SHMABHUNATH INSTITUTE OF ENGINEERING AND TECHNOLOGY

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SWITCHGEAR AND PROTECTION

B.Tech (Electrical Engineering, Electrical and Electronics Engineering)

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UNIT 1

About the subject

Hello dear students.

At present you are reading this notes on your laptops or computers. Ok got it……………. Before going ahead just thing about the power source of your computer. The power cable of your system is connected to a 5-pin power plug in which 230V ac supply is running. Now thing beyond it. From where's the power is coming. You say from local distribution station. Ok got it. Now again, think beyond it. From where's, the power is coming to distribution station. You say from secondary distribution station. Ok now let's come on the place where the electricity is generated i.e. generating station. Do you ever thing what would happen if there occur any fault between electricity generating stage and distribution stage. The whole world gonna be frozen. Why? Because we are now dependent on the energy which is called "electrical energy". So what should we do to prevent it? You will get your answer by the end of this session.

As the name suggest switchgear and protection it is clear that the subject is about to basic concepts of protection of power system. When we heard the term protection the first thing comes in our mind that what is the thing which we are going to protect and from what? So here's the answer. We are going to protect the power system elements like generator, transformers, transmission lines, busbars etc. from the faults. Short circuits are usually called faults by the power engineers. Strictly speaking, the term fault simply means a 'defect'. Some defects, other then short circuits, are also termed as fault. For example the failure of conducting path due to a break in a conductor is a type of fault. We can't stop the occurring of fault, either it may occur because of human error or by any electrical abnormal condition, in power system but we can prevent it by further spreading.

The subject SGP in engineering course provide a basic idea of prevention of power system failure due to faults. In this subject we are going to study different types of protecting devices and protection methods to stabiles power system. There are many devices and elements which plays a vital role in protection such as electrical relays, isolators, circuit breakers, switches, contactors, C.T.s, P.T.s etc. There are some elements which are automatic while some are manually operated.

So here we understand why the power system needs protection and how can we protect it.

Unit 1

Introduction to Protection System and Relays

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.

1.1 Functions of protecting relaying

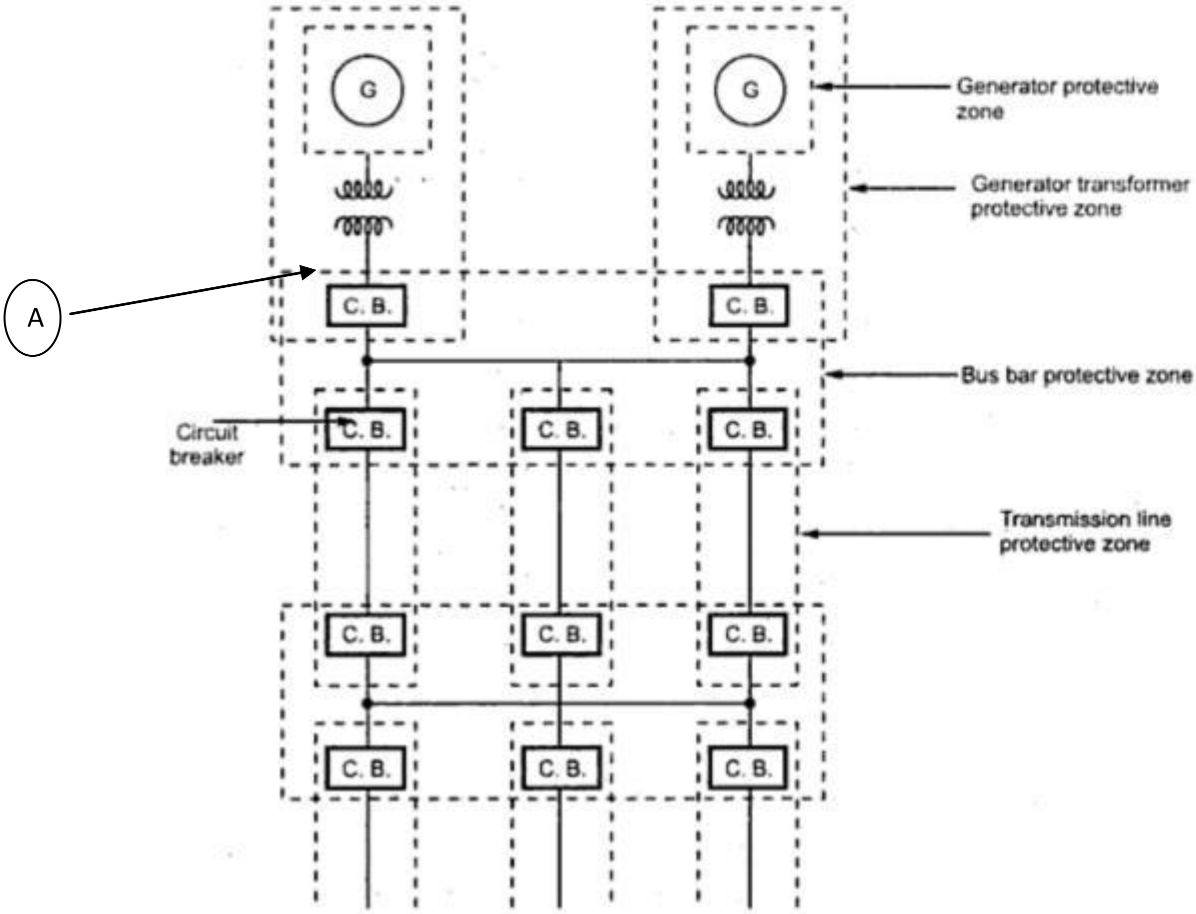
- Relay sense the fault and give a trip signal to circuit breaker for opening the contacts of circuit breaker
- To disconnect the abnormally operating part so as to avoid the damage or interference within effective operation of the rest of the system.
- To improve the system performance, system reliability, system stability and service continuity.

