20EE601

Hall Ticket Number: **SCHEME OF EVALUATION**

III/IV B.Tech (Regular) DEGREE EXAMINATION

July/August,2023 **Electrical and Electronics Engineering**

Sixth Semester **Power system Protection**

Time: Three Hours **Maximum:** 70 Marks

Answer question 1 compulsory. **(14X1 = 14Marks)**

Answer one question from each unit. **(4X14=56 Marks)**

1 a) What is a symmetric Fault? CO1 L1 1M

Ans: That fault on the power system which gives rise to symmetrical fault currents (i.e., equal fault currents in the lines with 120° displacement) is called a symmetrical fault.

b) List the causes of faults in power system. CO1 L2 1M

Ans: i. Failure or conducting path failures

ii. Certain foreign particles, such as fine cement dust or any dirt.

iii. Overvoltage due to lightning or switching surges.

iv. Punctured or breaking of Insulation insulator.

v. Certain foreign particles, such as fine cement dust or any dirt.

vi. Conducting objects falling on the overhead lines like tree branches.

vii. Poor quality of the system components or because of a faulty system design

c) Where is the directional relay used? CO1 L1 1M

Ans: Directional overcurrent relay is used for the protection of ring main distribution lines. When there exists a sub-transmission network or a complex distribution, the relays is used to improve the coordination of the system.

d) Classify the advantages of static relays over electromechanical relays? CO2 L2 1M

Ans: i. No moving contacts

ii. Low power consumption as low as 1mW

iii. No gravity effect on operation of static relays. Hence can be used in vessels ie, ships, aircrafts etc.

iv. A single relay can perform several functions like over current, under voltage, single phasing protection by incorporating respective functional blocks. This is not possible in electromagnetic relays

v. static relay is compact

e) What is phase comparator. CO2 L2 1M

Ans: A phase comparator compares two input quantities in phase angle (vertically) irrespective of the magnitude and operates if the phase angle between them is < 90°.

f) What is the percentage differential relay? CO2 L1 1M

Ans: The percentage differential relay is defined as the relay that operates on the phase difference of two or more similar electrical quantities. It is the advanced form of differential protection relay. The only difference between them is the restraining coil. The percentage differential relay consists restraining coil for overcoming the trouble arising out of differences in the current ratio for the high value of an external short circuit current.

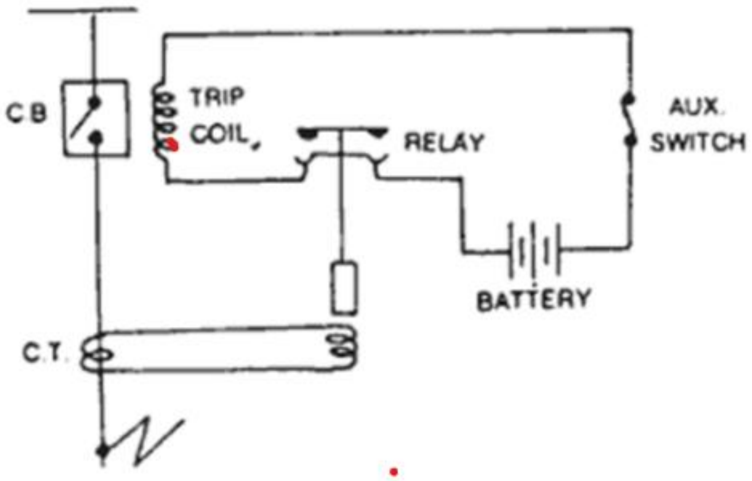
g) What is frame leakage protection? CO3 L1 1M

Ans: Frame leakage protection is one of the simplest forms of bus-bar protection available, suitably designed to withstand the earth faults occurring within the indoor installations. This type of protection is applicable to metal-clad switchgear of small size. All the metal frameworks are attached together and insulated from the ground.

h) Is any back-up protection employed for the protection of an alternator? CO3 L2 1M

Ans: In the case of alternators, primary protection is provided to the stator, by percentage differential protection or by restricted earth-fault protection, etc. The backup protection is provided by over-current protection and earth-fault protection.

i) Draw the Simplified diagram of circuit breaker control for opening operation CO4 L2 1M



Circuit Breaker

j) Write two methods of arc interruption: CO4 L1 1M

Ans: High resistance method,

Low resistance method or current zero interruption method.

k) List the various components of a protection system? CO1 L2 1M

Ans:) i. Relays.

ii. Circuit Breakers.

iii. Tripping and Other Auxiliary Supplies.

vi. Current Transformer (CT)

v. Voltage Transformers (VT)

vi. Linear Coupler.

l) Infer the essential qualities of a protective relay. CO1 L2 1M

Ans: Reliability, Selectivity and Discrimination, Speed and Time, Sensitivity, Stability, Adequateness, Simplicity and Economy.

m) Which type of fault is most dangerous? CO1 L1 1M

Ans: Symmetrical fault- A fault due to short circuit in all three phases is categorized as a symmetrical fault. It is the most severe fault.

n) Where Impedance relay, Reactance relay, and Mho relays are employed? CO2 L1 1M

Ans: The Impedance relay is suitable for the phase faults relaying for the lines of moderate lengths Reactance type relays are employed for the ground faults while Mho type of relays are best suited for the long transmission lines and particularly where synchronizing power surge may occur.

Unit-I

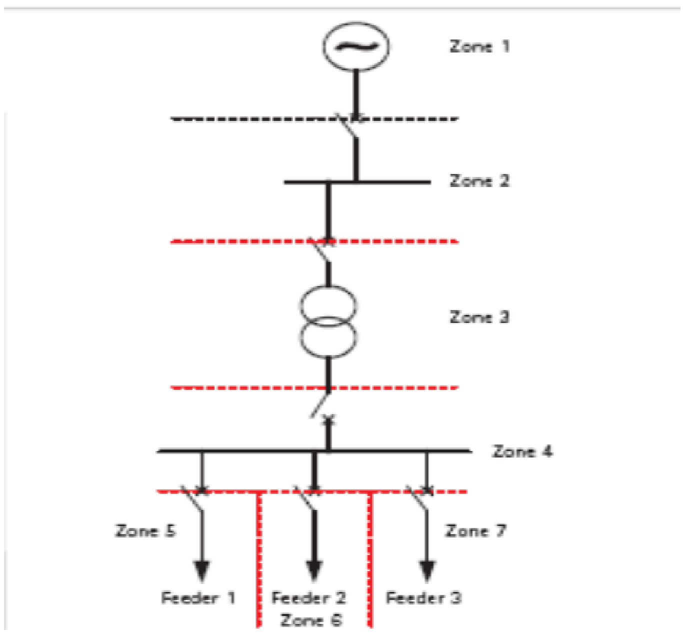
2 a) Recall what do you understand by a zone of protection? Discuss Various zones of protection for a modern power system. CO1 L2 7M

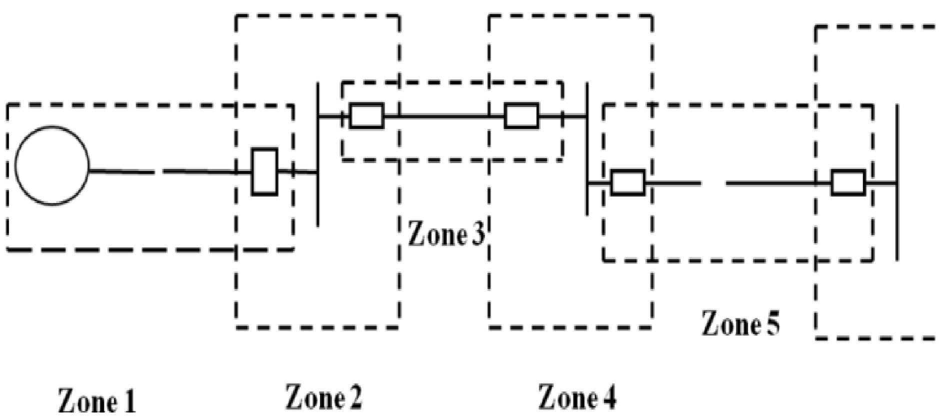
Ans: An electric power system is divided into several zones of protection. Each zone of protection, contains one or more components of a power system in addition to two circuit breakers.

• When a fault occurs within the boundary of a particular zone, then the protection system responsible for the protection of the zone acts to isolate (by tripping the Circuit Breakers) every equipment within that zone from the rest of the system.

• The circuit Breakers are inserted between the component of the zone and the rest of the power system. Thus, the location of the circuit breaker helps to define the boundaries of the zones of protection.

