design and maintenance. Each digital relay can run self-test routines to confirm its readiness and alarm if a fault is detected. Numeric relays can also provide functions such as communications (SCADA) interface, monitoring of contact inputs, metering, waveform analysis, and other useful features. Digital relays can, for example, store two sets of protection parameters, which allows the behavior of the relay to be changed during maintenance of attached equipment. Digital relays also can provide protection strategies impossible to synthesize with electromechanical relays, and offer benefits in self-testing and communication to supervisory control systems.

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Discuss merits and demerits of static relay over other type of relay.	**RGPV/ June 2013**	7
Q.2	Compare performance of static relay with electromechanical relay.	**RGPV/ June 2011**	7

Unit-02 /Lecture-05

Electromagnetic Relay Working

Electromagnetic relays are those relays which are operated by electromagnetic action. Modern electrical protection relays are mainly micro processor based, but still **electromagnetic relay** holds its place. It will take much longer time to be replaced the all **electromagnetic relays** by micro processor based static relays. So before going through detail of protection relay system we should review the various **types of electromagnetic relays**.

Electromagnetic Relay Working

Practically all the relaying device are based on either one or more of the following **types of electromagnetic relays**.

1. Magnitude measurement,
2. Comparison,
3. Ratio measurement.

Principle of **electromagnetic relay working** is on some basic principles. Depending upon working principle these can be divided into following **types of electromagnetic relays**.

1. Attracted Armature type relay,
2. Induction Disc type relay,
3. Induction Cup type relay,
4. Balanced Beam type relay,
5. Moving coil type relay,
6. Polarized Moving Iron type relay.

Attraction Armature Type Relay

Attraction armature type relay is the most simple in construction as well as its working principle. These types of electromagnetic relays can be utilized as either magnitude relay or ratio relay. These relays are employed as auxiliary relay, control relay, over current, under current, over voltage, under voltage and impedance measuring relays.
Hinged armature and plunger type constructions are most commonly used for these types of electromagnetic relays. Among these two constructional design, hinged armature type is more commonly used. We know that force exerted on an armature is directly proportional to the square of the magnetic flux in the air gap. If we ignore the effect of saturation, the equation for the force experienced by the armature can be expressed as,

$$F = (KI^2 - K')$$

Where F is the net force, K' is constant, I is rms current of armature coil, and K' is the restraining force. The threshold condition for relay operation would therefore be reached when $KI^2 = K'$.

If we observe the above equation carefully, it would be realized that the relay operation is dependent on the constants K' and K for a particular value of the coil current.

From the above explanation and equation it can be summarized that, the operation of relay is influenced by

1. Ampere – turns developed by the relay operating coil,
2. The size of air gap between the relay core and the armature,

3. Restraining force on the armature.

Construction of Attracted Type Relay

This relay is essentially a simple electromagnetic coil, and a hinged plunger. Whenever the coil becomes energized the plunger being attracted towards core of the coil. Some NO-NC (Normally Open and Normally Closed) contacts are so arranged mechanically with this plunger, that, NO contacts become closed and NC contacts become open at the end of the plunger movement. Normally **attraction armature type relay** is dc operated relay. The contacts are so arranged, that, after relay is operated, the contacts cannot return their original positions even after the armature is de energized. After relay operation, this types of electromagnetic relays are reset manually.

Attraction armature relay by virtue of their construction and working principle, is instantaneous in operation.

Induction Disc Type Relay

Induction disc type relay mainly consists of one rotating disc.

Induction Disc type Relay Working- Every **induction disc type relay** works on the same well known Ferraries principle. This principle says, a torque is produced by two phase displaced fluxes, which is proportional to the product of their magnitude and phase displacement between them. Mathematically it can be expressed as-

The induction disc type relay is based on the same principle as that of an ammeter or a volt meter, or a wattmeter or a watt hour mater. In induction relay the deflecting torque is produced by the eddy currents in an aluminium or copper disc by the flux of an ac electromagnet. Here, an aluminium (or copper) disc is placed between the poles of an AC magnet which produces an alternating flux ϕ lagging from I by a small angle. As this flux links with the disc, there must be an induced emf E_2 in the disc, lagging behind the flux ϕ by 90^o. As the disc is purely resistive, the induced current in the disc I_2 will be in phase with E_2. As the angle between ϕ and I_2 is 90°, the net torque produced in that case is zero. As,

$$T = \phi I_2 \cos 90^\circ = 0$$

In order to obtain torque in induction disc type relay, it is necessary to produce a rotating field.

