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DEPARTMENT OF ELECTRICAL ENGINEERING

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# Lecture notes on Electrical Power System Protection

Submitted By
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# Short/Interview/Viva Questions

### What are the functions of protective relays

To detect the fault and initiate the operation of the circuit breaker to isolate the defective element from the rest of the system, thereby protecting the system from damages consequent to the fault.

### Give the consequences of short circuit.

Whenever a short-circuit occurs, the current flowing through the coil increases to an enormous value. If protective relays are present , a heavy current also flows through the relay coil, causing it to operate by closing its contacts.The trip circuit is then closed , the circuit breaker opens and the fault is isolated from the rest of the system. Also, a low voltage may be created which may damage systems connected to the supply.

### Define protected zone.

Are those which are directly protected by a protective system such as relays, fuses or switchgears.If a fault occurring in a zone can be immediately detected and or isolated by a protection scheme dedicated to that particular zone.

### What are unit system and non unit system?

A unit protective system is one in which only faults occurring within its protected zone are isolated.Faults occurring elsewhere in the system have no influence on the operation of a unit system.A non unit system is a protective system which is activated even when the faults are external to its protected zone.

### What is primary protection?

It is the protection in which the fault occurring in a line will be cleared by its own relay and circuit breaker.It serves as the first line of defence.

### What is back up protection?

It is the second line of defence , which operates if the primary protection fails to activate within a definite time delay.

**Name the different kinds of over current relays.**

Induction type non-directional over current relay,Induction type directional over current relay & current differential relay.

**Define energizing quantity.**

It refers to the current or voltage which is used to activate the relay into operation.

**Define operating time of a relay.**

It is defined as the time period extended from the occurrence of the fault through the relay detecting the fault to the operation of the relay.

**Define resetting time of a relay.**

It is defined as the time taken by the relay from the instant of isolating the fault to the moment when the fault is removed and the relay can be reset.

**What are over and under current relays?**

Overcurrent relays are those that operate when the current in a line exceeds a predetermined value. (eg: Induction type non-directional/directional overcurrent relay, differential overcurrent relay)whereas undercurrent relays are those which operate whenever the current in a circuit/line drops below a predetermined value.(eg: differential over-voltage relay)

**Mention any two applications of differential relay.**

Protection of generator & generator transformer unit; protection of large motors and busbars .

**What is biased differential bus zone reduction?**

The biased beam relay is designed to respond to the differential current in terms of its fractional relation to the current flowing through the protected zone. It is essentially an over-current balanced beam relay type with an additional restraining coil. The restraining coil produces a bias force in the opposite direction to the operating force.

**What is the need of relay coordination?**

The operation of a relay should be fast and selective, i.e, it should isolate the fault in the shortest possible time causing minimum disturbance to the system. Also, if a relay fails to operate, there should be sufficiently quick backup protection so that the rest of the system is protected. By coordinating relays, faults can always be isolated quickly without serious disturbance to the rest of the system.

**Mention the short comings of Merz Price scheme of protection applied to a power transformer.**

In a power transformer, currents in the primary and secondary are to be compared. As these two currents are usually different, the use of identical transformers will give differential current, and operate the relay under no-load condition. Also, there is usually a phase difference between the primary and secondary currents of three phase transformers. Even CT's of proper turn-ratio are used, the differential current may flow through the relay under normal condition.

**What are the various faults to which a turbo alternator is likely to be subjected?**

Failure of steam supply; failure of speed; overcurrent; over voltage; unbalanced loading; stator winding fault .

**What is an under frequency relay?**

An under frequency relay is one which operates when the frequency of the system (usually an alternator or transformer) falls below a certain value.

**Define the term pilot with reference to power line protection.**

Pilot wires refers to the wires that connect the CT's placed at the ends of a power transmission line as part of its protection scheme. The resistance of the pilot wires is usually less than 500 ohms.

**Mention any two disadvantage of carrier current scheme for transmission line only.**

The program time (ie, the time taken by the carrier to reach the other end-upto .1% mile); the response time of band pass filter; capacitance phase-shift of the transmission line .

**What are the features of directional relay?**

High speed operation; high sensitivity; ability to operate at low voltages; adequate short-time thermal ratio; burden must not be excessive.

**What are the causes of over speed and how alternators are protected from it? Sudden loss of all or major part of the load causes over-speeding in alternators.**

Modern alternators are provided with mechanical centrifugal devices mounted on their driving shafts to trip the main valve of the prime mover when a dangerous over-speed occurs.

**What are the main types of stator winding faults?**

Fault between phase and ground; fault between phases and inter-turn fault involving turns of the same phase winding.

**Give the limitations of Merz Price protection.**

Since neutral earthing resistances are often used to protect circuit from earth-fault currents, it becomes impossible to protect the whole of a star-connected alternator. If an earth-fault occurs near the neutral point, the voltage may be insufficient to operate the relay. Also it is extremely difficult to find two identical CT's. In addition to this, there always an inherent phase difference between the primary and the secondary quantities and a possibility of current through the relay even when there is no fault.

**What are the uses of Buchholz's relay?**

Bucholz relay is used to give an alarm in case of incipient( slow-developing) faults in the transformer and to connect the transformer from the supply in the event of severe internal faults. It is usually used in oil immersion transformers with a rating over 750KVA.

**What are the types of graded used in line of radial relay feeder?**

Definite time relay and inverse-definite time relay.