Different neighboring zones of protection are made to overlap each other, which ensure that no part of the power system remains without protection. However, occurrence of the fault with in the overlapped region will initiate a tripping sequence of different circuit breakers so that the minimum necessary to disconnect the faulty element.





b) Depict an induction disc relay and discuss its operating principle. CO1 L2 7M

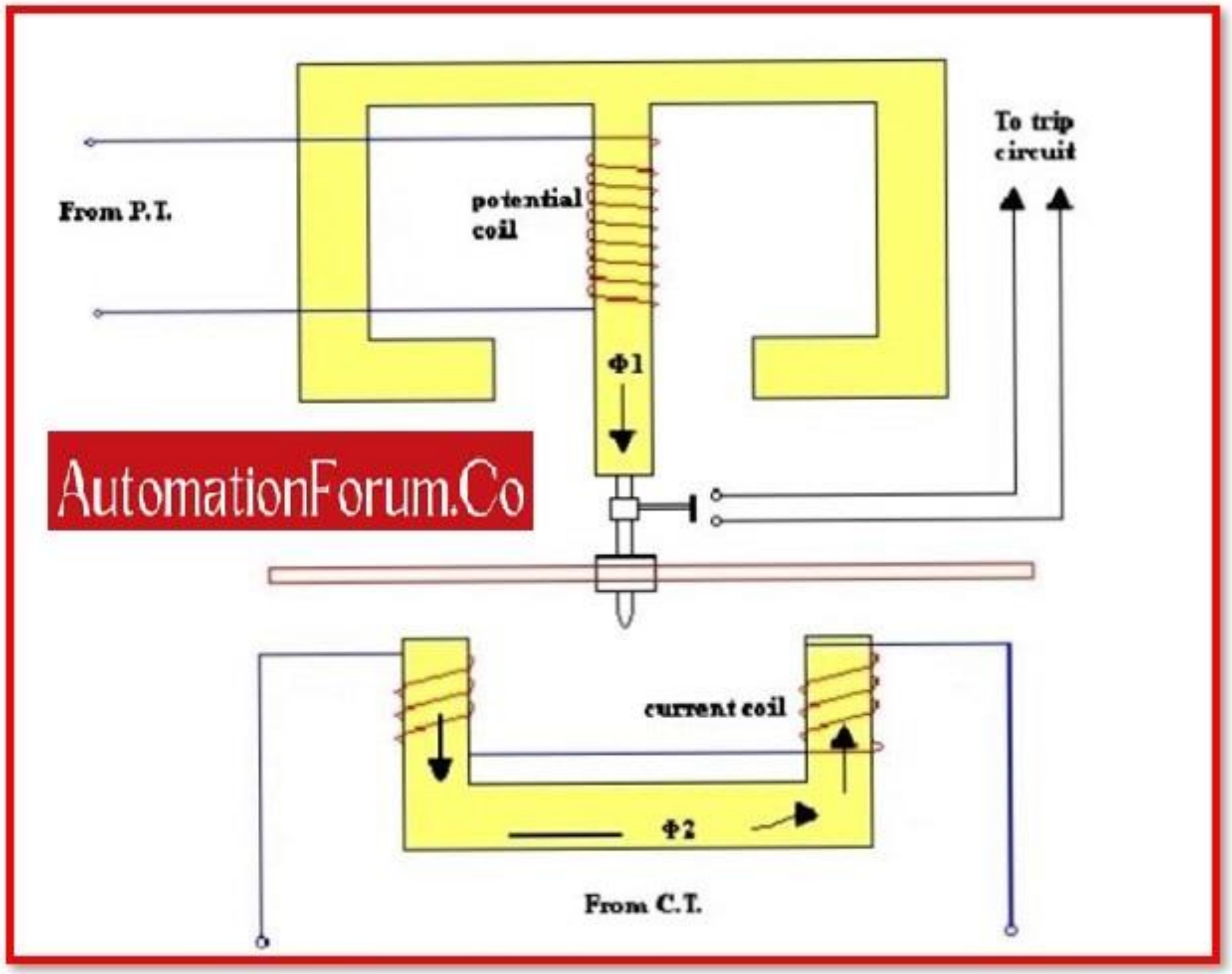
Ans: Similar to induction motors, induction disc relays operate on the electromagnetic induction principle. Torque is produced in these relays by the interaction of alternating flux with one of the Magnets and Eddy currents induced in the rotor (disc) by the other alternating flux. Despite having the same frequency, there will be a phase difference between the two fluxes. These relays are

therefore restricted to alternating current circuits.
This relay's moving contact is fastened to a disc, which serves as its moving component. Similar to induction motors, induction disc relays operate on the electromagnetic induction principle. Torque is produced in these relays by the interaction of alternating flux with one of the

Magnets and

Eddy currents

induced in the rotor (disc) by the other alternating flux. Despite having the same frequency, there will be a phase difference between the two fluxes. These relays are therefore restricted to alternating current circuits.
This relay's moving contact is fastened to a disc, which serves as its moving component.
The coils become energised and create a magnetic field when the system has a malfunction. Eddy currents will be induced by this magnetic field, and these eddy currents will generate their own magnetic field within the disc.



Torque is produced on the disc when the magnetic fields created by the coil's magnetic field and the eddy currents' magnetic field interact. Due to the rotation of the disc and movement of the moving contact toward the fixed contact, the trip circuit is closed.

The spring's restraining force prevents the disc from moving until the fault current drops below the pickup value, which releasing the trip circuit by moving the moving contact away from the fixed contact.

(OR)

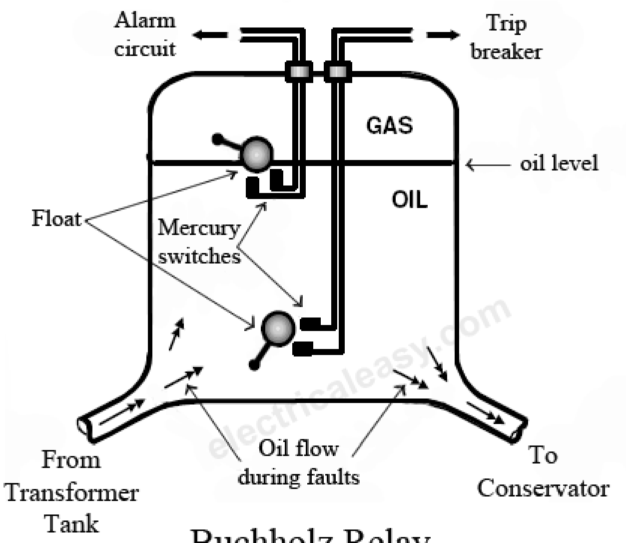
3 a) What is Buchholz relay? Which equipment is protected by it? For what types of faults is it employed? Discuss its working principle. CO1 L2 7M

Ans: Buchholz relay is a safety device which is generally used in large oil immersed transformers (rated more than 500 kVA). It is a type of oil and gas actuated protection relay. It is used for the protection of a transformer from the faults occurring inside the transformer, such as impulse breakdown of the insulating oil, insulation failure of turns etc.

Working Principle Of Buchholz Relay

Whenever a fault occurs inside the transformer, such as insulation failure of turns, breakdown of core or excess core heating, the fault is accompanied by production of excess heat. This excess heat decomposes the transformer insulating oil which results in production of gas. The generation of gases depend on intensity the of fault. Gas bubbles tend to flow in upward direction towards conservator and hence they are collected in the buchholz relay which is placed on the pipe connecting the transformer tank and conservator.

Construction



Buchholz Relay

Buchholz relay consists of an oil filled chamber. There are two hinged floats, one at the top and other at the bottom in the chamber. Each float is accompanied by a mercury switch. The mercury switch on the upper float is connected to an alarm circuit and that on the lower float is connected to an external trip breaker.
The **construction of a buchholz relay** is shown in the figure.

How Does A Buchholz Relay Work?

Whenever a minor fault occurs inside the transformer, heat is produced by the fault currents. The produced heat causes decomposition of transformer oil and gas bubbles are produced. These gas bubbles flow in upward direction and get collected in the buchholz relay. The collected gas displaces the oil in buchholz relay and the displacement is equivalent to the volume of gas collected. The displacement of oil causes the upper float to close the upper mercury switch which is connected to an alarm circuit. Hence, when minor fault occurs, the connected alarm gets activated. The collected amount of gas indicates the severity of the fault occurred. During minor faults the production of gas is not enough to move the lower float. Hence, during minor faults, the lower float is unaffected.
During major faults, like phase to earth short circuit, the heat generated is high and a large amount of gas is produced. This large amount of gas will similarly flow upwards, but its motion is high enough to tilt the lower float in the buccholz relay. In this case, the lower float will cause the lower mercury switch which will trip the

transformer from the supply, i.e. transformer is isolated from the supply.