1.2 Protective zone

As we know that mostly each and every component of electrical system is protected by using protective devices. A protection zone is a separate zone which is established around each system element. The significance of such a protective zone is that any fault occurring within a given zone will cause the tripping of relays which further couses opening of all the circuit breakers located within that zone.

- Whenever a fault occur in a protective zone all the circuit breakers are tripped to open.
- The boundaries of protective zones are decided by the location of the current transformer
- The zone which is unprotected called dead zone

The given figure illustrate the different types of protection zone…



In the figure you can see that a single circuit breaker is contributed in two zones. For example there is a circuit breaker "A" which comes under two protection zones generator transformer protection zone and bus bar protection zone.

1.3 Primary and Backup Protection

Why do we need backup protection? Assume there is a fault occur in any protective zone but the relay do not trip because of any internal problem. The fault sustain for a long time, causes a huge damage to large proportion of power system. Primary protection may fail due to the following reasons

- Failure of DC supply to the tripping Circuit
- Failure in relay operating current or voltage
- Failure in circuit breaker tripping mechanism
- Failure of main protective relay operation
- Failure in the wiring of relaying system
- Failure of CTs or PTs operation

To prevent this we use backup protection. Backup protection comes into existence when primary relay or primary protection arrangement do not work properly. Now how these backup protection are provided.

1.4 Methods of Backup Protection

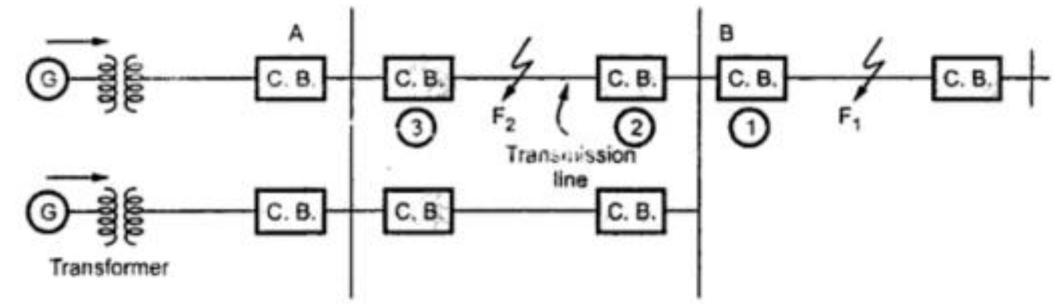
- **Relay backup protection:** In this protection system a single circuit breaker is used for primary as well secondary CB. There are two relays which are connected to the same CB. One is primary and other is backup relay. When primary relay do not operate backup relay operate with a little time lag.
- **Breaker backup protection:** In this method two circuit breakers and relay assembly is used. When primary relay or CB fails to trip then backup relay and CB assembly comes into existence. Both the arrangement are done at the same station. This system is generally employee for Bus-Bar protection.
- **Remote Backup protection:** In this method two CB are provided but both the breakers are at different stations and are independent of each other. It is most desirable because of the fact that it will not fail due to the factor causing the failure of the primary protection. It is widely used for backup protection of transmission lines.
- **Centrally co-ordinated backup protection:** All the stations have their own central rooms but also there is a common central room in which we can monitor all the nearby stations. Main central room continuously inspect the load flow and frequency of the system. If any element of any part of the system fails, load flow affected which is sensed by the control room. The control source consists of a digital computers which decides the proper switching action.

1.5 Essential Qualities of Protection

- **Reliability:** A protective relaying should be reliable is its basic quality. It indicates the ability of the relay system to operate under the predetermined conditions. There are various components which go into the operation before a relay operates. Therefore every component and circuit which is involved in the operation of a relay plays an important role. The reliability of a protection system depends on the reliability of various components like circuit breakers, relays, current transformers (C.T.s), potential transformers (P.T.s), cables, trip circuits etc. The proper maintenance also plays an important role in improving the reliable operation of the system. The reliability can not be expressed in the mathematical expressions but can be adjusted from the statistical data. The statistical survey and records give good idea about the reliability of the protective system. The inherent reliability is based on the design which is based on the long experience. This can be achieved by the factors like,

- Simplicity
- High contact pressure
- Good contact material
- Robustness
- Dust free enclosure
- Careful Maintenance
- Good workmanship and

- **Selectivity and Discrimination:** The selectivity id the ability of the protective system to identify the faulty part correctly and disconnect that part without affecting the rest of the healthy part of system. The discrimination means to distinguish between. The discrimination quality of the protective system is the ability to distinguish between normal condition and abnormal condition and also between abnormal condition within protective zone and elsewhere. The protective system should operate only at the time of abnormal condition and not at the time of normal condition. Hence it must clearly discriminate between normal and abnormal condition. Thus the protective system should select the fault part and disconnect only the faulty part without disturbing the healthy part of the system.The protective system should not operate for the faults beyond its protective zone. For example,



consider the portion of a typical power system shown in the Fig. 1.

It is clear from the Fig. 1 that if fault F_2 occurs on transmission line then the circuit breakers 2 and 3 should operate and disconnect the line from the remaining system. The protective system should be selective in selecting faulty transmission line only for the fault and it should isolate it without tripping the adjacent transmission line breakers or the transformer. If the protective system is not selective then it operates for the fault beyond its protective zones and unnecessary the large part of the system gets isolated. This causes a lot of inconvenience to the supplier and users.