Pole Shading Method of Producing Torque in Induction Disc Relay

In this method half of the pole is surrounded with copper ring as shown. Let ϕ_1 is the flux of unshaded portion of the pole. Actually total flux divided into two equal portions when the pole is divided into two parts by a slot.

$$Total\ flux,\ \phi = \phi_1 + \phi_2$$

As the one portion of the pole is shaded by copper ring. There will be induced current in the shade ring which will produce another flux ϕ_2' in the shaded pole. So, resultant flux of shaded pole will be vector sum of & phi;$_1$ and ϕ_2. Say it is ϕ_2, and angle between ϕ_1 and ϕ_2 is θ. These two fluxes will produce a resultant torque,

$$T = K\phi_1\phi_2 \sin\theta$$

There are mainly three types of shape of rotating disc are available for induction disc type relay. They are spiral shaped, round and vase shaped, as shown. The spiral shape is done to compensate against varying restraining torque of the control spring which winds up as the disc rotates to close its contacts. For most designs, the disc may rotate by as much as 280°. Further, the moving contact on the disc shift is so positioned that it meets the stationary contacts on the relay frame when the largest radius section of the disc is under the electromagnet. This is done to ensure satisfactory contact pressure in induction disc type relay.

Where high speed operation is required, such as in differential protection, the angular travel of the disc is considerably limited and hence circular or even vane types may be used in induction disc type electromagnetic relay.

Some time it is required that operation of an induction disc type relay should be done after successful operation of another relay. Such as inter locked over current relays are generally used for generator and bus bar protection. In that case, the shading band is replaced by a shading coil. Two ends of that shading coil are brought out across a normally open contact of other control device or relay. Whenever the latter is operated the normally open contact is closed and makes the shading coil short circuited. Only after that the over current relay disc starts rotating.

One can also change the time / current characteristics of an induction disc type relay, by deploying variable resistance arrangement to the shading coil.

Induction disc relay fed off a negative sequence filter can also be used as Negative-sequence protection device for alternators.

Induction Cup Type Relay

Induction cup type relay can be considered as a different version of induction disc type relay. The working principle of both type of relays are more or less some. **Induction cup type relay** are used where, very high speed operation along with polarizing and/or differential winding is requested. Generally four pole and eight pole design are available. The number of poles depends upon the number of winding to be accommodated.

The inertia of cup type design is much lower than that of disc type design. Hence very high speed operation is possible in induction cup type relay. Further, the pole system is designed to give maximum torque per KVA input. In a four pole unit almost all the eddy currents induced in the cup by one pair of poles appear directly under the other pair of poles – so that torque / VA is about three times that of an induction disc with a c-shaped electromagnet.

Induction cup type relay is practically suited as directional or phase comparison units. This is because, besides their sensitivity, induction cup relay have steady non vibrating torque and their parasitic torque due to current or voltage alone are small.

Induction Cup Type-Directional or Power Relay

It in a four pole induction cup type relay, one pair of poles produces flux proportional to voltage and other pair of poles produces flux proportional to current. The vector diagram is given below,

The torque $T_1 = K\, \phi_{vi} .\, \phi_i .\, \sin(90° - \theta)$ assuming flux produced by the voltage coil will lag 90° behind its voltage. By design, the angle can be made to approach any value and a torque equation $T = K.E.I.\cos(\varphi - \theta)$ obtained, where θ is the E – I system angle.

Accordingly, induction-cup type relay can be designed to produced maximum torque When system angle $\theta = 0°$ or 30° or 45° or 60°. The former is known as power relays as they produce maximum torque when $\theta = 0°$ and latter are known as directional relays – they are used for directional discrimination in protective schemes under fault conditions, as they are designed to produce maximum torque at faulty conditions.

Induction disc overcurrent relay

"Induction" disk meters work by inducing currents in a disk that is free to rotate; the rotary motion of the disk operates a contact. Induction relays require alternating current; if two or more coils are used, they must be at the same frequency otherwise no net operating force is produced.[1] These electromagnetic relays use the induction principle discovered by Galileo Ferraris in the late 19th century. The magnetic system in induction disc overcurrent relays is designed to detect overcurrents in a power system and operate with a pre-determined time delay when certain overcurrent limits have been reached. In order to operate, the magnetic system in the relays produces torque that acts on a metal disc to make contact, according to the following basic current/torque equation:

$$T = K \times \phi_1 \times \phi_2 \sin\theta$$

Where

K – is a constant $\phi 1$ and $\phi 2$ are the two fluxes θ is the phase angle between the fluxes

The relay's primary winding is supplied from the power systems current transformer via a plug bridge, which is called the plug setting multiplier (psm). Usually seven equally spaced tappings or operating bands determine the relays sensitivity. The primary winding is located on the upper electromagnet. The secondary winding has connections on the upper electromagnet that are energised from the primary winding and connected to the lower electromagnet. Once the upper and lower electromagnets are energised they produce eddy currents that are induced onto the metal disc and flow through the flux paths. This relationship of eddy currents and fluxes creates torque proportional to the input current of the primary winding, due to the two flux paths being out of phase by 90°.