Advantages Of Buchholz Relay

- Buchholz relay indicates the internal faults due to heating and it helps in avoiding the major faults.
- Severity of the fault can be determined without even dismantling the transformer.
- If a major fault occurs, the transformer can be isolated with the help of buchholz relay to prevent accidents.

b) With a neat sketch explain the operation of attracted armature type relays. CO1 L1 7M

Ans: Electromagnetic Attraction Relays:

Electromagnetic attraction relays operate by virtue of an armature being attracted to the poles of an electromagnet or a plunger being drawn into a solenoid. Such Basic Relays may be actuated by d.c. or a.c. quantities. The important types of electromagnetic attraction relays are :

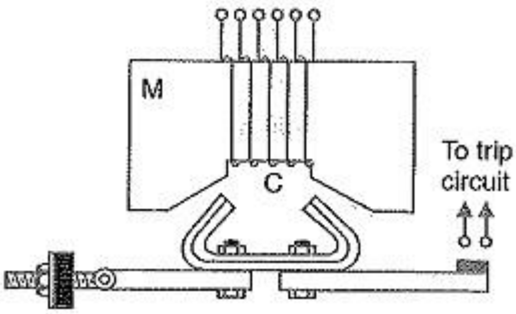


Fig. 21.3

(i) Attracted armature type relay: Fig. 21.3 shows the schematic arrangement of an attracted armature type relay. It consists of a laminated electromagnet M carrying a coil C and a pivoted laminated armature. The armature is balanced by a counterweight and carries a pair of spring contact fingers at its free end. Under normal operating conditions, the current through the relay coil C is such that counterweight holds the armature in the position shown. However, when a short cir suit occurs, the current through the relay coil increases sufficiently and the relay armature is attracted upwards. The contacts on the Basic Relays armature bridge a pair of stationary contacts attached to the relay frame. This completes the trip circuit which results in the opening of the circuit breaker and, therefore, in the disconnection of the faulty circuit.

The minimum current at which the relay armature is attracted to close the trip circuit is called pickup current. It is a usual practice to provide a number of tappings on the relay coil so that the number of turns in use and hence the setting value at which the relay operates can be varied.

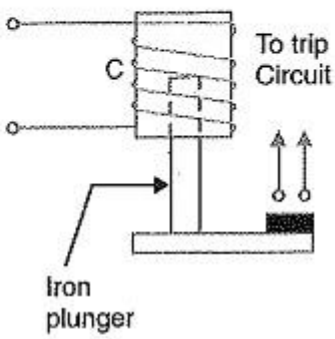


Fig. 21.4

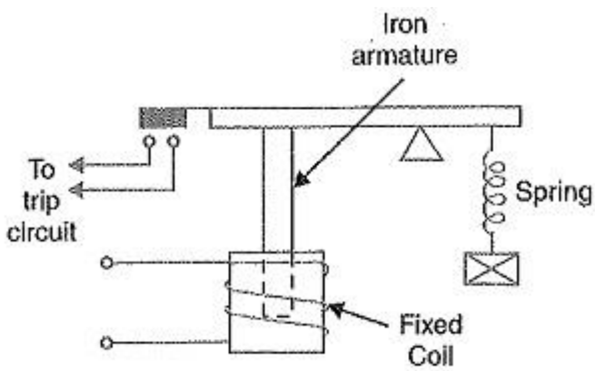


Fig. 21.5

(ii) Solenoid type relay: Fig. 21.4 shows the schematic arrangement of a solenoid type Basic Relays. It consists of a solenoid and movable iron plunger arranged as shown. Under normal operating conditions, the current through the relay coil C is such that it holds the plunger by gravity or spring in the position shown. However, on the occurrence of a fault, the current through the relay coil becomes more than the pickup value, causing the plunger to be attracted to the solenoid. The upward movement of the plunger closes the trip circuit, thus opening the circuit breaker and disconnecting the faulty circuit.

(iii) Balanced beam type relay: Fig. 21.5 shows the schematic arrangement of a balanced beam type relay. It consists of an iron armature fastened to a balance beam. Under normal operating conditions, the current through the relay coil is such that the beam is held in the horizontal position by the spring. However, when a fault occurs, the current through the relay coil becomes greater than the pickup value and the beam is attracted to close the trip circuit. This causes the opening of the circuit breaker to isolate the faulty circuit.

<u>Unit-II</u>

4 Discuss how an amplitude comparator can be converted to a phase comparator, and vice versa. CO2 L2 14M

Ans: These are Comparator Equation in Power System Protection of a circle on complex planes and indicate that an operating characteristic equation can be obtained either by a phase comparator or by an amplitude comparator through proper selection of the four constants K_1 through K_4. This further suggests the possibility of a simple relation between the two comparators and it can be proved that an inherent amplitude comparator becomes a phase comparator and vice versa, if the input quantities are changed to the sum and difference of the original two input quantities.

Consider the operation of an amplitude comparator with input signals A and B. It operates, say, when

$$|A|>|B|$$

If the inputs are changed to (A + B) and (A — B) so that it operates when

$$|A+B|>|A-B|$$

It has now become an inherent phase comparator as shown in Fig. (4.3) vector diagram, i.e. if the inputs are changed to (A + B) and (A—B) the original amplitude comparator would compare phases of A and B.

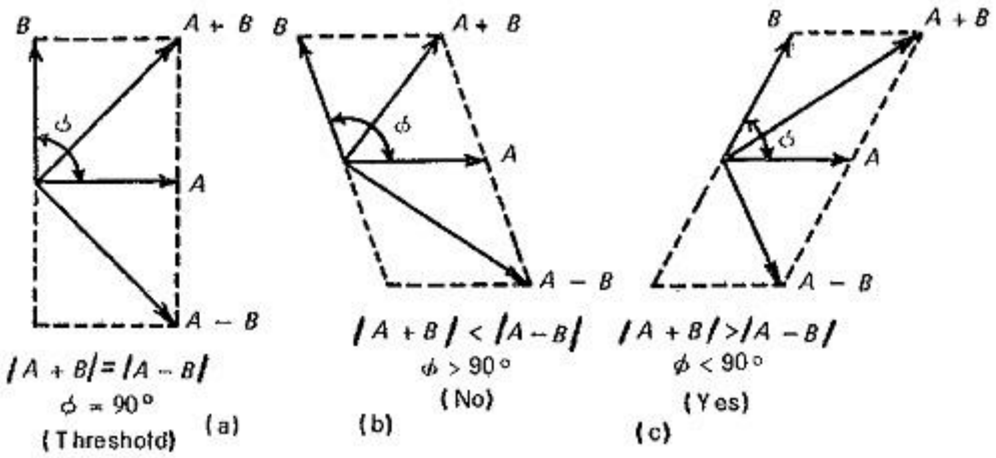


FIGURE 4.3 Phase comparison using an amplitude comparator.

Similarly, a phase comparator working with inputs A and B, operates when A and B have same directional sense. If now the inputs are changed to (A + B) and (A—B) it would operate when (A + B) and (A—B) have the same directional sense, i.e. |A| > |B| as shown in Fig. (4.4). Such comparators are known as **converted comparators**.

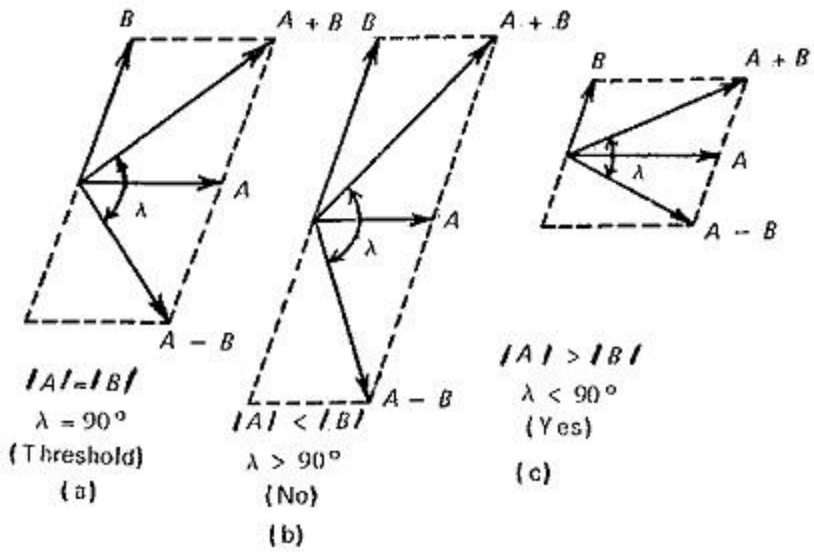
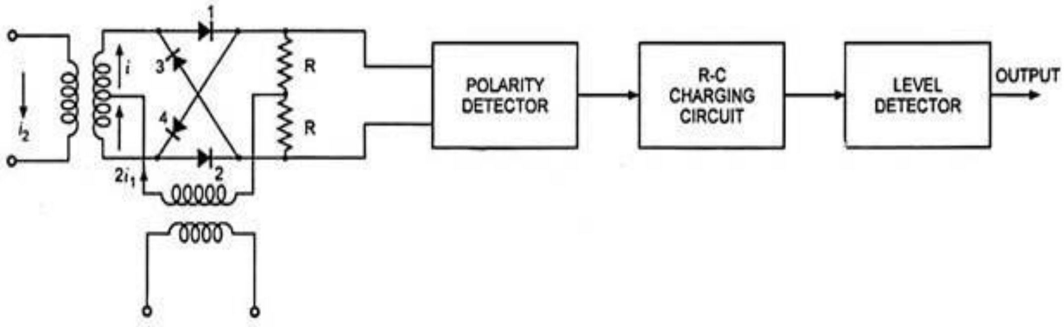


FIGURE 4.4 Amplitude comparison using a phase comparator.