**Stator faults**

1, Phase to phase faults 2, Phase to earth faults 3, Inter turn faults

(b)1, Earth faults

2, Fault between turns

3, Loss of excitation due to fuel failure

1, Over speed

2, Loss of drive

3, Vacuum failure resulting in condenser pressure rise, resulting in shattering of the turbine low pressure casing

1, Fault on lines

2, Fault on busbars

**Why neutral resistor is added between neutral and earth of an alternator?**

In order to limit the flow of current through neutral and earth a resistor is introduced between them.

**What is the backup protection available for an alternator?**

Overcurrent and earth fault protection is the backup protections.

**What are faults associated with an alternator?**

External fault or through fault

Internal fault

1, Short circuit in transformer winding and connection 2, Incipient or slow developing faults

**What are the main safety devices available with transformer?**

Oil level guage, sudden pressure delay, oil temperature indicator, winding temperature indicator .

**What are the limitations of Buchholz relay?**

Only fault below the oil level are detected.

Mercury switch setting should be very accurate, otherwise even for vibration, there can be a false operation.

The relay is of slow operating type, which is unsatisfactory.

**What are the problems arising in differential protection in power transformer and how are they overcome?**

Difference in lengths of pilot wires on either sides of the relay. This is overcome by connecting adjustable resistors to pilot wires to get equipotential points on the pilot wires.

Difference in CT ratio error difference at high values of short circuit currents that makes the relay to operate even for external or through faults. This is overcome by introducing bias coil.

Tap changing alters the ratio of voltage and currents between HV and LV sides and the relay will sense this and act. Bias coil will solve this.

Magnetizing inrush current appears wherever a transformer is energized on its primary side producing harmonics. No current will be seen by the secondary. CT's as there is no load in the circuit. This difference in current will actuate the differential relay. A harmonic restraining unit is added to the relay which will block it when the transformer is energized.

**What is REF relay?**

It is restricted earth fault relay. When the fault occurs very near to the neutral point of the transformer, the voltage available to drive the earth circuit is very small, which may not be sufficient to activate the relay, unless the relay is set for a very low current. Hence the zone of protection in the winding of the transformer is restricted to cover only around 85%. Hence the relay is called REF relay.

## What is over fluxing protection in transformer?

If the turns ratio of the transformer is more than 1:1, there will be higher core loss and the capability of the transformer to withstand this is limited to a few minutes only. This phenomenon is called over fluxing.

## Why busbar protection is needed?

Fault level at busbar is high

The stability of the system is affected by the faults in the bus zone.

A fault in the bus bar causes interruption of supply to a large portion of the system network.

## What are the merits of carrier current protection?

Fast operation, auto re-closing possible, easy discrimination of simultaneous faults .

## What are the errors in CT?

Ratio error

Percentage ratio error = [(Nominal ratio – Actual ratio)/Actual ratio] x 100 The value of transformation ratio is not equal to the turns ratio.

(b) Phase angle error:

Phase angle =180/π[(ImCos δ-I1Sin δ)/nIs]

## What is field suppression?

When a fault occurs in an alternator winding even though the generator circuit breaker is tripped, the fault continues to fed because EMF is induced in the generator itself. Hence the field circuit breaker is opened and stored energy in the field winding is discharged through another resistor. This method is known as field suppression.

## What are the causes of bus zone faults?

Failure of support insulator resulting in earth fault

Flashover across support insulator during over voltage Heavily polluted insulator causing flashover

Earthquake, mechanical damage etc.

**What are the problems in bus zone differential protection?**

Large number of circuits, different current levels for different circuits for external faults.

Saturation of CT cores due to dc component and ac component in short circuit currents. The saturation introduces ratio error.

Sectionalizing of the bus makes circuit complicated.

Setting of relays need a change with large load changes.

**What is static relay?**

It is a relay in which measurement or comparison of electrical quantities is made in a static network which is designed to give an output signal when a threshold condition is passed which operates a tripping device.

**What is power swing?**

During switching of lines or wrong synchronization surges of real and reactive power flowing in transmission line causes severe oscillations in the voltage and current vectors. It is represented by curves originating in load regions and traveling towards relay characteristics.

**What is a programmable relay?**

A static relay may have one or more programmable units such as microprocessors or microcomputers in its circuit.

**What is CPMC?**

It is combined protection, monitoring and control system incorporated in the static system.

**What are the advantages of static relay over electromagnetic relay? o Low power consumption as low as 1mW**

o No moving contacts; hence associated problems of arcing, contact bounce, erosion, replacement of contacts

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

o 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

o Static relay is compact

o Superior operating characteristics and accuracy

o Static relay can think , programmable operation is possible with static relay

o Effect of vibration is nil, hence can be used in earthquake-prone areas o Simplified testing and servicing. Can convert even non-electrical quantities to electrical in conjunction with transducers.

**What is resistance switching?**

It is the method of connecting a resistance in parallel with the contact space(arc). The resistance reduces the restriking voltage frequency and it diverts part of the arc current. It assists the circuit breaker in interrupting the magnetizing current and capacity current.

**What do you mean by current chopping?**

When interrupting low inductive currents such as magnetizing currents of the transformer, shunt reactor, the rapid deionization of the contact space and blast effect may cause the current to be interrupted before the natural current zero. This phenomenon of interruption of the current before its natural zero is called current chopping.