In an overcurrent condition, a value of current will be reached that overcomes the control spring pressure on the spindle and the braking magnet, causing the metal disc to rotate towards the fixed contact. This initial movement of the disc is also held off to a critical positive value of current by small slots that are often cut into the side of the disc. The time taken for rotation to make the contacts is not only dependent on current but also the spindle backstop position, known as the time multiplier (tm). The time multiplier is divided into 10 linear divisions of the full rotation time.

Providing the relay is free from dirt, the metal disc and the spindle with its contact will reach the fixed contact, thus sending a signal to trip and isolate the circuit, within its designed time and current specifications. Drop off current of the relay is much lower than its operating value, and once reached the relay will be reset in a reverse motion by the pressure of the control spring governed by the braking magnet.

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Derive the equation for torque produced by an induction relay	**RGPV/ Dec 2013**	7
Q.2	Describe the construction and principle of operation of an Induction type over current relay. Discuss the time current characteristics of the relay.	**RGPV/ June 2011**	7
Q.3	What is meant by directional relay? Describe the construction, principle of operation and application of a directional over current relay.	**RGPV/ June 2011**	7

Reactance or Mho Type Induction Cup Relay

By manipulating the current or voltage coil arrangements and the relative phase displacement angle between various fluxes, induction cup type relay can be made to measure pure reactance of a power circuit.

Balanced Beam Relay

Balanced beam type relay can be said a variant of attraction armature type relay, but still these are treated as different types of relay as they are employed in different field of application.

Balanced beam type relays were used in differential and distance protection schemes. The use of these relay becomes absolute as sophisticated induction disc type relay and induction cup type relays supersede them.

The working principle of a Balance Beam Relay is quite simple. Here one beam is supported by one hinge. The hinge supports the beam from some where in the middle of the beam. There are two forces acts on two ends of the beams, respectively. The direction of both of the forces are same. Not only direction, in normal working condition the torque produced by the forces in respect of the hinge, are also same. Due to these two same directional torques, the beam is held in horizontal position in normal working condition. One of these torques is restraining torque and other is operating torque.

The restraining torque can be provided either by restraining coil or by restraining spring.

This is a kind of attracted armature type relay. But balance beam relay is treated separately from their application point of view. When any fault occurred, the current through the operating coil, crosses its pick up value, and hence the mmf of operating coil increases and crosses its pick-up value. Due to this increased mmf, the coil attracts more strongly the beam end and hence, torque on respective end of the beam increases. As this torque is increased, the balance of the beam is being disturbed. Due to this unbalanced torque condition, the beam end associated with operating torque, moves downward, to close No contacts of the relay.

Now-a-days, balance beam relays become obsolete. In past these relays were widely used in differential and impedance measurements. The use of these relays is superseded by more sophisticated induction disc and cup type relays.

The main drawbacks of balance beam relay, is poor reset / operate ratio, susceptibility to phase displacement between the two energizing and mal-operation on transients.

Moving Coil Type Relay

The **moving coil relay** or polarized DC moving coil relay is most sensitive electromagnetic relay. Because of its high sensitive, this relay is used widely for sensitive and accurate measurement for distance and differential protection. This type of relays is inherently suitable for D.C system. Although this type of relay can be used for A.C system also but necessary rectifier circuit should be provided in current transformer.

In a **moving coil relay** the movement of the coil may be rotary or axial. Both of them have been perfected to a large extent by the various manufactures but the inherent limitation of a moving coil relay remains i.e to lead the current in and out of the moving coil system which, far reasons of sensitivity has to be designed to be very delicate.

Between these two types of moving coil relay a axial moving type has twice sensitivity than that of rotary type. With moving coil relay, sensitivities of the order of 0.2 mW to 0.5 mW are typical. Speed of operation depends upon damping provided in the relay.

Induction Cup Relay Working Principle Construction and Types

Induction Cup Relay

This relay in nothing but one version of induction disc relay. Induction cup relay work in same principle of induction disc relay. The basis construction of this relay is just like four poles or eight pole induction motor. The number of poles in the protective relay depends upon the number of winding to be accommodated. The figure shows a four pole induction cup relay.

Actually when any one replaces disc of induction relay by a aluminum cup, the inertia of rotating system of relay is significantly reduced. Due to low mechanical inertia, the operating speed of induction cup relay is much higher than that of induction disc relay. Moreover, projected pole system is designed to give maximum torque per VA input.