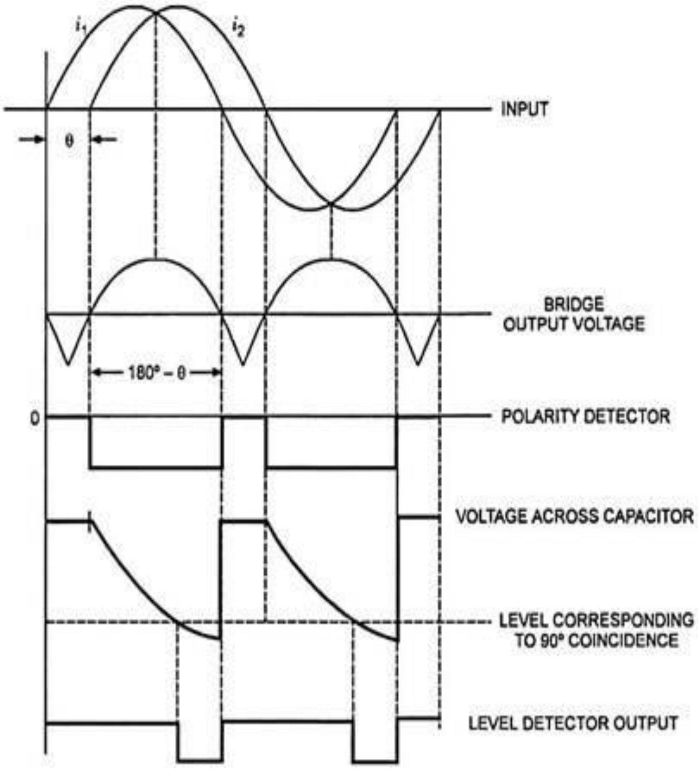
Though a given relay characteristic can be obtained using either of the two comparators, consideration of the constants calculated for required characteristics would indicate which type of comparator is preferable. In general, an inherent comparator is better than the converted type, because if one quantity is very large compared with the other, a small error in the large quantity may cause an incorrect comparison when their sum and difference are supplied as inputs to the relay.

(OR)

5	a)	Discuss the operating principle of a rectifier bridge phase comparator. Ans: It consists of a rectifier phase comparator followed by a polarity detection circuit, R-C charging circuit and a level detector. It is a circulating current bridge whose output current is supplied to a center tapped resistance R-R. The output current is equal to the smaller of the two input currents.	CO2	L1	7M



(a) Basic Circuit



(b) Waveforms

Fig. 3.21. ***Integrating Type Phase Comparator With Rectifier Bridge AND Gate***

The path of the current through the bridge is established by the larger of two input currents and depends upon their relative instantaneous polarity. If i_1 exceeds i_2, the currents will flow in top and bottom rectifiers; 1 and 2 if i_1 is positive and in diagonal rectifiers 3 and 4 if i_1 is negative. When i_2 exceeds i_1 the current flows in rectifiers 1 and 4 if i_2 is positive and in rectifiers 2 and 3 if i_2 is negative. If i_1 and i_2 are of the same polarity, the output voltage (voltage across R-R) is positive, and if of opposite polarity the output voltage will be negative.

It means the output voltage is positive during positive or negative coincidence periods and negative during non-coincidence period. This is illustrated in Fig. 3.21 (b). The operating time with single bridge is less than half a cycle. The bridge gives more circular characteristics than the amplitude comparator bridge and hence it is preferred for mho and directional relays.

b) Depict the schematic diagram of a numerical relay and briefly describe the functions of its various components. CO2 L2 7M

- Ans: Numerical is the relay in which the measured AC quantities are sequentially sampled and converted into numerical data that is mathematically and/or logically processed to make trip decisions.
- Numerical relay is the latest development in the area of power system protection.
- The design and method of operation these relays are different from the conventional electromechanical relays.
- Numerical relays are based on numerical devices such as microprocessors, microcontrollers and digital signal processors etc.
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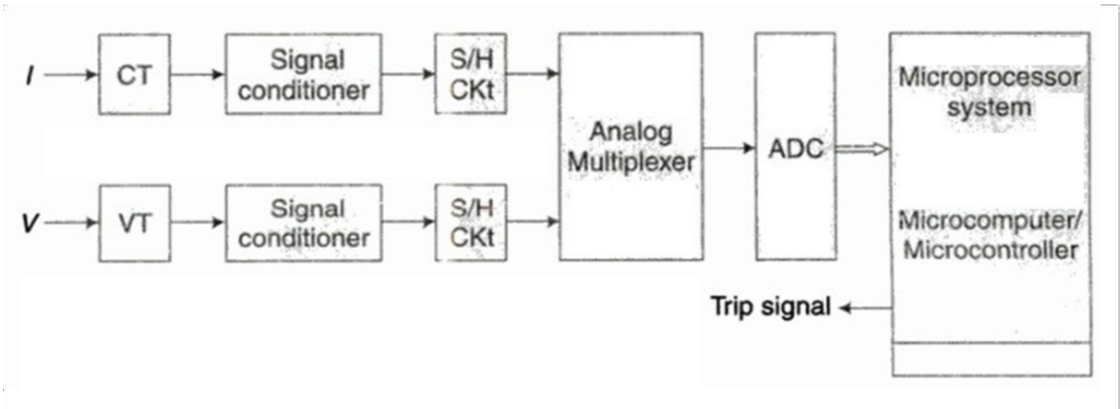


- A relay using digital device like microprocessor for decision making based on digital numbers representing instantaneous values of the signals is called numerical relay, digital relay, microprocessor-based relay or computer-based relay.
- The voltage and current signals in the power system **are** brought down to suitable level using C.T and P.T.
- The signals from C.T and P.T are given to the antialiasing filters which are low pass filters. This removes the unwanted frequency components.
- The signals from the signal conditioning circuits are sampled using sample and hold circuit. With the help of analog multiplexer and ADC, the equivalent digital form of analog input signal is achieved.
- The analog multiplexer gives the facility to accommodate a larger number of input signals.
- The digital output of ADC is given to microprocessor where it is stored in the memory.
- This signal is processed with the help of numerical relaying algorithm and accordingly trip decision is made.
- The trip signal is digital signal hence converted to analog using digital to analog converter (DAC).This tripping analog signal is given to the trip coil of a relay.

Characteristics

Compact design and lower cost due to integration of many functions in to one relay

High availability even with less maintenance due to integral self-monitoring

- No drift (aging) of measuring characteristics due to fully numerical processing

- High measuring accuracy due to digital filtering and optimized measuring algorithms
- Many integrated add-on functions, for example, for load monitoring and event/fault recording
- Local operation keypad and display designed to modern ergonomic criteria (Menu- driven human interfaces)

➢

Unit-III

6	a)	What do you understand by field suppression of an alternator? How is it achieved?	CO3	L1	7M

Ans: It is a method of discharging stored energy in the field through a resistor. • Whenever a fault occurs in the alternator winding, its C.B is tripped.

• But fault remains there since the voltage is induced in the generator with the help of field.

• Hence the field C.B needs to be opened and the stored energy in the field winding is to be discharged through a resistor.

• This discharge resistor is to be connected in parallel to the field winding before the field C.B is opened.

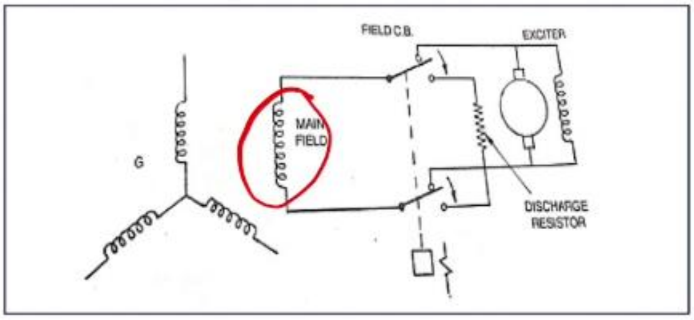


Fig (a) Principle of Field Suppression

	b)	Which type of protective scheme is employed for the protection of a large power transformer against short-circuits? With neat sketches discuss its working principle.	CO3	L1	7M

Ans:

Differential Protection of Transformer:

Differential protection of transformer is also known as Merz-price protection or circulating current protection used for protecting the transformer against phase-to-phase faults and phase to ground faults. The principle of operation of this protection scheme is based on the comparison of currents entering and leaving the transformer. The below shows the arrangement of percentage differential relaying as used for a star-delta transformer.