- **Speed and Time:** a protective system must disconnect the faulty system as fast as possible. If the faulty system is not disconnect for a long time then,

1. The devices carrying fault currents may get damaged.

2. The failure leads to the reduction in system voltage. Such low voltage may affect the motors and generators running on the consumer side.
3. If fault persists for long time, then subsequently other faults may get generated.

The high speed protective system avoids the possibility of such undesirable effects. The total time required between the instant of fault and the instant of final arc interruption in the circuit breaker is called **fault clearing time**. It is the sum of relay time and circuit breaker time. The **relay time** is the time between the instant of fault occurrence and the instant of closure of relay contacts. The **circuit breaker times** is the time taken by the circuit breaker to operate to open the contacts and to extinguish the arc completely. The fault clearing time should be as small as possible to have high speed operation of the protective system.

Though the small fault clearing time is preferred, in practice certain time lag is provided. This is because,
1. To have clear discrimination between primary and backup protection
2. To prevent unnecessary operation of relay under the conditions such as transient, starting inrush of current etc.

Thus fast protective system is an important quality which minimises the damage and it improves the overall stability of the power system.

- **Sensitivity:** The protective system should be sufficiently sensitive so that it can operate reliably when required. The sensitivity of the system is the ability of the relay system to operate with low value of actuating quantity. It indicates the smallest value of the actuating quantity at which the protection starts operating in relation with the minimum value of the fault current in the protected zone.
- **Stability:** The stability is the quality of the protective system due to which the system remains inoperative and stable under certain specified conditions such as transients, disturbance, through faults etc. For providing the stability, certain modifications are required in the system design. In most of the cases time delays, filter circuits, mechanical and electrical bias are provided to achieve stable operation during the disturbances.
- **Adequateness:** There are variety of faults and disturbance those may practically exists in a power system. It is impossible to provide protection against each and every abnormal condition which may exist in practice, due to economical reasons. But the protective system must provide adequate protection for any element of the system. The adequateness of the system can be assessed by considering following factors,
    1. Ratings of various equipments
    2. Cost of the equipments
    3. Locations of the equipments

4. Probability of abnormal condition due to internal and external causes.
5. Discontinuity of supply due to the failure of the equipment

- **Simplicity and Economy:** In addition to all the important qualities, it is necessary that the cost of the system should be well within limits. In practice sometimes it is not necessary to use ideal protection scheme which is economically unjustified. In such cases compromise is done. As a rule, the protection cost should not be more than 5% of the total cost. But if the equipments to be protected are very important, the economic constrains can be relaxed. The protective system should be as simple as possible so that it can be easily maintained. The complex system are difficult from the maintenance point of view. The simplicity and reliability are closely related to each other. The simpler system are always more reliable.

1.6 Classification of protective relays

- **Electromagnetic attraction type Relay**

1. Solenoid type
2. Attracted Armature Type
3. Balanced Beam type

- **Induction type Relay**

1. Induction Disc Type
2. Induction Cup Type

- **Directional Type Relay**

1. Reverse current type
2. Reverse Power Type

- **Relay Based on Timing**

1. Instantaneous Type
2. Definite Time Lag Type
3. Inverse Time Lag Type

- **Distance Type Relays**

1. Impedance Type
2. Reactnace Type
3. Admittance Type

- **Differential Type Relays**

1. Current differential Type
2. Voltage Differential Type

1.7 Terminologies used in Protective Relaying

Relay Time: It is the time between the instant of fault occurrence and the instant of closure of relay contacts.

Breaker Time: It is the time between the instant at CB operate and opens the contacts, to the instant of extinguishing the arc completely.

Fault Clearing Time: The total time required between the instant of fault and the instant of final arc interruption in the CB is fault clearing time.

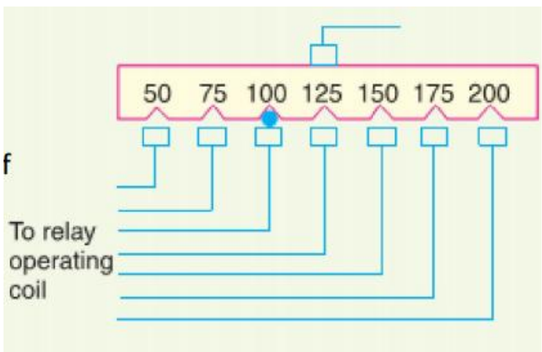
Pickup: A relay is said to be picked up when it moves from the 'OFF' position to 'ON' position. Thus when relay operates it is said that relay has picked up.

Pickup Value: It is the minimum value of an actuating quantity at which relay start operating. In most of the relays actuating quantity is current in the relay coin and pickup value of current is indicated along with the relay.

Time Delay: The time taken by the relay to operate after it has sensed the fault is called time delay of relay.

Dropout or Reset: A relay is said to dropout or reset when it comes back to its original position

Current setting: The pickup value of current can be adjusted to the required level in the relay which is called current setting of the relay. It is achieved by use of tappings on the relay coil, which are brought out to a plug bridges. The tap value is expressed in in terms of percentagefull load ratings of CT with which relay is associated.



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

That means,

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

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,

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

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 current.

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

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

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.