In four pole unit, shown in our example, the eddy current produced in the cup due to one pair of poles, directly appears under other pair of poles. This makes, torque per VA of this relay is about three times more than that of induction disc type relay with a C-shaped electromagnet.

If magnetic saturation of the poles can be avoided by designing, the operating characteristics of the relay can be made linear and accurate for a wide range of operation.

Working Principle of Induction Cup Relay

As we said earlier, the working principle of induction cup relay, is same as the induction motor. A rotating magnetic field is produced by different pairs of field poles. In four poles design both pair of poles are supplied from same current transformer's secondary, but phase difference between the currents of two pole pairs is 90 deg; This is done by inserting an inductor in series with coil of one pole pair, and by inserting a resistor in series with coil of another pole pair.

The rotating magnetic field induces current in the aluminum brum or cup. As per working principle of induction motor, the cup starts rotating in the direction of rotating magnetic field, with a speed slightly less than the speed of rotating magnetic field.

The aluminum cup is attached with a hair spring : In normal condition the restoring torque of the spring is higher than deflecting torque of the cup. So there is no movement of the cup. But during faulty condition of system, the current through the coil is quite high, hence, deflecting torque produced in the cup is much higher than restoring torque of spring, hence the cup start rotating as rotor of induction motor. The contacts attached to the moving of the cup to specific angle of rotation.

Construction of Induction Cup Relay

The magnetic system of the relay is constructed by attaching numbers of circular cut steel sheets. The magnetic pole are projected in the inner periphery of these laminated sheets.

The field coils are wound on these laminated poles. The field coil of two opposite facing poles are connected in series.The aluminum cup or drum, fitted on a laminated iron core is carried by a spindle whose ends fit in jeweled cups or bearings. The laminated magnetic field is provided on inside the cup or drum to strengthen the magnetic field cutting the cup.

Induction Cup Type Relay

Induction Cup Directional or Power Relay

Induction cup relay is very suitable for directional or phase comparison units. This is because, besides the sensitivity, induction cup relay have steady non vibrating torque and parasitic torques due to current or voltage alone are small.

In induction cup directional or power relay, coils of one pair of poles are connected across voltage source, and coils of another pair of poles are connected with current source of the system. Hence, flux produced by one pair of poles is proportional to voltage and flux produced by another pair of poles is proportional to electric current.

Here, in the vector diagram, the angle between system voltage V and current I is θ

The flux produced due to current I is ϕ_1 which is in phase with I.

The flux produced due to voltage V, is ϕ_2 which is in quadrature with V.

Hence, angle between ϕ_1 and ϕ_2 is (90° – θ).

Therefore, if torque produced by these two fluxes is T_d.

where K is constant of proportionality.

Here in this equation we have assumed that, flux produced by voltage coil lags 90° behind its voltage. By designing this angle can be made to approach any value and a torque equation

T = KVIcos (θ – ϕ) obtained where θ is angle between V & I. Accordingly, induction cup relays can be designed to produce maximum torque when the angle θ = 0 or 30°, 45° or 60°.

The relays which are such designed, that, they produce maximum torque at θ = 0, is P induction cup power relay. The relays produce maximum torque when θ = 45° or 60°, are used as directional protection relay.

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Induction Cup Directional or Power Relay	**RGPV/ June 2013**	7
Q.2	Reactance or Mho Type Induction Cup Relay	**RGPV/ June 2011**	7

Unit-02 /Lecture-07

Over Current Relay Working Principle Types

In an **over current relay** or **o/c relay** the actuating quantity is only current. There is only one current operated element in the relay, no voltage coil etc. are required to construct this protective relay.

Working Principle of Over Current Relay

In an over current relay, there would be essentially a current coil. When normal current flows through this coil, the magnetic effect generated by the coil is not sufficient to move the moving element of the relay, as in this condition the restraining force is greater than deflecting force. But when the current through the coil increased, the magnetic effect increases, and after certain level of current, the deflecting force generated by the magnetic effect of the coil, crosses the restraining force, as a result, the moving element starts moving to change the contact position in the relay.

Although there are different **types of over current relays** but basic **working principle of over current relay** is more or less same for all.

Types of Over Current Relay

Depending upon time of operation, there are various **types of OC relays**, such as,

1. **Instantaneous over current relay**.
2. **Definite time over current relay**.
3. **Inverse time over current relay**.