**What are the methods of capacitive switching?**

Opening of single capacitor bank

Closing of one capacitor bank against another

**What is an arc?**

Arc is a phenomenon occurring when the two contacts of a circuit breaker separate under heavy load or fault or short circuit condition.

**Give the two methods of arc interruption?**

High resistance interruption:-the arc resistance is increased by elongating, and splitting the arc so that the arc is fully extinguished

Current zero method:-The arc is interrupted at current zero position that occurs100 times a second in case of 50Hz power system frequency in ac.

**What is restriking voltage?**

It is the transient voltage appearing across the breaker contacts at the instant of arc being extinguished.

**What is meant by recovery voltage?**

The power frequency rms voltage appearing across the breaker contacts after the arc is extinguished and transient oscillations die out is called recovery voltage.

**What is RRRV?**

It is the rate of rise of restriking voltage, expressed in volts per microsecond. It is closely associated with natural frequency of oscillation.

**What is circuit breaker?**

It is a piece of equipment used to break a circuit automatically under fault conditions. It breaks a circuit either manually or by remote control under normal conditions and under fault conditions.

**Write the classification of circuit breakers based on the medium used for arc extinction?**

Air break circuit breaker

Oil circuit breaker

Minimum oil circuit breaker

Air blast circuit breaker

SF6 circuit breaker

Vacuum circuit breaker

**What is the main problem of the circuit breaker?**

When the contacts of the breaker are separated, an arc is struck between them. This arc delays the current interruption process and also generates enormous heat which may cause damage to the system or to the breaker itself. This is the main problem.

**What are demerits of MOCB?**

Short contact life

Frequent maintenance Possibility of explosion

Larger arcing time for small currents Prone to restricts

**What are the advantages of oil as arc quenching medium?**

It absorbs the arc energy to decompose the oil into gases, which have excellent cooling properties

It acts as an insulator and permits smaller clearance between line conductors and earthed components

**What are the hazards imposed by oil when it is used as an arc quenching medium? There is a risk of fire since it is inflammable. It may form an explosive mixture**

with arc. So oil is preferred as an arc quenching medium.

**What are the advantages of MOCB over a bulk oil circuit breaker?**

It requires lesser quantity of oil

It requires smaller space

There is a reduced risk of fire

Maintenance problem are reduced

**What are the disadvantages of MOCB over a bulk oil circuit breaker?**

The degree of carbonization is increased due to smaller quantity of oil

There is difficulty of removing the gases from the contact space in time

The dielectric strength of the oil deteriorates rapidly due to high degree of carbonization.

**What are the types of air blast circuit breaker?**

Arial-blast type

Cross blast Radial-blast

**What are the advantages of air blast circuit breaker over oil circuit breaker?**

o The risk of fire is diminished

o The arcing time is very small due to rapid buildup of dielectric strength between contacts

o The arcing products are completely removed by the blast whereas oil deteriorates with successive operations

**What are the demerits of using oil as an arc quenching medium?**

The air has relatively inferior arc quenching properties

The air blast circuit breakers are very sensitive to variations in the rate of rise of restriking voltage

Maintenance is required for the compression plant which supplies the air blast

**What is meant by electro negativity of SF6 gas?**

SF6 has high affinity for electrons. When a free electron comes and collides with a neutral gas molecule, the electron is absorbed by the neutral gas molecule and negative ion is formed. This is called as electro negativity of SF6 gas.

**What are the characteristic of SF6 gas?**

It has good dielectric strength and excellent arc quenching property. It is inert, non-toxic, non inflammable and heavy. At atmospheric pressure, its dielectric strength is 2.5 times that of air. At three times atmospheric pressure, its dielectric strength is equal to that of the transformer oil.

**Write the classifications of test conducted on circuit breakers.**

Type test

Routine test Reliability test

Commissioning test

**What are the indirect methods of circuit breaker testing?**

o Unit test

o Synthetic test

o Substitution testing o Compensation testing o Capacitance testing

**What are the advantages of synthetic testing methods?**

The breaker can be tested for desired transient recovery voltage and RRRV.

Both test current and test voltage can be independently varied. This gives flexibility to the test

The method is simple

With this method a breaker capacity (MVA) of five time of that of the capacity of the test plant can be tested.

**How does the over voltage surge affect the power system?**

The over voltage of the power system leads to insulation breakdown of the equipments. It causes the line insulation to flash over and may also damage the nearby transformer, generators and the other equipment connected to the line.

**What is pick up value?**

It is the minimum current in the relay coil  at which the relay starts to operate.

**Define target.**

It is the indicator used for showing the operation of the relay.

**Define reach.**

It is the distance upto which the relay will cover for protection.

**Define blocking.**

It means preventing the relay from tripping due to its own characteristics or due to additional relays.

**Define a over current relay.**

Relay which operates when the current ia a line exceeds a predetermined value.

**Define an under current relay?**

Relays which operates whenever the current in a circuit drops below a predetermined value.

**Mention any 2 applications of differential relays.**

Protection of generator and generator-transformer unit: protection of large motors and bus bars

**Mention the various tests carried out in a circuit breaker at HV labs. Short circuit tests, Synthetic tests& direct tests.**

**Mention the advantages of field tests.**

The circuit breaker is tested under actual conditions like those that occur in the network.

Special occasions like breaking of charging currents of long lines ,very short line faults ,interruption of small inductive currents etc… can be tested by direct testing only.

**State the disadvantages of field tests.**

The circuit breaker can be tested at only a given rated voltage and network capacity.