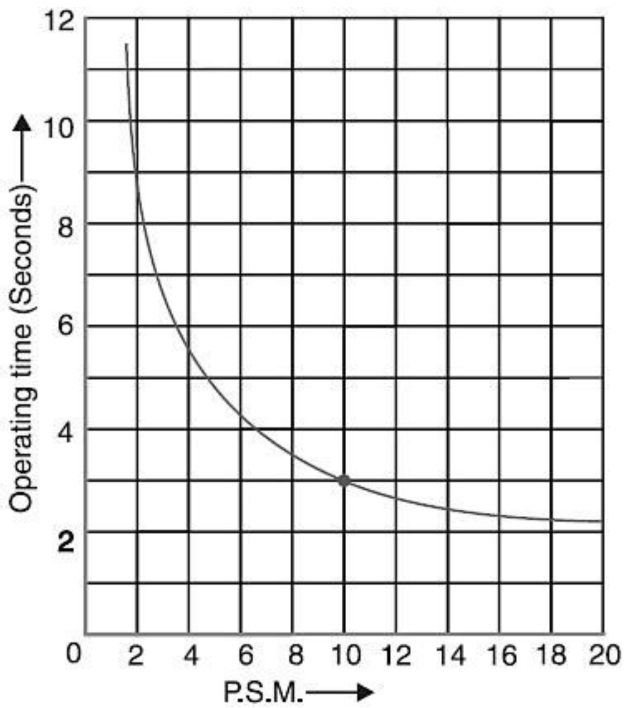
But by adjusting only time setting multiplier, we can not set the actual time of operation of an electrical relay. As we already said, the time of operation also depends upon the speed of operation. The speed of moving parts of relay depends upon the force due to current in the relay coil. Hence it is 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/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.

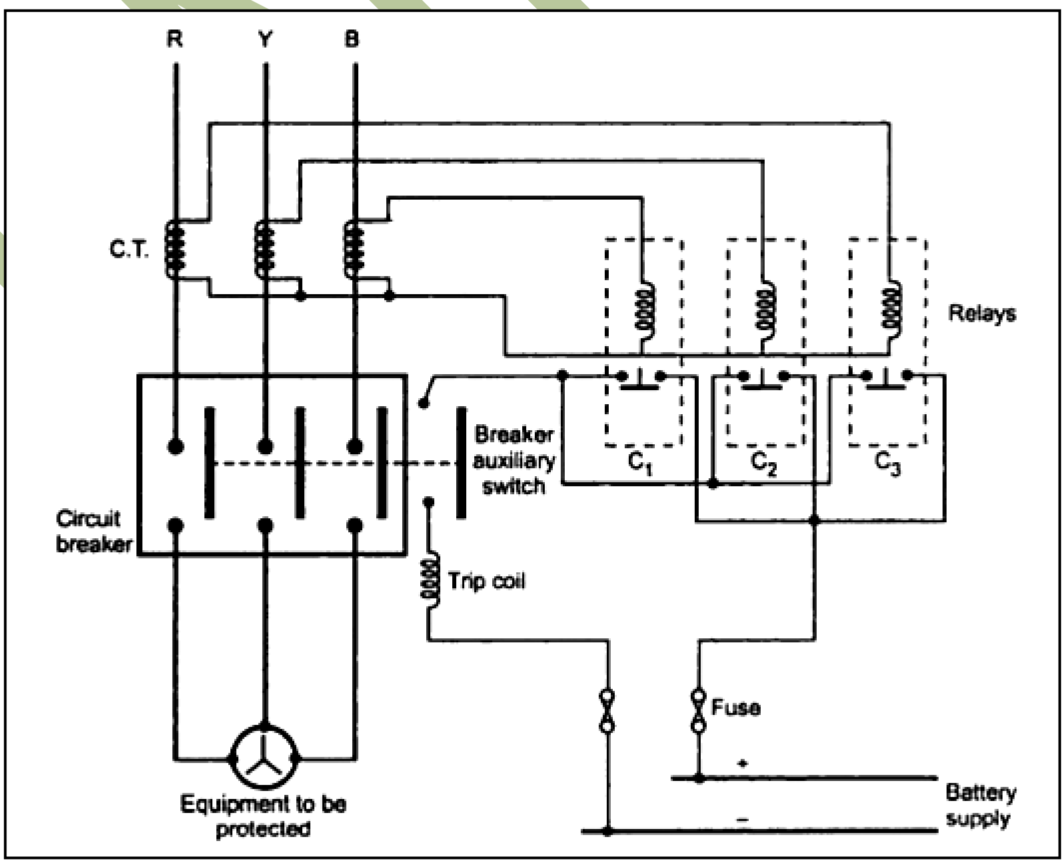
1.8 Tripping schemes in circuit breakers

Two schemes are very popularly used for tripping in CBs are:

- Relay with make type contact
- Relay with break type contact

Let us understand the working of these mechanism.

Relay with make type contact: The circuit diagram for make type contact is given bellow.