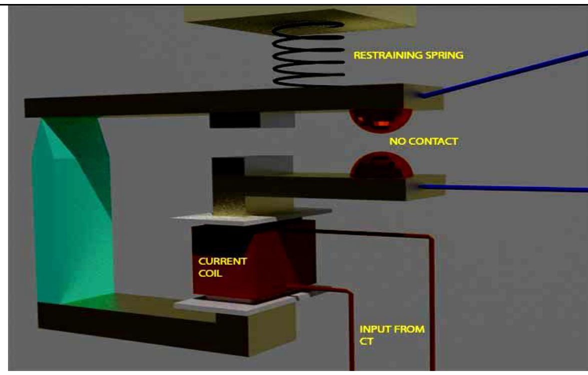
Inverse time over current relay or simply **inverse OC relay** is again subdivided as **inverse definite minimum time** (IDMT), **very inverse time**, **extremely inverse time over current relay** or **OC relay**.

Instantaneous Over Current Relay

Construction and working principle of **instantaneous over current relay** quite simple.

current relay” width=”640” height=”485” class=”aligncenter size-full wp-image-11661” /> Here generally a magnetic core is wound by current coil. A piece of iron is so fitted by hinge support and restraining spring in the relay, that when there is not sufficient current in the coil, the NO contacts remain open. When current in the coil crosses a present value, the attractive force becomes sufficient to pull the iron piece towards the magnetic core and consequently the No contacts are closed.

The preset value of current in the relay coil is referred as pick up setting current. This relay is referred as instantaneous over current relay, as ideally, the relay operates as soon as the current in the coil gets higher than pick up setting current. There is no intentional time delay applied. But there is always an inherent time delay which can not be avoided practically. In practice the operating time of an instantaneous relay is of the order of a few milliseconds. Fig.



Definite Time Over Current Relay

This relay is created by applying intentional time delay after crossing pick up value of the current. A **definite time over current relay** can be adjusted to issue a trip output at definite amount of time after it picks up. Thus, it has a time setting adjustment and pick up adjustment.

Inverse Time OC Relay

Inverse time is a natural character of any induction type rotating device. This means the speed of rotation of rotating art of the device is faster if input current is increased. In other words, time of operation inversely varies with input current. This natural characteristic of electromechanical induction disc relay in very suitable for over current protection. This is because, in this relay, if fault is more severe, it would be cleared more faster. Although time inverse characteristic is inherent to electromechanical induction disc relay, but the same characteristic can be achieved in microprocessor based relay also by proper programming.

Inverse Definite Minimum Time Over Current Relay or IDMT O/C Relay

Ideal inverse time characteristics can not be achieved, in an over current relay. As the current in the system increases, the secondary current of the current transformer is increased proportionally. The secondary current is fed to the relay current coil. But when the CT becomes saturated, there would not be further proportional increase of CT secondary current with increased system current.

From this phenomenon it is clear that from trick value to certain range of faulty level, an inverse time relay shows exact inverse characteristic. But after this level of fault, the CT becomes saturated and relay current does not increase further with increasing faulty level of the system. As the relay current is not increased further, there would not be any further reduction in time of operation in the relay. This time is referred as minimum time of operation.

Hence, the characteristic is inverse in the initial part, which tends to a definite minimum operating time as the current becomes very high. That is why the relay is referred as **inverse definite minimum time over current relay** or simply **IDMT relay**.

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Definite Time Over Current Relay	**RGPV/ June 2013**	7
Q.2	Types of Over Current Relay	**RGPV/ June 2011**	7

Unit-02 /Lecture-08

Distance Relay or Impedance Relay Working Principle Types

There is one type of relay which functions depending upon the distance of fault in the line. More specifically, the relay operates depending upon the impedance between the point of fault and the point where relay is installed. These relays are known as **distance relay** or **impedance relay**.

Working Principle of Distance or Impedance Relay

The **working principle of distance relay** or **impedance relay** is very simple. There is one voltage element from potential transformer and an current element fed from current transformer of the system. The deflecting torque is produced by secondary current of CT and restoring torque is produced by voltage of potential transformer. In normal operating condition, restoring torque is more than deflecting torque. Hence relay will not operate. But in faulty condition, the current becomes quite large whereas voltage becomes less. Consequently, deflecting torque becomes more than restoring torque and dynamic parts of the relay starts moving which ultimately close the No contact of relay. Hence clearly operation or working principle of distance relay, depends upon the ratio of system voltage and current. As the ratio of voltage to current is nothing but impedance a distance relay is also known as impedance relay.

The operation of such relay depends upon the predetermined value of voltage to current ratio. This ratio is nothing but impedance. The relay will only operate when this voltage to current ratio becomes less than its predetermined value. Hence, it can be said that the relay will only operate when the impedance of the line becomes less than predetermined impedance (voltage / current). As the impedance of a transmission line is directly proportional to its length, it can easily be concluded that a distance relay can only operate if fault is occurred within a predetermined distance or length of line.