The necessity to interrupt the normal services and to test only at light load conditions.

Extra inconvenience and expenses in installation of controlling and measuring equipment in the field.

**Define composite testing of a circuit breaker.**

In this method the breaker is first tested for its rated breaking capacity at a reduced voltage and afterwards for rated voltage at a low current.This method does not give a proper estimate of the breaker performance.

**State the various types of earthing.**

Solid earthing, resistance earthing , reactance earthing , voltage transformer earthing and zig-zag transformer earthing.

**What are arcing grounds?**

The presence of inductive and capacitive currents in the isolated neutral system leads to formation of arcs called as arcing grounds.

**What is arc suppression coil?**

A method of reactance grounding used to suppress the arc due to arcing grounds.

**State the significance of single line to ground fault.**

In single line to ground fault all the sequence networks are connected in series. All the sequence currents are equal and the fault current magnitude is three times its sequence currents.

**What are symmetrical components?**

It is a mathematical tool to resolve unbalanced components into balanced components.

**State the three sequence components.**

Positive sequence components, negative sequence components and zero sequence components.

**Define positive sequence component.**

-has 3 vectors equal in magnitude and displaced from each other by an angle 120 degrees and having the phase sequence as original vectors.

**Define zero sequence component.**

They has 3 vectors having equal magnitudes and displaced from each other by an angle zero degees.

**State the significance of double line fault.**

It has no zero sequence component and the positive and negative sequence networks are connected in parallel.

**Define negative sequence component.**

It has 3 vectors equal in magnitude and displaced from each other by an angle 120 degrees and has the phase sequence in opposite to its original phasors.

**State the different types of faults.**

Symmetrical faults and unsymmetrical faults and open conductor faults. 92. State the various types of unsymmetrical faults.

Line to ground ,line to line  and double line to ground faults

**Mention the withstanding current in our human body.**

9mA

**State the different types of circuit breakers.**

Air ,oil,vacuum circuit breakers.

**Define per unit value.**

It is defined as the ratio of actual value to its base value. 96. Mention the inductance value of the peterson's coil.

$L=1/3\omega c^2$

**Define single line diagram.**

Representation of various power system components in a single line is defined as single line diagram.

**Differentiate between a fuse and a circuit breaker.**

Fuse is a low current interrupting device. It is a copper or an aluminium wire.Circuit breaker is a high current interrupting device and it act as a switch under normal operating conditions.

**How direct tests are conducted in circuit breakers?**

Using a short circuit generator as the source.

Using the power utility system or network as the source.

**What is dielectric test of a circuit breaker?**

It consists of overvoltage withstand test of power frequency lightning and impulse voltages.Testa are done for both internal and external insulation with switch in both open and closed conditions.

## What is protective relay?

It is an electrical device designed to initiate the isolation of a part of the electrical installation, or to operate an alarm signal, in the event of abnormal condition or a fault. In simple words relay is an electrical device that gives signal to isolation device (eg: Circuit Breaker) after sensing the fault and helps to isolate the fault system from the healthy electrical system.

## What are the different relays that employed for protection of apparatus and transmission lines?

The relays that are usually employed for protection of transmission lines include

- Over current relay
- Directional relay
- Distance relay
- Under Voltage relay
- Under-frequency relay
- Thermal relay
- Differential relay
- Phase sequence relays
- pilot relays

## How the electrical power system protection is divided?

The overall system protection is divided into

- Generator protection
- Transformer protection
- Busbar protection
- Transmission line protection and
- Feeder protection

## How relays are connected in the power system?

The relays are connected to the power system through the current transformer (CT) or potential transformer (PT).

## What are different types of principles of operation of electro-mechaical relays?

Eletro-mechanical relays operate by two principles. Electro-magnetic attraction and electro-magnetic induction. In electromagnetic attraction relay plunger is drawn to the solenoid or an armature is attracted to the poles of the electromagnet. In case of electro-magnetic induction, principle of operation is similar to induction motor. Torque is developed by electromagnetic induction principle.

## Action carried out by the relay and circuit breaker during fault condition?

After the relay sensing the fault condition, relay operates and close the trip coils. The effect of this will be circuit breaker operate to open the contacts.

## What is Relay Time?

Relay time is the interval between the occurrence of the fault and the closure of the relay contacts is called relay time.

## What is fault clearance time?

When the fault occurs relay operates and close the trip coils and circuit breaker operates and open the contacts subsequently and fault is cleared. Therefore fault clearance time is the sum of relay operating time and circuit breaker operating time and clearing the fault

## What is Reach?

Distance relay operates whenever the impedance seen (V/I) seen by the relay is less than the specified set value. This impedance or corresponding distance is known as reach of the relay. Reach is the limiting distance covered by the relay for protection of line. Faults beyond the distance (reach of the relay) relay will not operate and should be covered by the other relay.

## What are the fundamental elements of relay?

Basic fundamental elements of the relay are:

- *Sensing element:* It is the measuring element measures the actuating quantity. Actuating quantity is change in current in case of over current relay

- *Comparing element:* It compares the actuating quantity with the relay pre-setting of the relay
- *Control element:* On pick up of the relay control element carryout the final switching operations such as closing the circuit to operate the circuit breaker

**What are the good features of protective relaying?**

Some of the good features for protective relaying are: Reliability, Selectivity, Sensitivity, Simplicity, Speed and economy

**Some of the causes for relay failures?**

Primary reason for relay failure to operate during faults are wrong settings, bad contacts and open circuit in the relay coil.