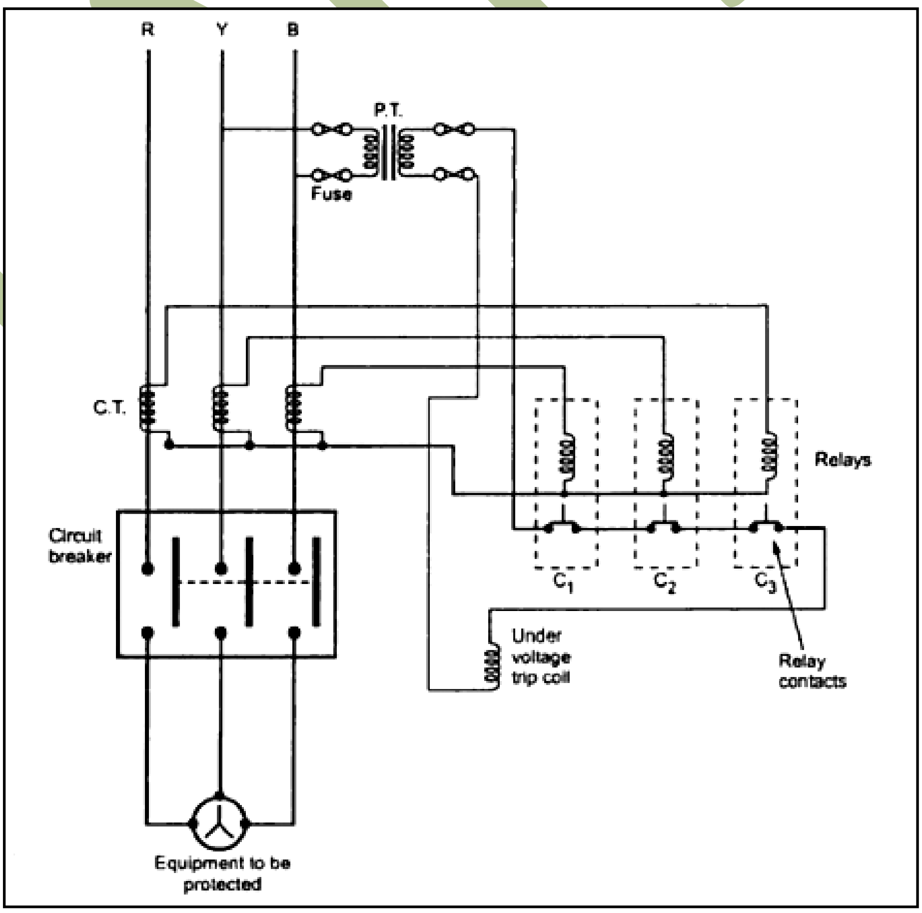


as you can see in the diagram there are three CTs are used in this arrangement whose primary are connected in The phase line R, Y, B and secondary connected to relay coils. The relay coils are C1, C2, C3. A separate D.C. supply is given to each relay for holding the relay contacts in open position. In healthy condition a normal current flows through secondary of CTs or relay coil (relay coil is connected with secondary of CTs). This current is produces a attraction force but is not enough to make the contacts of relay (because the restraining force produced by the dc supply is greater then force produce by relay current). When the fault occur a very high current start flowing in the secondary of CTs which is generally connected to the relay coil, this intern energizes the relay. The relay coil produces a force greater the restraining force and relay contacts get tripped.

There is a auxiliary switch which is directly coupled with CBs contacts. Initially CB contacts are closed and so auxiliary switch. When the relay contacts trips a current start flowing through trip coil of CB because at that time auxiliary switch is closed. This causes the opening of CBs contacts.

As soon as the CBs opens and so auxiliary switch the current in trip coil interrupt and relay contacts reset to their initial position. CBs contacts get closed as soon as the fault being clear.

Relay with break type contact: circuit diagram for break type contact is given bellow.



In the above diagram you can see the relay contacts are connected connected with the secondary of CTs. A under voltage trip coil is also used in this scheme. This coil produces a force which is capable of holding the relay contacts close. Under the normal condition attraction force by relay coils is less than the restraining force which is driven by under voltage trip coil. When fault occur a heavy current flows through relay contacts and produces a large attraction force this further causes the breaking of relay contacts. the arrangement is made so that when the under voltage trip coli de-energizes the contacts of CBs get open.

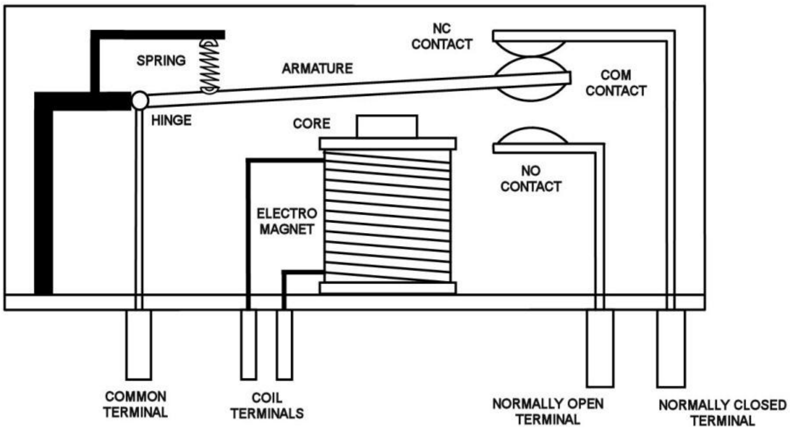
1.9 Electro Magnetic Attraction Relays

As the name suggest Electromagnetic attraction relay a electromagnetic material is used. A coil is wound on the electromagnet. When the fault current flows through the coil it energizes the electromagnet and armature get attracted because of which the contacts of relay get close.

There are two types of electromagnetic attraction relay.

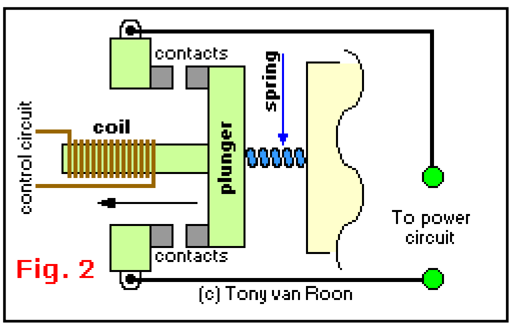
Attracted armature type relay: The constructional diagram of relay is shown in the fig. in the fig there are five terminal out from the relay.

- Common terminal
- Coil terminal
- Normally open
- Normally closed



We connect the secondary of CTs with coil terminals. When the current flows through it produces the operating torque. When this torque becomes greater then restraining torque given by spring the core attract the armature and move the contact from normally closed terminal to normally open terminal.

Solenoid and plunger type relay: the working principle of this is same as that of attracted armature type relay but the difference is when coil energizes it attract the plunger which is attached to a spring. The



spring provide restraining torque. When fault occur relay attract the plunger and relay contacts get closed.