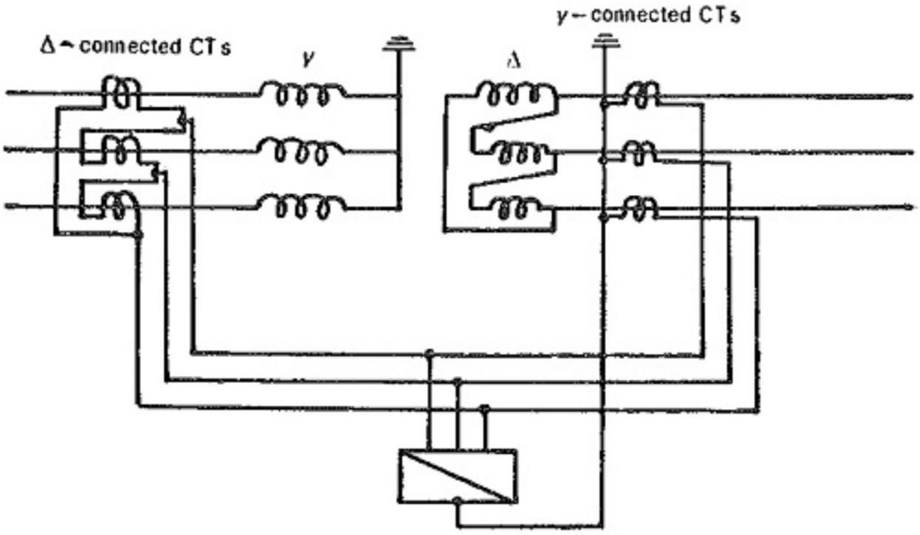


FIGURE 6.1 Differential protection for a Y-Δ power transformer.

The CTs on the delta side of the transformer is connected in star and on the star side they are connected in delta. Because the line currents of star/delta power transformer have a phase shift of 30°. It is required that this phase displacement must be made zero by connecting the CTs in that fashion.

This means that for internal faults the line currents of the two CTs are such that the difference of currents is double the total current and is fed to the relay operating coil and the relay operates. For all external faults, the line currents of the two CTs should be equal in magnitude and in phase opposition so that the difference of the currents is zero, which makes the relay inoperative.

(OR)

7	a)	What type of protection scheme is used for the protection of an alternator during earth fault and Short circuits.	CO3	L1	7M

Ans:

The most common system used for the protection of stator winding faults employs circulating-current principle (Refer back to Art. 21.18). In this scheme of Differential Protection of Alternators, currents at the two ends of the protected section are compared. Under normal operating conditions, these currents are equal but may become unequal on the occurrence of a fault in the protected section. The difference of the currents under fault conditions is arranged to pass through the operating coil of the relay. The relay then closes its contacts to isolate protected section from the system. This form of protection is also known as **Merz-Price Circulating Current Scheme**.

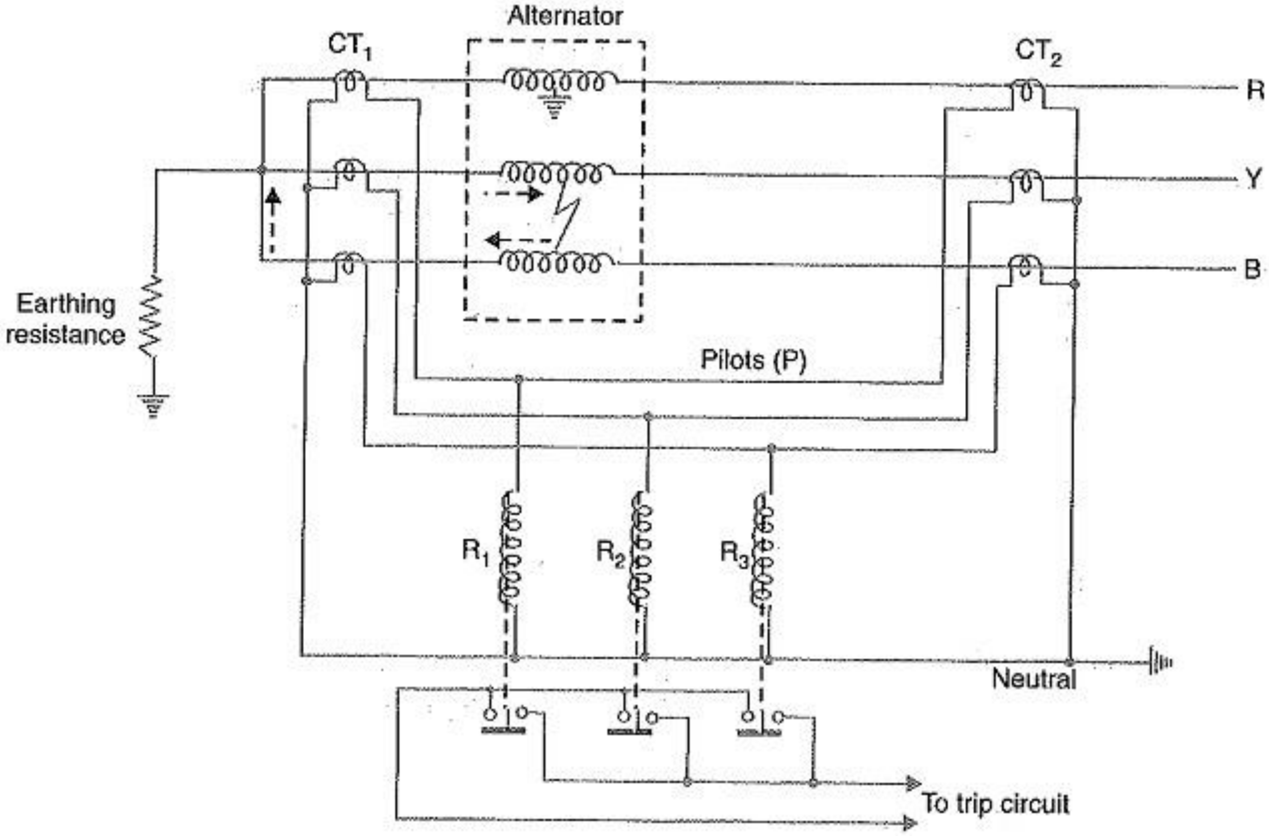


Fig. 22.2

Schematic arrangement: Fig. 22.2 shows the schematic arrangement of Differential Protection of Alternators for a 3-phase alternator. Identical current transformer pairs CT_1 and CT_2 are placed on either side of each phase of the stator windings. The secondaries of each set of current transformers are connected in star ; the two neutral points and the corresponding terminals of the two star groups being connected together by means of a four-core pilot cable. Thus there is an independent path for the currents circulating in each pair of current transformers and the corresponding pilot P.

The relay coils are connected in star, the neutral point being connected to the current-transformer common neutral and the outer ends one to each of the other three pilots. In order that burden on each current transformer is the same, the relays are connected across equipotential points of the three pilot wires and these equipotential points would naturally be located at the middle of the pilot wires. The relays are generally of electromagnetic type and are arranged for instantaneous action since fault should be cleared as quickly as possible.

Operation: Referring to Fig. 22.2, it is clear that the relays are connected in shunt across each circulating path. Therefore, the circuit of Fig. 22.2 can be shown in a simpler form in Fig. 22.3. Under normal operating conditions, the current at both ends of each winding will be equal and hence the currents in the secondaries of two CTs connected in any phase will also be equal. Therefore, there is balanced circulating current in the pilot wires and no current flows through the operating coils (R_1, R_2 and R_3) of the relays. When an earth-fault or phase-to-phase fault occurs, this condition no longer holds good and the differential current flowing through the relay circuit operates the relay to trip the circuit breaker.

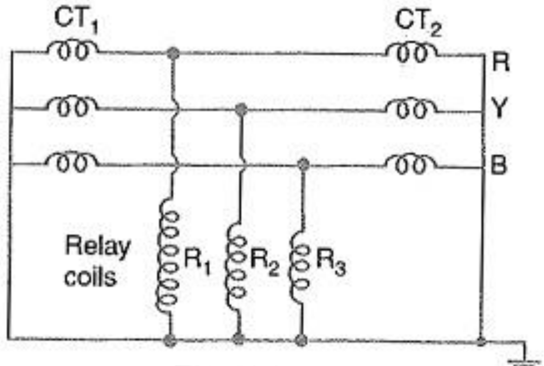


Fig. 22.3

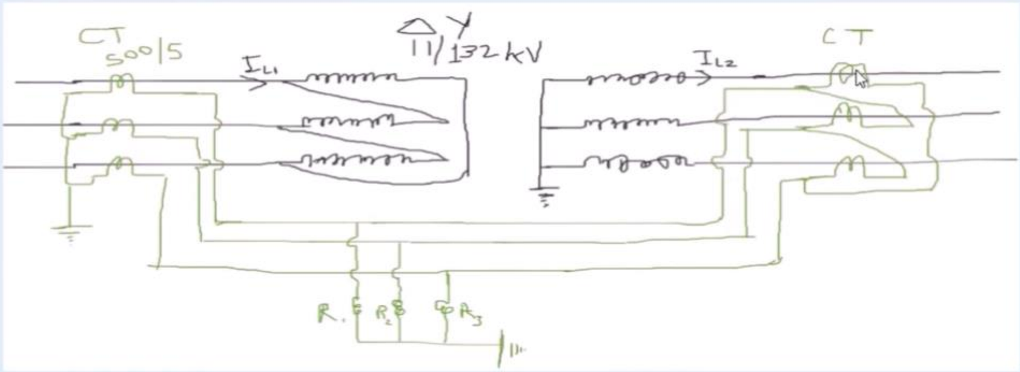
(i) Suppose an earth fault occurs on phase R due to breakdown of its insulation to earth as shown in Fig. 22.2. The current in the affected phase winding will flow through the core and frame of the machine to earth, the circuit being completed through the neutral earthing resistance. The currents in the secondaries of the two CTs in phase R will become unequal and the difference of the two currents will flow through the corresponding relay coil (i.e. R_1), returning via the neutral pilot. Consequently, the relay operates to trip the circuit breaker.