**Q1 )State any four functions of protective relaying.**

- To disconnect the abnormally operating part so as to avoid the damage within effective operation of the rest of the system.
- To prevent the subsequent faults arising due to the primary fault.
- To disconnect the faulty part as quickly as possible so as to minimize the damage to the faulty part itself.
- To improve system performance, reliability and service continuity

**Q2) Give the consequences of short circuit.**

Whenever a short-circuit occurs, the current flowing through the coil increases to an enormous value. If protective relays are present , a heavy current also flows through the relay coil, causing it to operate by closing its contacts. The trip circuit is then closed , the circuit breaker opens and the fault is isolated from the rest of the system. Also, a low voltage may be created which may damage systems connected to the supply.

**Q3) What are unit system and non unit system?**

A unit protective system is one in which only faults occurring within its protected zone are isolated. Faults occurring elsewhere in the system have no influence on the operation of a unit

system. A non unit system is a protective system which is activated even when the faults are external to its protected zone.

**Q4) List the basic requirements or essential qualities of protective relaying.**

(i)Reliability (ii) selectivity and discrimination (iii) speed and time (iv)sensitivity (v) stability (vi) adequateness

(vii) simplicity and economy.

**What is primary protection?**

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**What is back up protection?**

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**Define energizing quantity.**

It :s to the current or voltage which is used to activate the relay into operation.

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**Define resetting time of a relay.**

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**What are over and under current relays?**

Overcurrent relays are those that operate when the current in a line exceeds a predetermined value. (eg: Induction type non-directional/directional overcurrent relay, differential overcurrent relay)whereas undercurrent relays are those which operate whenever the current in a circuit/line drops below a predetermined value.(eg: differential over-voltage relay)

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The biased beam relay is designed to respond to the differential current in terms of its fractional relation to the current flowing through the protected zone. It is essentially an over current balanced beam relay type with an additional restraining coil. The restraining coil produces a bias force in the opposite direction to the operating force.

**Define pickup value and plug setting multiplier.**

Pickup value: it is the minimum value of an actuating quantity at which relay starts operating. In most of the relays actuating quantity is current in the relay coil and pickup value of current is indicated along with the relay.

Plug setting multiplier: the ratio of actual fault current in the relay coil to the pickup current is called plug setting multiplier(P.S.M.).

**Why the secondary of the C.T. should not be open?**

If the secondary of the C.T. is kept open then current through the secondary becomes zero hence the ampere turns produced by secondary which generally oppose primary ampere turns becomes zero. As there is no counter m.m.f., unopposed primary m.m.f. produce high flux in the core. This produces excessive core loss heating the core. It also produces heavy e.m.f. on primary and secondary side which may damage the insulation of the winding. This is dangerous from the operator point of view as well. Hence the secondary of C.T. should not be open.

**What is pickup current?**

The minimum value of the actuating current at which the relay starts operating is called pickup current of the relay.

## What are the different types of faults in a power system?

Symmetrical faults: the fault which gives rise to equal fault currents in all the lines with displacement of 120° between them. The example is line to line fault i.e. shorting of all three lines.

Unsymmetrical faults: The fault which gives rise to unequal fault currents in all the lines with unequal displacement between them. The example is line ground, line to line, line to line to ground faults.

## What are the causes of faults in a power system?

The various causes are failure of insulation of conductor at one or more places, conducting objects comes in contact with the live part of the system, mechanical failure, excessive internal and external stress, over voltages due to switching surges, lightning strokes, heavy winds and storms, falling of trees on the lines, accidents of vehicles with the towers or poles, perching of birds on the lines, accidental short circuits due to snakes, kites, strings etc.

## What are the various methods of earthing in substations?

- Solid or effective grounding
- Resistance grounding
- Reactance grounding
- Resonant grounding

## Why earth wire is provided in overhead transmission lines?

- To protect the line conductors from direct lightning strokes.
- To reduce the line outages
- To reduce the interference on neighbouring installations.
- To transmit telecommunication signals.

**What is the difference between a short circuit and an overload?**

When there is a short circuit, the impedance at the fault point is almost zero and the voltage at the fault point is zero. The short circuit current is very high. While an overload means the load is higher than the rated load which is specified as the safe load. Thus the current is also higher than the safe load. The overload does not causes damage instantly but if persists for long time, can cause damage to the system.

**Differentiate between a fuse and a circuit breaker.**

Fuse is a low current interrupting device. It is a copper or an aluminium wire. Circuit breaker is a high current interrupting device and it act as a switch under normal operating conditions.

**Define auto re-closing.**

Auto recloser, is a circuit breaker equipped with a mechanism that can automatically close the breaker after it has been opened due to a fault.

**Summarize the functions of isolating switch**.

In sub-stations, it is often desired to disconnect a part of the system for general maintenance and repairs. This is accomplished by an isolating switch or isolator. An isolator is essentially a knife switch and is designed to open a circuit under *no load.* In other words, isolator switches are operated only when the lines in which they are connected carry no current.

**surge absorber. Differentiate it from surge diverter.**

A **surge absorber** is a protective device which reduces the steepness of wave front of a surge by absorbing surge energy. Although both surge diverter and surge absorber eliminate the surge, the manner in which it is done is different in the two devices. The surge diverter diverts

the surge to earth but the surge absorber absorbs the surge energy.