In DC operation, electromagnetic force is constant. When this force is exceeds the restraining force, the relay operation

$F_e = K_1 I^2$ $\quad$ $F_r = K_2$

F_e = Electromagnetic Force $\quad$ F_r = Restraining force due to spring

K_1 = Constant $\quad$ F_2 = Constant

I = Operating current in coil

On the verge of relay operating, electromagnetic force is just equal to the restraining force

$K_1 I^2 = K_2$

$I^2 = \frac{K_2}{K_1}$

$I = \sqrt{\frac{K_2}{K_1}}$

Advantages or merits:

- Electromagnetic relays have fast operation and fast reset
- They can be used for both ac and dc systems for protection of ac and dc equipments
- Electromagnetic relays operating speeds which has the ability to operate in milliseconds are also can be possible
- They have the properties such as simple, robust, compact and most reliable
- These relays are almost instantaneous. Though instantaneous the operating time of the relay varies with the current. With extra arrangements like dashpot, copper rings etc. slow operating times and reset can be possible

Disadvantages or demerits:

- High burden level instrument transformers are required (CTs and PTs of high burden is required for operating the electromagnetic relays compared to static relays)
- The directional feature is absent in electromagnetic relays
- Requires periodic maintenance and testing unlike static relays
- Relay operation can be affected due to ageing of the components and dust, pollution resulting in spurious trips
- Operation speed for an electromagnetic relays is limited by the mechanical inertia of the component

Applications:

- Electromagnetic relays are employed for the protection of various ac and dc equipments
- The over/under current and voltage protection of various ac and dc equipments
- For differential protection
- Used as auxiliary relays in the contact systems of protective relay schemes

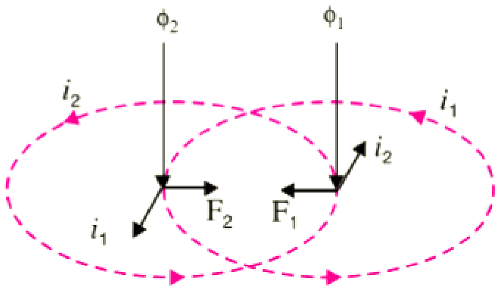
1.10 Induction type Relay

I this type of Relay anyhow we create two fluxes which interact with each other and produces a net torque required for relay operation. Based on how we produce these two fluxes the induction relays are classified. We will start from the easiest model of induction relay and then go ahead. But before studying the classification let us understand the basics of how torque produces in induction relay.

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-

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

To understand the production of torque in an induction relay, refer to the elementary arrangement shown in Fig. below



The two a.c. 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 I2 and I 1 respectively. These currents lag behind their respective fluxes by of eddy currents I2 and I 1 respectively. These currents lag behind their respective fluxes by 90 Referring to Fig. below (ii) where the two a.c. fluxes and induced currents are shown

separately for clarity, let

$$\phi_1 = \phi_{1max} \sin \omega t$$

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

where ϕ1 and ϕ2 are the instantaneous values of fluxes and ϕ2 leads ϕ1 by an angle α. Assuming that the paths in which the rotor currents flow have negligible self-inductance, the rotor currents will be in phase with their voltages

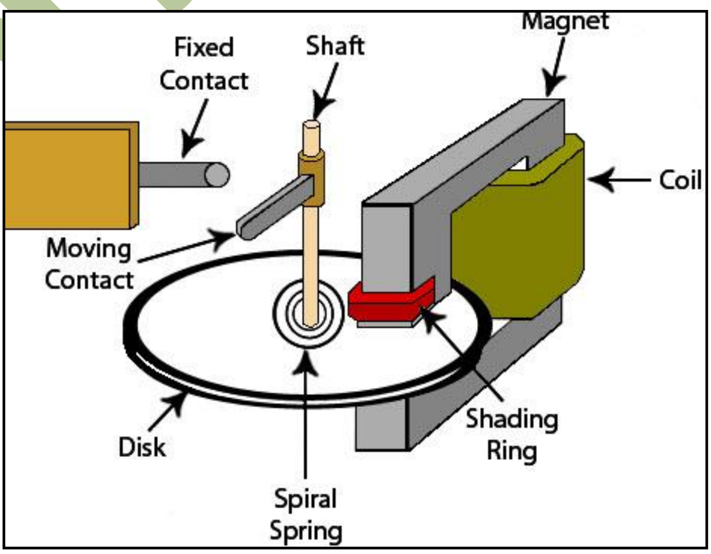
$$i_1 \propto \frac{d\phi_1}{dt} \propto \frac{d}{dt}(\phi_{1max} \sin \omega t)$$
$$\propto \phi_{1max} \cos \omega t$$
$$i_2 \propto \frac{d\phi_2}{dt} \propto \phi_{2max} \cos(\omega t + \alpha)$$
$$F_1 \propto \phi_1 i_2 \quad \text{and} \quad F_2 \propto \phi_2 i_1$$

The net force F at the instant considered is

$$F \propto F_2 - F_1$$
$$\propto \phi_2 i_1 - \phi_1 i_2$$
$$\propto \phi_{2max} \sin(\omega t + \alpha)\, \phi_{1max} \cos \omega t - \phi_{1max} \sin \omega t\, \phi_{2max} \cos(\omega t + \alpha)$$
$$\propto \phi_{1max}\, \phi_{2max} [\sin(\omega t + \alpha) \cos \omega t - \sin \omega t \cos(\omega t + \alpha)]$$
$$\propto \phi_{1max}\, \phi_{2max} \sin \alpha$$
$$\propto \phi_1\, \phi_2 \sin \alpha \qquad ...(i)$$