(ii) Imagine that now a short-circuit fault occurs between the phases Y and B as shown in Fig. 22.2. The short-circuit current circulates via the neutral end connection through the two windings and through the fault as shown by the dotted arrows. The currents in the secondaries of two CTs in each affected phase will become unequal and the differential current will flow through the operating coils of the relays (i.e. R_2 and R_3) connected in these phases. The relay then closes its contacts to trip the circuit breaker.

It may be noted that the relay circuit is so arranged that its energizing causes (i) opening of the breaker connecting the alternator to the bus-bars and (ii) opening of the field circuit of the alternator.

b) A three-phase, 11 kV/132 kV, D-Y connected power transformer is protected by differential protection. The CTs on the LV side have a current ratio of 500/5. What must be the current ratio of the CTs on the HV side and how should they be connected. CO3 L3 7M

Ans:



Let I_{L1} = Line current in primary winding of transformer

I_{L2} = Line current in secondary winding of transformer

Let I_{L1} = Line current in primary winding of transformer
I_{L2} = Line current in secondary winding of transformer

Then we know for a transformer, $\sqrt{3}\, V_{L1}\, I_{L1} = \sqrt{3}\, V_{L2}\, I_{L2}$

$$\sqrt{3} * 11 * I_{L1} = \sqrt{3} * 132 * I_{L2}$$

Now if I_{L1} = 500 (assumed), then

$$I_{L2} = 41.66 \text{ A.}$$

Since CTs on primary side are Star Connected, 5A current flows in pilot which will be the line current for Delta connected CTs present on secondary side of power transformer & hence the phase current for CT will be $5/\sqrt{3}$

Therefore, The CT ratio for CTs on HV side will be $41.66/5/\sqrt{3}$ or 72.15/5

Unit-IV

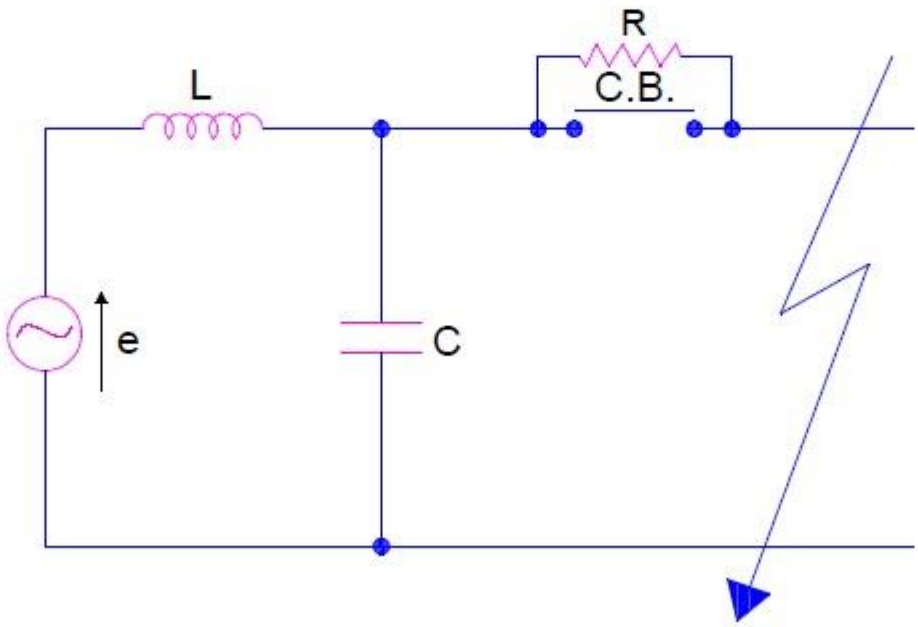
8 a) What is resistance switching? Derive the expression for critical resistance in terms of system inductance and capacitance, which gives no transient oscillation. CO4 L1 7M

Ans:

Resistance Switching in Circuit Breaker refers to a method adopted for dampening the over voltage transients due to current chopping, capacitive current breaking etc. In this method, a shunt resistance is connected across the contacts of circuit breaker.

How does Resistance Switching Work?

Let us consider a circuit and connect a shunt resistance R across the contacts of the breaker as shown below. Suppose a fault occurs on the line. Because of the occurrence of fault, the contacts of breaker will open and an arc will stuck between the contacts.

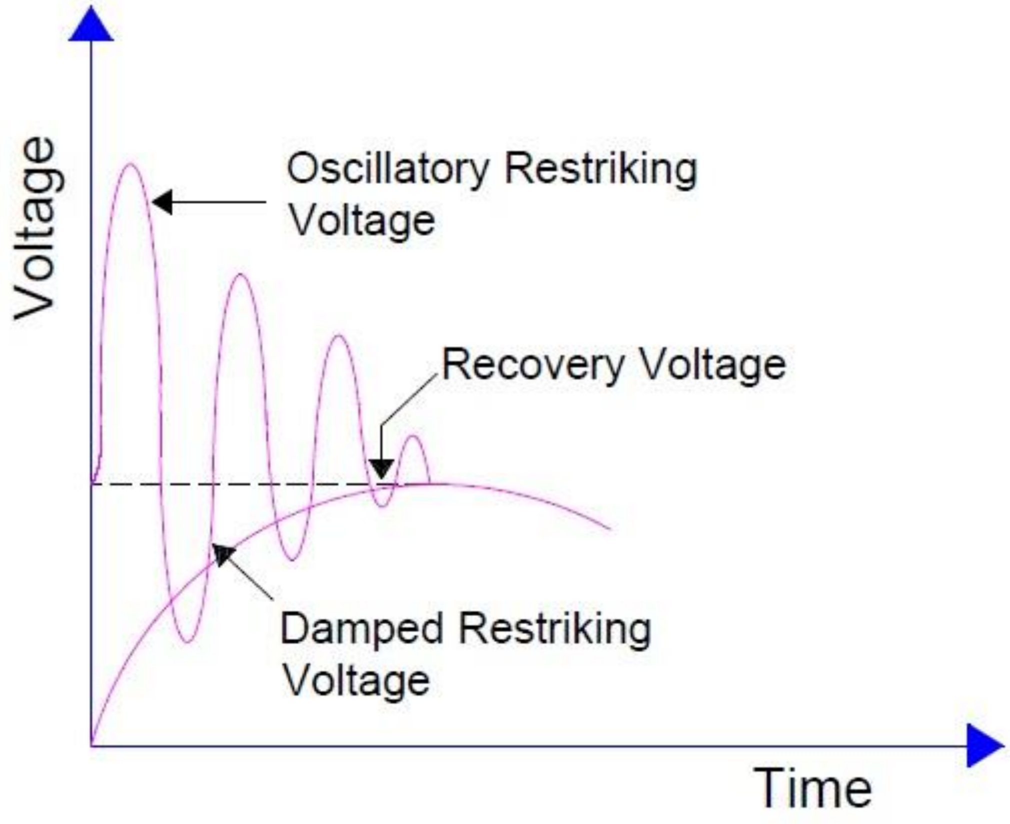


Since the contacts of breaker are shunted by resistance R, therefore a part of arc current will flow through this resistance R. Due to this the magnitude of arc current will reduce which in turn will result in increase in the rate of de-ionization of arc path. In this way, the arc resistance increases. This increased arc resistance leads to further increases in the current through the shunt resistance R. Thus again, the arc current will reduce and hence the arc resistance increases. This cumulative process will continue till the magnitude of arc current becomes so low that it is not able to maintain the arc. Thus the arc extinguishes and the current is interrupted by the breaker.

Resistance Switching also reduces the oscillatory growth of Re-striking Voltage. The natural frequency of the circuit shown above is given by

$f_n = (1/2\pi)\sqrt{(1/LC - 1/4R^2C^2)}$

The main role of shunt resistance R is to limit the growth of re-strike voltage and cause it to grow exponentially up to recovery voltage. If the value of R is so selected that the circuit becomes critically damped then re-strike voltage rises exponentially till recovery voltage is reached.