## PART * B

**(i) Describe the Essential Qualities of Protective Relaying. (8 M)**

**Answer: Three main functions/duties:**

1. Safeguard the entire system to maintain continuity of supply

2. Minimize damage and repair costs where it senses fault

3. Ensure safety of personnel. (2 M)

**Necessity:**

Necessary for early detection and localization of faults, prompt removal of faulty equipment from service.

- **Selectivity**: detect, isolate, the faulty item.
- **Stability**: leave all healthy circuits, intact to ensure continuity or supply.
- **Sensitivity**: Detect even the smallest fault, current or system abnormalities and operate correctly at its setting before the fault, irreparable damage.
- **Speed**: operate speedily, when it is called upon to do so, minimizing damage to the surroundings and ensuring safety to personnel.
- meet all of the above requirements, protection must be reliable.
- **Dependable**: must trip when called upon to do so.
- **Secure**: must not trip when it is not supposed to. (6 M)

**(ii) Discuss the Nature and Causes of Faults in a power system. (7M)**

**Various causes of faults**:

- Breaking of conductors or failure of insulation. (1 M)
- Mechanical failure, accidents, excessive internal and external stresses, affects the supply to the neighbouring zone.(1 M)

- The maximum possibility of fault occurrence, transmission lines, greater lengths, exposure to atmospheric conditions. (1 M)
- Deterioration of insulation, perching of birds, accidental short circuiting by snakes, kite strings, three branches etc. (1 M)
- Switching surges or surges caused by lighting.(1 M)
- Fire which destroys the equipment, spreads up in the system and causes total failure.(1 M)

**(iii)Explain the overlapping of protective zones with neat sketch. (13M)**

**Answer :**

**Protective Zones**: Protective relaying scheme, the circuit breakers , appropriate points, power system can be disconnected for repairing work, usual operation and maintenance requirements, under abnormal conditions like short circuits.

- overlapped, no chance of existence of a dead spot in a system. No part of the system is left unprotected. (3 M)
- **Primary and Backup Protection**:
- The backup protection, main protection can fail, reasons : Failure in circuit breaker, Failure in protective relay, Failure in tripping circuit, Failure in d.c tripping voltage.( 5 M)
- Diagram: (3 M)

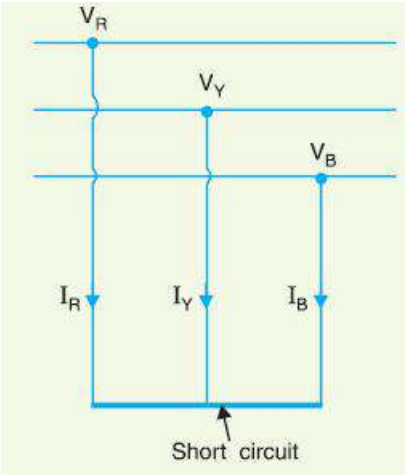
**Various components in protective zone:** Generators, transformers, transmission lines, bus bars, cables, capacitors etc. (2 M)

**(iv) Classify and analyse the different faults in power system. Which of these are more frequent? (13M)**

**Answer :**

- **Types of fault**s: Symmetrical and unsymmetrical faults, Open circuited phases, winding faults, simultaneous faults, cross country earth fault.( 3 M)
- **Symmetrical faults**

Gives rise to symmetrical fault currents, also known as balanced faults, two types: line to line to line to ground (L-L-L-G) and line to line to line (L-L-L). (3 M)




**Unsymmetrical faults:** gives rise to unsymmetrical currents, the magnitude of fault currents in the three lines are different having unequal phase displacement.

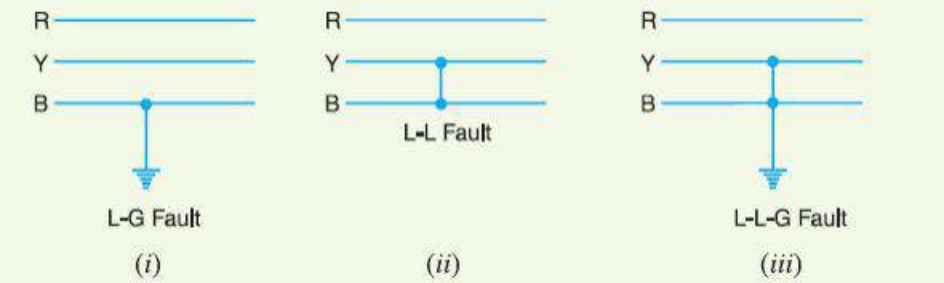
Very common and less severe than symmetrical faults. (7 M)

**Three types**: Line to ground (L-G), line to line (L-L) and double line to ground (LL-G) faults.

**(*i*) Single line-to-ground fault (*L* — *G*):** Between a line and ground. Most common type of fault.

**(*ii*) Line-to-line fault (*L* — *L*):** Between two lines

**(*iii*) Doube line-to-ground fault (*L* — *L* — *G*): Between** two lines and ground.




(v) **Explain the fault current calculation using symmetrical components.(13M)**

**Answer :Page 423 - V.K.Mehta**

**Symmetrical components:**

The positive, negative and zero phase sequence components are called the symmetrical components of the original unbalanced system (Definition- 2 M)