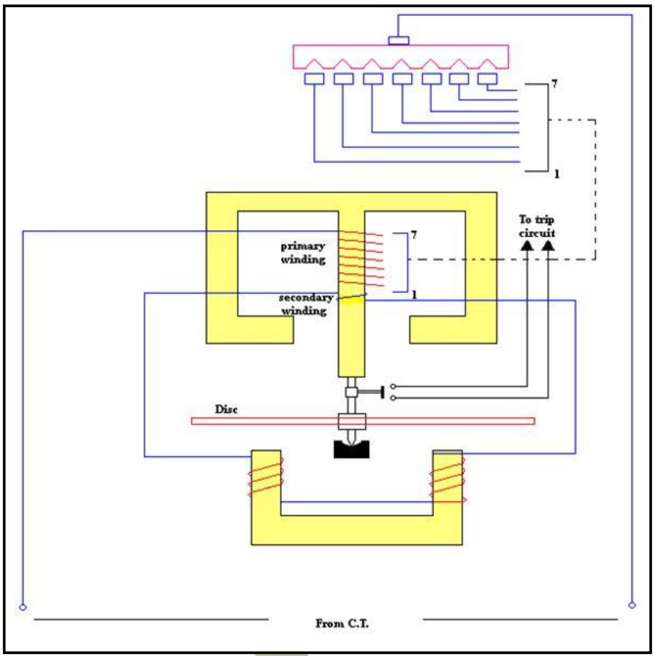
- Thus the total torque produced by the induction relay are proportional to $\emptyset_1 \emptyset_2 \sin \alpha$.

Shaded Pole Induction Relay: In the figure you can see that there is a electro magnet whose coil is energize by fault current. The pole of electromagnet is equally divided in two parts in which one part is covered with shadding band. The shading band is made up of highly inductive material hence produces a flux which is displaced in time and space compared to main flux.



On the disc, a shaft is mounted in vertical position as shown in figure. A moving contact is attached with it. When disc rotate the shaft rotates and thus moving contact.

Watthour Meter Type Induction Relay:

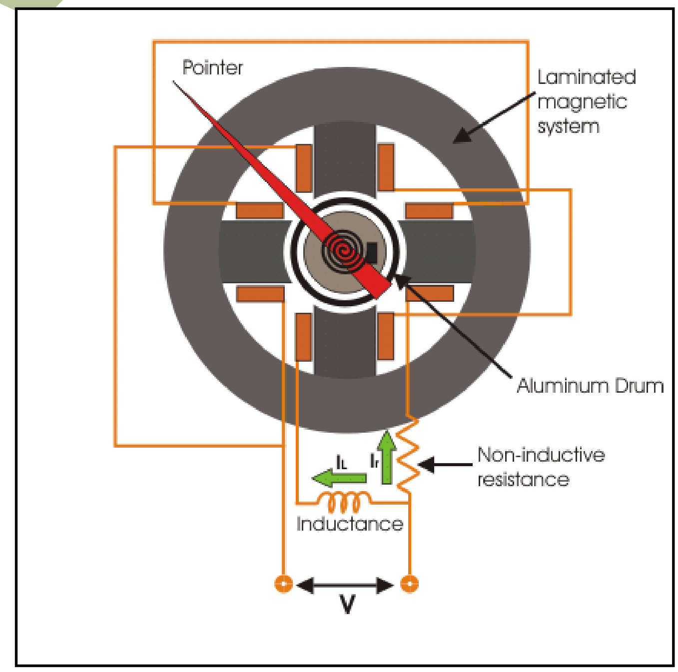


In this type of relay there are two types of electromagnets are used. The upper magnet is E shaped and lower magnet is U shaped. The primary windings which is fed by the secondary of CT with the help of plug setting bridge and wound on the E shaped magnet. The secondary winding is wound on U shaped magnet but a part of secondary winding is also wound on E shaped magnet as shown in figure. A metallic disc is allowed to rotate in between the two electromagnet.

When the fault occur, The primary coin energized and produces a flux $\emptyset_1$. This flux links with the secondary windings and produces an e.m.f. hence produces a secondary current in secondary windings. This secondary current produces the flux $\emptyset_2$. Let the phase angle between $\emptyset_1$ And $\emptyset_2$ is α. Assuming that the entire flux $\emptyset_1$ enters the disc from upper magnet and entire flux $\emptyset_2$ enters the disc from lower magnet, we can write

$$T = \emptyset_1 \emptyset_2 \sin \alpha$$

Most of the induction relays are of this type. An important features of this type relay is that its operation can be controlled by opening or cloasing of the secondary windings.



Induction Cup Type 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. 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.

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 drum 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.

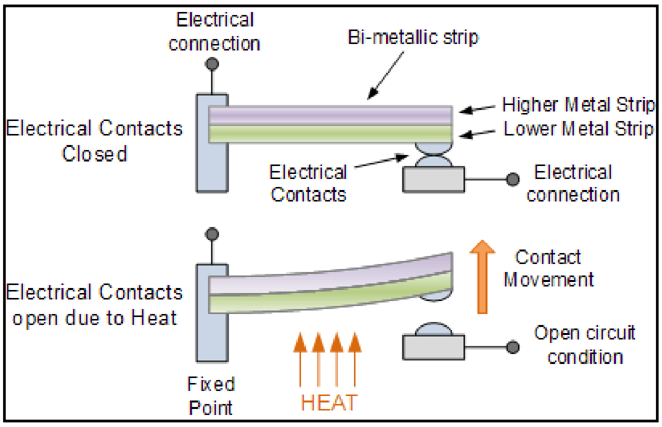
The aluminum cup is attached with a hair spring: In normal condition the restoring torque of the spring is higher than deflecting torque of the cup. So there is no movement of the cup. But during faulty condition of system, the current through the coil is quite high, hence, deflecting torque produced 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.