Construction of Time Distance Impedance Relay

The relay mainly consists of a current driven element like double winding type induction over current relay. The spindle carrying the disc of this element is connected by means of a spiral spring coupling to a second spindle which carries the bridging piece of the relay contacts. The bridge is normally held in the open position by an armature held against the pole face of an electromagnet excited by the voltage of the circuit to be protected.

Operating Principle of Time Distance Impedance Relay

During normal operating condition the attraction force of armature fed from PT is more than force generated by induction element, hence relay contacts remain in open position when a short circuit fault occurs in the transmission line, the current in the induction element increases. Then the induction in the induction element increases. Then the induction element starts rotating. The speed of rotation of induction elements depends upon the level of fault i.e. quantity of current in the induction element. As the rotation of the disc proceeds, the spiral spring coupling is wound up till the tension of the spring is sufficient to pull the armature away from the pole face of the voltage excited magnet.

The angle through which the disc travels the disc travel before relay operate depends upon the pull of the voltage excited magnet. The greater the pull, the greater will be the travel of the disc. The pull of this magnet depends upon the line voltage. The greater the line voltage the greater the pull hence longer will be the travel of the disc i.e. operating time is proportional to V.

Again, speed of rotation of induction element approximately proportional to current in this element. Hence, time of operation is inversely proportional to current. Therefore time of operation of relay,

$$Operating\ time\ T \propto \frac{Voltage}{Current} \propto Impedance \propto Distance\ along\ transmission\ line$$

Types of Distance or Impedance Relay

There are mainly two **types of distance relay**-

1. **Definite distance relay**.
2. **Time distance relay**.

Let us discuss one by one.

Definite Distance Relay

This is simply a variety of balance beam relay. Here one beam is placed horizontally and supported by hinge on the middle. One end of the beam is pulled downward by the magnetic force of voltage coil, fed from potential transformer attached to the line. Other end of the beam is pulled downward by the magnetic force of current coil fed from current transformer connected in series with line. Due to torque produced by these two downward forces, the beam stays at an equilibrium position. The torque due to voltage coil, serves as restraining torque and torque due to current coil, serves as deflecting torque.

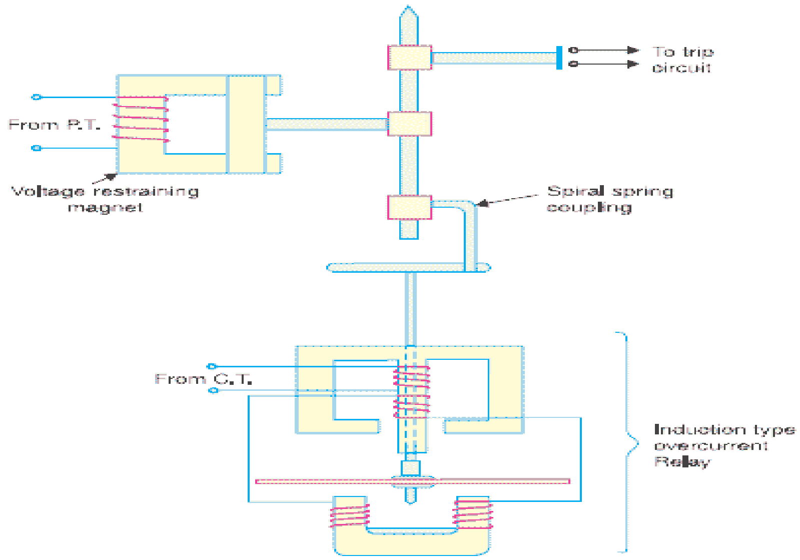
Under normal operating condition restraining torque is greater than deflecting torque. Hence contacts of this distance relay remain open. When any fault is occurred in the feeder, under protected zone, voltage of feeder decreases and at the same time current increases. The ratio of voltage to current i.e. impedance falls below the pre-determined value. In this situation, current coil pulls the beam more strongly than voltage coil, hence beam tilts to close the relay contacts and consequently the circuit breaker associated with this impedance relay will trip.

Time Distance Impedance Relay

This delay automatically adjusts its operating time according to the distance of the relay from the fault point. The time distance impedance relay not only be operated depending upon voltage to current ratio, its operating time also depends upon the value of this ratio. That means,

$$Operating\ time\ T \propto \frac{Voltage}{Current} \propto Impedance \propto Distance\ along\ transmission\ line$$

Construction of Time Distance Impedance Relay



The relay mainly consists of a current driven element like double winding type induction over current relay. The spindle carrying the disc of this element is connected by means of a spiral spring coupling to a second spindle which carries the bridging piece of the relay contacts. The bridge is normally held in the open position by an armature held against the pole face of an electromagnet excited by the voltage of the circuit to be protected.