**Operator 'a':**

The operator „a" is one, which when multiplied to a vector rotates the vector through 120º in the anticlockwise direction. ( operator 'a' explanation- 3 M)

$$\begin{aligned}
\overrightarrow{I_R} &= \overrightarrow{I_{R1}} + \overrightarrow{I_{R2}} + \overrightarrow{I_{R0}} \\
\overrightarrow{I_Y} &= \overrightarrow{I_{Y1}} + \overrightarrow{I_{Y2}} + \overrightarrow{I_{Y0}} \\
&= a^2\,\overrightarrow{I_{R1}} + a\,\overrightarrow{I_{R2}} + \overrightarrow{I_{R0}} \\
\overrightarrow{I_B} &= \overrightarrow{I_{B1}} + \overrightarrow{I_{B2}} + \overrightarrow{I_{B0}} \\
&= a\,\overrightarrow{I_{R1}} + a^2\,\overrightarrow{I_{R2}} + \overrightarrow{I_{R0}}
\end{aligned}$$

(vi) **Define the terms pick-up current, Plug setting multiplier and auto reclosure. (6M)** BTL1

**Pick up current:**

The deflecting force, controlling force, the moving parts, initiate to move, to change the position of the contacts in the relay. The current which the relay initiates its operation.(2 M)

**Plug setting multiplier:**

Ratio of fault current in the relay to its pick up current.

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

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

**Auto reclosure:**

Relay receives the fault initiation from the protection relay, triggers the auto reclose function. After tripping the circuit breaker (CB), the Auto reclose function reclose the CB.(2 M)

(vii) **Explain in detail about surge absorbers. ( 13M)**

**Answer :Page 3.38- Bakshi**

**Surge absorber:** Reduce the steepness of wave front, absorbs energy containing in travelling wave. Eliminate the surge, Surge diverter- diverts the surge to earth. (3 M)

Surge absorber using capacitor: Impedance of capacitor inversely proportional to frequency. Used for protection of transformer winding, free from very high stresses. Series combination of resistor and capacitor. Diagram. (4 M)

Parallel combination of resistance and inductance.

Ferranti surge absorber: Inductive coil magnetically coupled, not electrically to a metal shield and steel tank containing it. Filter effect, high frequency currents, prevented from passing freely through the absorber. Energy transferred through mutual induction, heat dissipation. Diagram. (4 M)

Field of application: Near rotating machines or switchgear, across series reactors. (2 M)

## PART*C

1. **Explain the various methods of earthing the neutral point of the power system. (15 M)**

**Answer :Page 1.15- Thiagarajan**

**Grounding:**

➢ Connecting the metallic frame of electrical equipment or some electrical part of the system (e.g. neutral point in a star-connected system) to earth (i.e. soil) (2 M)

**Classifications: (*i*)** Equipment grounding **(*ii*)** System grounding.

**Equipment Grounding:**

Connecting non-current-carrying metal parts (i.e. metallic enclosure) of the electrical equipment to earth (i.e. soil) ,insulation failure, the enclosure remains at earth potential. (1 M)

**System grounding:**

Connecting some electrical part of the power system (e.g. neutral point of a star connected system, one conductor of the secondary of a transformer etc.) to earth (i.e. soil)(1 M)

**Advantages of Neutral Grounding:** (3 M)

**(*i*)** Voltages of the healthy phases do not exceed line to ground voltages *i.e.* they remain nearly constant.

**(*ii*)** The high voltages due to arcing grounds are eliminated.

**(*iii*)** The protective relays can be used to provide protection against earth faults. In case earth fault occurs on any line, the protective relay will operate to isolate the faulty line.

**(*iv*)** The overvoltages due to lightning are discharged to earth.

**(*v*)** Provides greater safety to personnel and equipment.

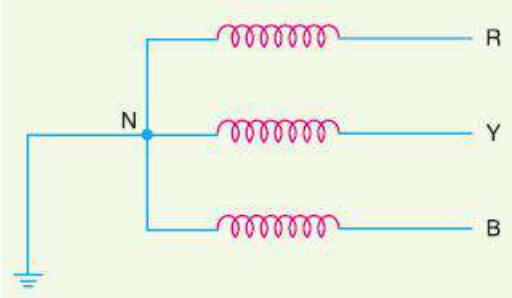
**(*vi*)** Provides improved service reliability.

**(*vii*)** Operating and maintenance expenditures are reduced.

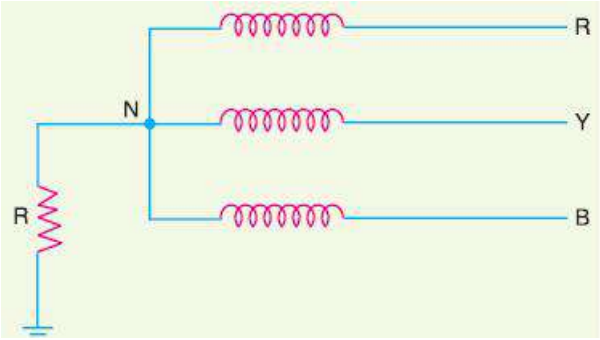
➢ **Methods of Neutral Grounding**

• **Solid Grounding:** When the neutral point of a 3-phase system (e.g. 3- phase generator,