The value of R for critical damping can be find as

$1/LC - 1/4R^2C^2 = 0$

$\Rightarrow 1/LC = 1/4R^2C^2$

$\Rightarrow L = 4R^2C$

$\Rightarrow R^2 = L / 4C$

$\Rightarrow \mathbf{R = 0.5 \sqrt{(L/C)}}$

Thus the advantages of resistance switching are as follows:

- It reduces the rate of rise of re-striking voltage and the peak value of re-striking voltage.
- Resistance Switching helps to reduce the voltage transient surge during current chopping and capacitive current breaking.

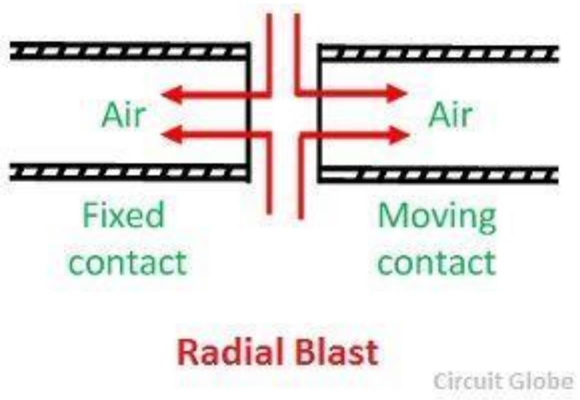
b) List the different types of air blast circuit breaker? Discuss their operating principle and area of applications. CO4 L2 7M

Ans:

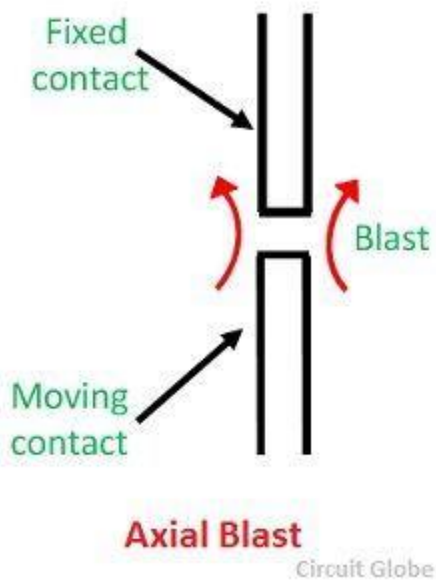
Types of Air Blast Circuit Breaker

All air blast circuit breakers follow the principle of separating their contacts in a flow of arc established by the opening of a blast valve. The arc which is drawn is usually rapidly positioned centrally through a nozzle where it is kept to a fixed length and is subjected to the maximum range by the air flow. The air blast circuit breakers according to the type of flow of blast of compressed around the contacts are of three types namely axial, radial and cross blast.

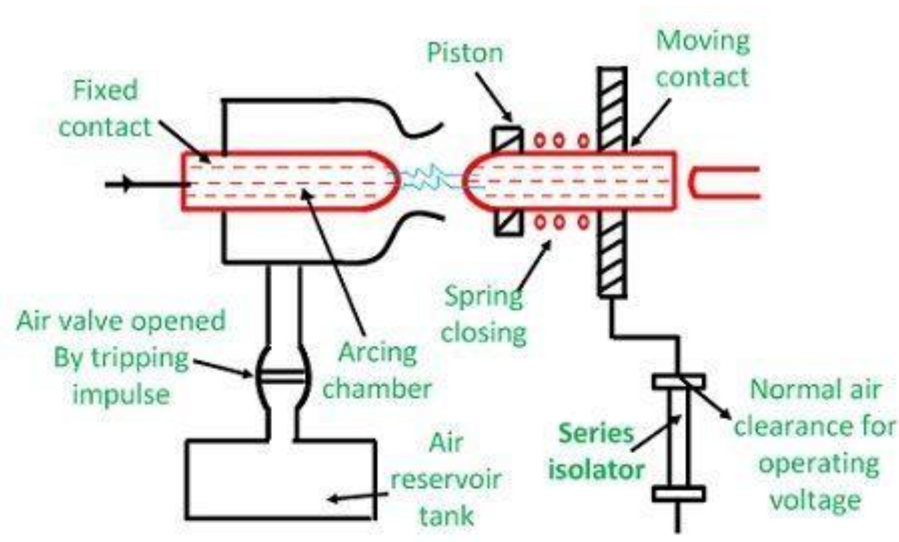
Axial blast Air Circuit Breaker – In the air blast circuit breaker, the flow of air is longitudinal along the arc. Air blast circuit breaker may be a single blast or double blast. Breaking employing double blast arrangement are sometimes called radial blast circuit breakers as the air blast flows radially into the nozzle or space between the contacts.



The essential feature of air blast circuit breaker is shown above. The fixed and moving contacts are kept in a closed position by spring pressure under normal operating conditions. The air reservoir tank is connected to the arc chamber through an air valve, which is opened by a triple impulse.



When the fault occurs, the tripling impulse causes opening of the air valve connecting the reservoir to the arcing chamber. The air entering the arc chamber exerts pressure on the moving contacts which moves when the air pressure exceeds the spring force.

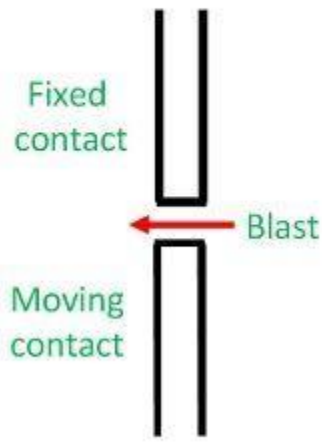


Axial Blast Air Circuit Breaker

 The contacts are separated, and an arc is developed between them. The air flowing at a great speed axially along the arc cause removal of heat from the edge of the arc and the diameter of the arc reduced to a very small value at current zero.

Thus, the arc is interrupted, and the space between the contact is flushed with fresh air flowing through the nozzle. The flow of fresh air removes the hot gasses between the contact space and rapidly build up the dielectric strength between them.

Cross Blast Air Circuit Breaker – In such breaker, an arc blast is directed at right angles to the arc. The schematic representation of the cross principle of cross blast air circuit breaker is given in the figure below. A moving contact arm is operated in close spaces to draw an arc which is forced by a transverse blast of air into the splitter plates, thereby lightening it to the point when it cannot restrike after zero current.



Cross Blast

 Resistance switching is not normally required as the lightening of arc automatically introduces some resistance to control the restriking voltage transient but if extra resistance is thought desirable. It is possible to introduce it by connecting it in the section across the arc splitter.

(OR)

9 a) Expound the phenomenon of current chopping in a circuit breaker. What measures are taken to reduce it? CO4 L2 7M

Ans:

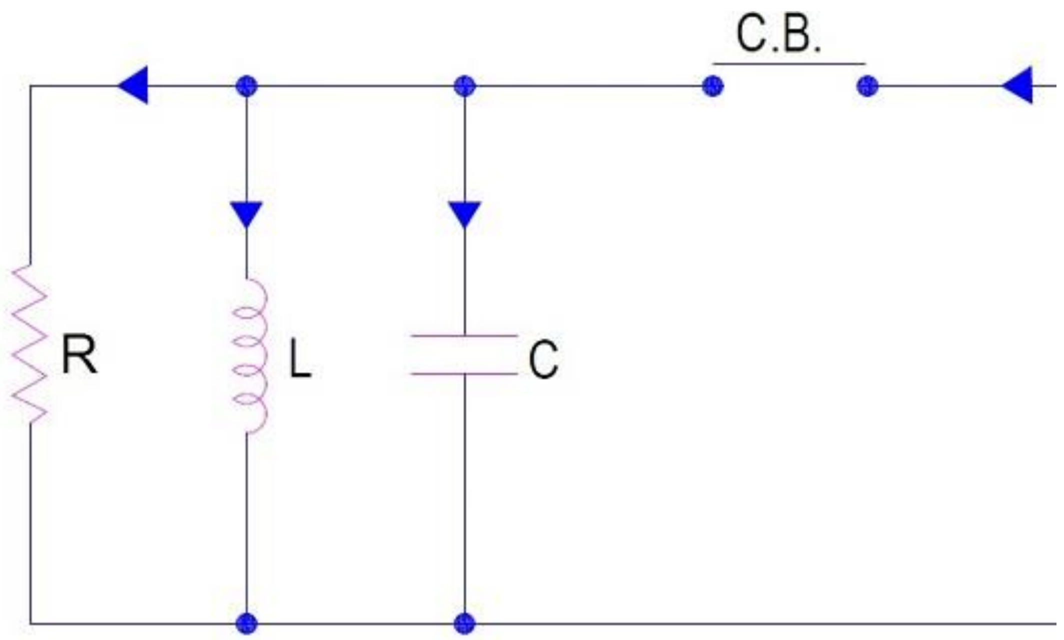
Current Chopping in circuit breaker is defined as a phenomena in which current is forcibly interrupted before the natural current zero. Current Chopping is mainly observed in Vacuum Circuit Breaker and Air Blast Circuit Breaker. There is no such phenomena in Oil Circuit Breaker. Current chopping is predominant while switching Shunt Reactor or unloaded Transformer.