Operating Principle of Time Distance Impedance Relay

During normal operating condition the attraction force of armature fed from PT is more than force generated by induction element, hence relay contacts remain in open position when a short circuit fault occurs in the transmission line, the current in the induction element increases. Then the induction in the induction element increases. Then the induction element starts rotating. The speed of rotation of induction elements depends upon the level of fault i.e. quantity of current in the induction element. As the rotation of the disc proceeds, the spiral spring coupling is wound up till the tension of the spring is sufficient to pull the armature away from the pole face of the voltage excited magnet.

The angle through which the disc travels the disc travel before relay operate depends upon the pull of the voltage excited magnet. The greater the pull, the greater will be the travel of the disc. The pull of this magnet depends upon the line voltage. The greater the line voltage the greater the pull hence longer will be the travel of the disc i.e. operating time is proportional to V. Again, speed of rotation of induction element approximately proportional to current in this element. Hence, time of operation is inversely proportional to current. Therefore time of operation of relay,

$$Hence,\ operating\, time\ \propto\ \frac{1}{I}$$

$$T\ \propto\ \frac{V}{I}\ or\ T\ \propto\ Z$$

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	What is distance protection? Explain characteristics. Write down the applications and derive general torque equation of distance relay.	**RGPV/ June 2012**	7
Q.2	Develop the characteristics of following type of distance relay in relay R-X plane.(i)Impedance (ii) Modified impedance (iii) reactance (iv) admittance	**RGPV/ June 2013**	7
Q.3	In what ways a distance relay is superior to over current protection of transmission line. admittance	**RGPV/ June 2013**	7
Q.4	How the directional features are provided to (i) reactance (ii) impedance relay.	**RGPV/ June 2013**	7

Unit-02 /Lecture-09

Thermal Relay

Working Principle Construction of Thermal Overload Relay

The coefficient of expansion is one of the basis properties of any material. Two different metals always have different degree of linear expansion. A bimetallic strip always bends when it heated up, due to this inequality of linear expansion of two different metals.

Working Principle of Thermal Relay

A thermal relay works depending upon the above mentioned property of metals. The basic working principle of thermal relay is that, when a bimetallic strip is heated up by a heating coil carrying over current of the system, it bends and makes normally open contacts.

Construction of Thermal Relay

The construction of thermal relay is quite simple. As shown in the figure above the bimetallic strip has two metals – metal A and metal B. Metal A has lower coefficient of expansion and metal – B has higher coefficient of expansion. One heating coil is would on the bimetallic strip. When over current flows through the heating coil, it heats up the bimetallic strip.

Due to the heat generated by the coil, both of the metals are expanded. But expansion of metal B is more than expansion of metal A. Due to this dissimilar expansion the bimetallic strip will bend towards metal A as shown in the figure below.

Thermal Relay

The strip bends, the No contact is closed which ultimately energizes the trip coil of a circuit breaker. The heating effect is not instantaneous. As per Joule's law of heating, the amount of heat generated, where I is the over current flowing through the heating coil of thermal relay.

R is the electrical resistance of the heating coil. t is the time for which the current I flows through the heating coil. Hence from the above equation it is clear that, heat generator by the coil is directly proportional to the time during which the over current flows through the coil. Hence there is a prolonged time delay in the operation of thermal relay. That is why this type of relay is generally used where over load is allowed to flow for a predetermined amount of time before it trips. If overload or over current falls down to normal value before this predetermined time, the relay will not be operated to trip the protected equipment.

NO	RGPV QUESTIONS	Year	Marks
Q.1	Working Principle Construction of Thermal Overload Relay	**RGPV/ June 2012**	7

Recap of the unit

Relays by functions

The various protective functions available on a given relay are denoted by standard ANSI Device Numbers. For example, a relay including function 51 would be a timed over current protective relay.

Over current relay

A digital over current relay is a type of protective relay which operates when the load current exceeds a pickup value. The ANSI device number is 50 for an instantaneous over current (IOC) and 51 for a time over current (TOC). In a typical application the over current relay is connected to a current transformer and calibrated to operate at or above a specific current level. When the relay operates, one or more contacts will operate and energize to trip (open) a circuit breaker.