1.11 Thermal 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.

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. The figure illustrates the thermal relay.

I the figure there are two conditions are shown. In healthy condition the bimetallic strip remains straight and the relay contacts are closed. But in any abnormal condition a high amount of current flows through the heater coil, which generate a huge amount of heat. Due to this excess heat the bimetallic strip bends and open the contacts.



The heating effect is not instantaneous. As per Joule's law of heating, the amount of heat generated,

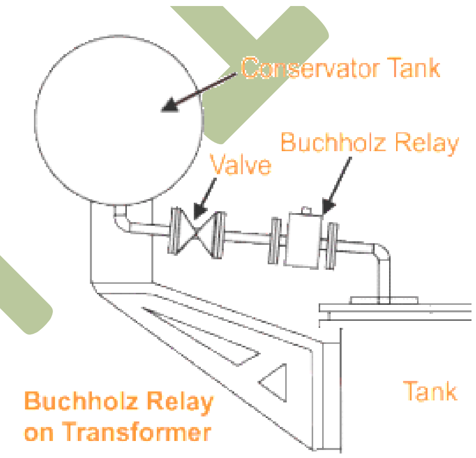
$$H \propto I^2 Rt$$

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. A typical application of thermal relay is overload protection of electric motor.

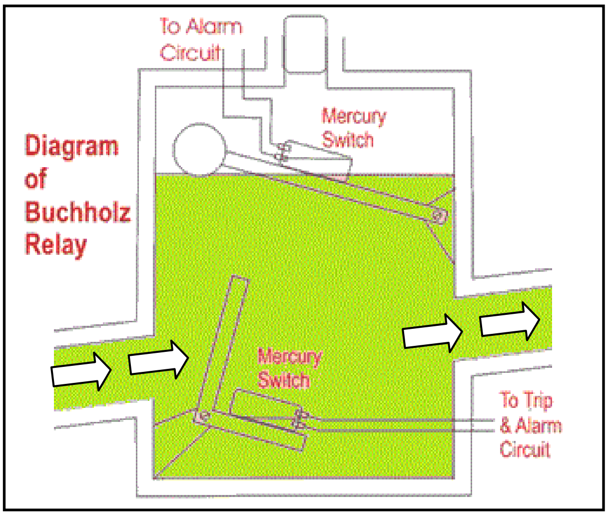
Gas Actuated Relay (Buchholz Relay)

Transformer is a very important part of power system so it is also required to protect the transformer from electrical faults. There are many types of internal faults in transformer such as an insulation faults between turns, break down of core of transformer, core heating etc. Bhuchholz Relay is a relay which is used for the protection of transformer. Buchholz relay in transformer is an oil container connected between the main tank and conservator.



Construction:

Buchholz relay function is based on very simple mechanical phenomenon. It is mechanically actuated. Whenever there will be a minor internal fault occur in the transformer. It has mainly two elements. The upper element consists of a float. The float is attached to a hinge in such a way that it can move up and down depending upon the oil level in the Buchholz relay Container. One mercury switch is fixed on the float. The alignment of mercury switch hence depends upon the position of the float. The lower element consists of a baffle plate and mercury switch. This plate is fitted on a hinge just in front of the inlet (main tank side) of Buchholz relay in transformer in such a way that when oil enters in the relay from that inlet



in high pressure the alignment of the baffle plate along with the mercury switch attached to it, will change.

Working:

Whenever there will be a minor internal fault in the transformer such as an insulation faults between turns, break down of core of transformer, core heating, the transformer insulating oil will be decomposed in different hydrocarbon gases, CO_2 and CO. The gases produced due to decomposition of transformer insulating oil will accumulate in the upper part the Buchholz container which causes fall of oil level in it. Fall of oil level means lowering the position of float and thereby tilting the mercury switch. The contacts of this mercury switch are closed and an alarm circuit energized.

Sometime due to oil leakage on the main tank air bubbles may be accumulated in the upper part the Buchholz container which may also cause fall of oil level in it and alarm circuit will be energized. By collecting the accumulated gases from the gas release pockets on the top of the relay and by analyzing them one can predict the type of fault in the transformer. More severe types of faults, such as short circuit between phases or to earth and faults in the tap changing equipment, are accompanied by a surge of oil which strikes the baffle plate and causes the mercury switch of the lower element to close. This switch energized the trip circuit of the circuit breakers associated with the transformer and immediately isolate the faulty transformer from the rest of the electrical power system by inter tripping the circuit breakers associated with both LV and HV sides of the transformer. This is how Buchholz relay functions**.**

Advantage

- It is the simplest form of transformer protection.
- It detects the incipient faults at a stage much earlier than is possible with other forms of protection.

Disadvantages

- It can only be used with oil immersed transformers equipped with conservator tanks.
- The device can detect only faults below oil level in the transformer.Therefore, separate protection is needed for connecting cables.

IMPORTANT QUESTIONS

- What are essential requirements of protection system?
- What are the different types of faults occurring in the power sYstem?
- Write the importance of ground wire.
- Write the essential qualities of protection.
- Explain the importance of protective schemes employed in power system.
- Differentiate the following :

(i) Primary and Backup Protection
(ii) (ii) Pickup and Reset value.
(iii) Operating time and Reset time.
(iv) Normal and Abnormal conditions

- What is the zone of protection? Discuss various zones of protection with suitable diagram?
- What are the design consideration of electromagnetic relay?
- Give the construction feature, principle of working and characteristic of directional over current relay. What do you understand by IDMT relay. Draw the typical characteristic of IDMT relay.

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