Theory of Current Chopping

Generally the arc extinction in a circuit breaker take place at natural current zero. But this is true if the capacity of the breaker to extinguish the arc is varies with the level of fault current. This means that, the arc extinction capability of breaker will always ensure that arc extinction is taking place at natural current zero.

Now, let us assume Air Blast Circuit Breaker. In Air Blast Circuit Breaker or Vacuum Circuit Breaker, the fault clearing capacity is fixed and independent of the fault current level. In this case, when breaker is used to break the circuit of unloaded transformer or shunt reactor, the current will be brought to zero well before the natural current zero. This is because, the breaker is interrupting only the magnetizing current which is very less compared to full load current or fault current. As the capability of breaker arc extinction is high enough, therefore the low magnetizing current will be brought to zero before the natural current zero position. This phenomena is known as Current Chopping. Let us understand current chopping in detail.

Consider a shunt reactor as shown in figure below.

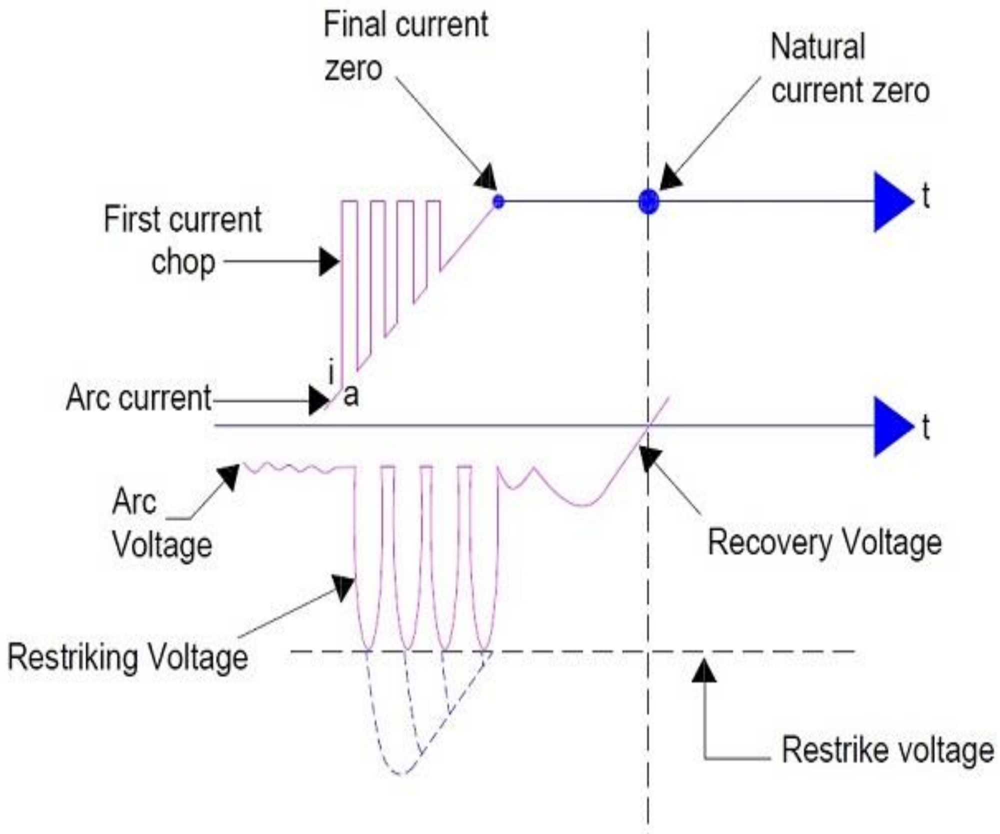


In the figure above, L is the inductance of shunt reactor, C is the capacitance of winding and R is for eddy current loss in the reactor. Breaker in the figure above is Air Blast Circuit Breaker.

We know that shunt reactor always takes magnetizing current. This magnetizing current is, of course, low. Under normal condition, the current flowing through the reactor is I (say) and hence the stored magnetic energy in it is (LI^2 / 2). But as soon as the breaker is open, current chopping will take place and the current through the reactor becomes zero. Due to this sudden drop of current through the inductor, a high voltage will be developed across it according to Faraday's Law. Therefore, the voltage across the capacitor will also rise. Now, the question arises, where did the store energy of reactor go?

The stored energy in the inductance of reactor is basically transferred to the capacitor. Therefore mathematically we can write as

$LI^2 / 2 = CV^2 / 2$
Here V = Voltage across the capacitor
Thus, $V = I \sqrt{(L/C)}$
This is the prospective voltage across the capacitor during current chopping. Notice that this prospective voltage is above the natural voltage of the system. This means that there will be a high voltage stress on the shunt reactor during current chopping. Note that the prospective voltage V is directly proportional to the value of current chopped and the surge impedance of the reactor.
Thus we see that, the magnitude of V is quite high. Again, if this voltage V is high enough, then it may lead to the restrike of arc in the breaker and thus current again start to flow through the circuit. Again, there will be chopping of current and but this time the level of current chopped will reduce and therefore the voltage stress on the reactor is less. Thus a number of current chopping will take place till the prospective voltage become low enough to restrike the arc.

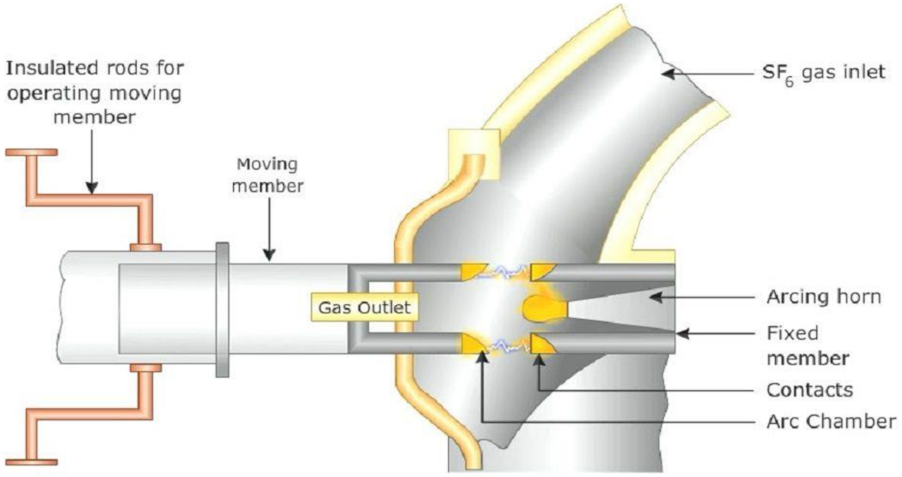


Carefully observe the figure above. In the figure you can see, 4 current chopping. In each current chopping the magnitude of current reduces. This is because of dampening effect of losses in the equipment like eddy current loss and hysteresis loss.

b) Discuss the arc extinction phenomenon in SF6 circuit breakers. CO4 L1 7M

Ans: Sulphur Hexafluoride(SF6) circuit breaker:

In SF6 circuit breakers, sulphur hexafluoride (SF6) gas is used as the arc quenching medium. The SF6 is an electro-negative gas and has a strong tendency to absorb free electrons. The contacts of the breaker are opened in a high-pressure flow of SF6 gas and an arc is struck between them. The conducting free electrons in the arc are rapidly captured by the gas to form relatively immobile negative ions. This loss of conducting electrons in the arc quickly builds up enough insulation strength to extinguish the arc. The SF6 circuit breakers have been found to be very effective for high power and high voltage service.



Construction of SF6 circuit breaker:

The figure above shows the parts of a typical **SF6 circuit breaker**. It consists of fixed and moving contacts enclosed in a chamber (called arc interruption chamber) containing SF6 gas. This chamber is connected to the SF6 gas reservoir. When the contacts of breaker are opened, the valve mechanism permits a high-pressure SF6 gas from the reservoir to flow towards the arc interruption chamber.

The fixed contact is a hollow cylindrical current carrying contact fitted with an arcing horn. The moving contact is also a hollow cylinder with rectangular holes in the sides to permit the SF6 gas to let out through these holes after flowing along and across the arc. The tips of fixed contact, moving a contact and arcing horn are coated with copper-tungsten arc-resistant material. Since SF6 gas is costly, it is reconditioned and reclaimed by a suitable auxiliary system after each operation of the breaker.

Working Principle of SF6 circuit breaker:

In the closed position of the **SF6 circuit breaker**, the contacts remain surrounded by SF6 gas at a pressure of about 2·8 kg/cm2. When the breaker operates, the moving contact is pulled apart and an arc is struck between the contacts. The movement of the moving contact is synchronized with the opening of a valve which permits SF6 gas at 14 kg/cm2 pressure from the reservoir to the arc interruption chamber.

The high-pressure flow of SF6 rapidly absorbs the free electrons in the arc path to form immobile negative ions which are ineffective as charge carriers. The result is that the medium between the contacts quickly builds up high dielectric strength and causes the extinction of the arc. After the breaker operation (i.e., after arc extinction), the valve is closed by the action of a set of springs.

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