Distance relay

The most common form of protection on high voltage transmission systems is distance relay protection. Power lines have set impedance per kilometre and using this value and comparing voltage and current the distance to a fault can be determined. The ANSI standard device number for a distance relay is 21.It is also called as the impedance relay as it calculates the line fault with the use of the impedance per meter of the transmission line

There are many types of distance relays including *impedance distance*, *reactance distance*, *offset distance* and *mho distance*.[4]

Current differential protection

Another common form of protection for apparatus such as transformers, generators, busses and power lines is current differential. This type of protection works on the basic theory of Kirchhoff's current law, which states that the sum of the currents entering and exiting a node will equal zero. Differential protection requires a set of current transformers (smaller transformers that transform currents down to a level which can be measured) at each end of the power line, or each side of the transformer. The current protection relay then compares the currents and calculates the difference between the two.

As an example, a power line from one substation to another will have a current differential relay at both substations which communicate with each other. In a healthy condition, the relay at substation A may read 500 amps (power exporting) and substation B will read 500 amps (power importing). If a path to earth or ground develops there will be a surge of current. As supply grids are generally well interconnected the fault in the previous example will be fed from both ends of the power line. The relay at substation A will see a massive increase in current and will continue to export. Substation B will also see a massive increase in current, however it will now start to export as well. In turn the protection relay will see the currents traveling in opposite directions (180 degrees phase shift) and instead of cancelling each other out to give a summation of zero it will see a large value of current. The relays will trip the associated circuit breakers. This type of protection is called unit protection, as it only protects what is between the current transformers.

Often, differential protection relays will have a "rising" characteristic to make the operating setpoint a function of the "through" current. The higher the current in the line, the larger the differential current required for the relay to detect as a fault. This is required due to the mismatches in current transformers. Small errors will increase as current increases to the point where the error could cause a false trip, if the current differential relay only had an upper limit instead of the rising differential characteristic. Current transformers have a point where the core saturates and the current in the CT is no longer proportional to the current in the line. A CT can become inaccurate or even saturate because of a fault outside of its protected zone (through fault) where the CTs see a large magnitude but still in the same direction.

Directional relay

A directional relay uses an additional polarizing source of voltage or current to determine the direction of a fault. The fault can be located upstream or downstream of the relay's location, allowing appropriate protective devices to be operated inside or outside of the zone of protection.

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Explain working principle of differential relay.	**RGPV/ June 2011**	7
Q.2	With the help of neat schematic diagram, explain the principle of static differential relay.	**RGPV/ June 2011**	7
Q.3	Describe with a schematic diagram, the construction of impedance relay.	**RGPV/ June 2014**	7

Important Model Questions for Unit Test and MID SEM Examinations

Switchgear and protection (EX-603)

(Strictly Based on RGPV EXAMINATION)

Unit-2

1. Explain the functional characteristics of a protective relay. **RGPV/ June 2014**
2. Discuss classification of relay. **RGPV/ June 2014**
3. Describe with a schematic diagram, the construction of impedance relay. **RGPV/ June 2014**
4. Explain the fundamental requirement of a protective relaying. How relays are classified according to (i) Principle of operation (ii) Time of operation **RGPV/ June 2013**
5. Develop the characteristics of following type of distance relay in relay R-X plane.(i)Impedance (ii) Modified impedance (iii) reactance (iv) admittance

   RGPV/ June 2013
6. In what ways a distance relay is superior to over current protection of transmission line. admittance **RGPV/ June 2013**
7. With the help of neat schematic diagram, explain the principle of static differential relay. Discuss merits and demerits of static relay over other type of relay.

   RGPV/ June 2013, Dec2013
8. Discuss briefly about following (i) Pickup, reset and drop-off (ii) Reset of relay and burden of relay (iii) operating time (iv) seal in relay **RGPV/ Dec 2013,2012,2011**
9. Derive the equation for torque produced by an induction relay. **RGPV/ Dec 2013**
10. How the directional features are provided to (i) reactance (ii) impedance relay.

    RGPV/ Dec 2013
11. Numerical on PSM and Time of operation of relay. **RGPV/ Dec 2012**
12. Explain the following terms Selectivity, PSM, TSM, Protective zone, primary and back up relay, quality of relay. **RGPV/ June 2012**
13. What is distance protection? Explain characteristics. Write down the applications and derive general torque equation of distance relay. **RGPV/ June 2012**
14. Compare performance of static relay with electromechanical relay. **RGPV/ June 2011**
15. Describe the construction and principle of operation of an Induction type over current relay. Discuss the time current characteristics of the relay. . **RGPV/ June 2013**
16. Explain working principle of differential relay. **RGPV/ June 2011**
17. What is meant by directional relay? Describe the construction, principle of operation and application of a directional over current relay. **RGPV/ June 2012**