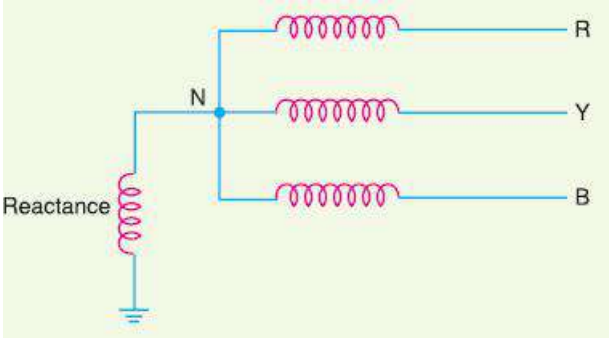
3-phase transformer etc.) is directly connected to earth (i.e. soil) through a wire of negligible resistance and reactance, it is called solid grounding or effective grounding. (2 M)




**Resistance Grounding:** When the neutral point of a 3-phase system (e.g. 3-phase generator, 3-phase transformer etc.) is connected to earth (i.e. soil) through a resistor, it is called resistance grounding. (2 M)

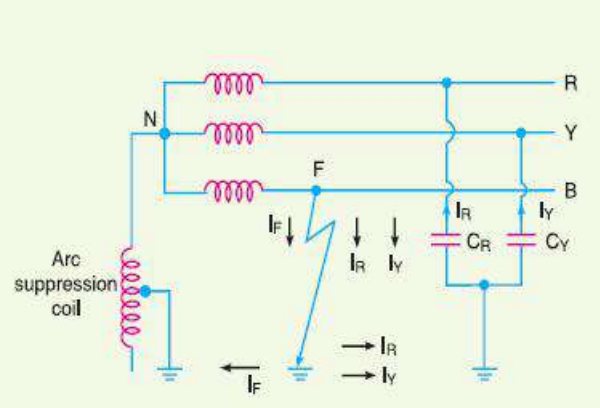



**Reactance Grounding:**In this system, a reactance is inserted between the neutral and ground. (2 M)



**Resonant Groundings/Peterson coil Groundings**

When the value of L of arc suppression coil is such that the fault current $I_F$ exactly balances the capacitive current $I_C$, it is called resonant grounding. (2 M)



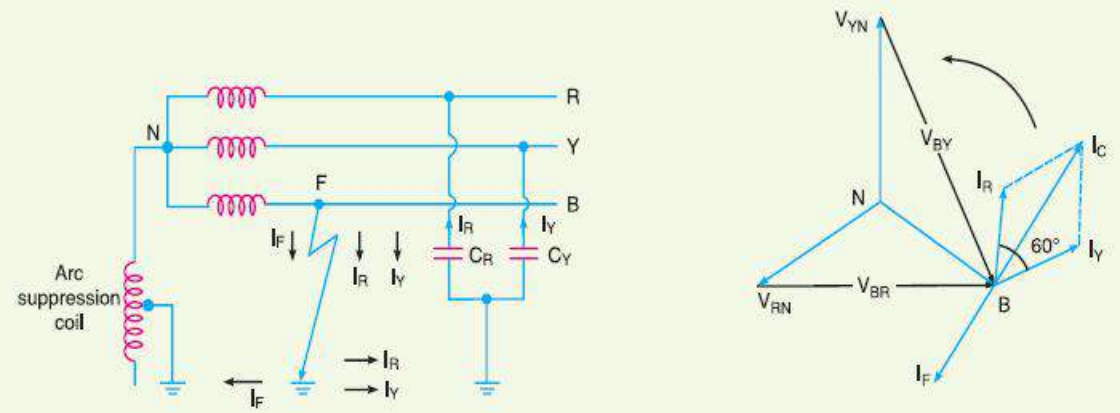

**(2) Write a note on RESONANT GROUNDING (OR) ARC SUPPRESSION COIL GROUNDING (OR) PETERSON COIL (8 M)**

**Answer :Page: 1.21 - Thiagarajan**

- Capacitive currents, responsible for producing arcing grounds, capacitive currents flow, capacitance exists between each line and earth (3 M)
- value of L of arc suppression coil ,fault current $I_f$ exactly balances the capacitive current IC, resonant grounding.

$$L = \frac{1}{3\omega^2 C}$$

(Derivation: 3 M)




**Advantages:**

i. The Peterson coil has the advantages of ungrounded neutral system.

ii. The Peterson coil is completely effective in preventing any damage by an arcing ground.

**Disadvantages.**

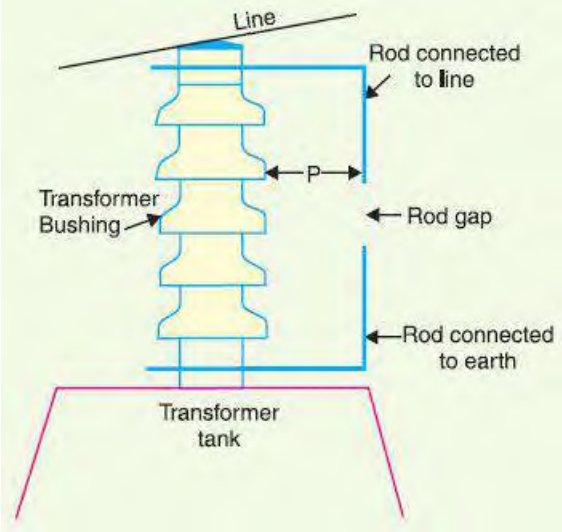
**(*i*)** Due to varying operational conditions, the capacitance of the network changes from time to time. Therefore, inductance *L* of Peterson coil requires readjustment.

**(*ii*)** The lines should be transposed. (2 M)

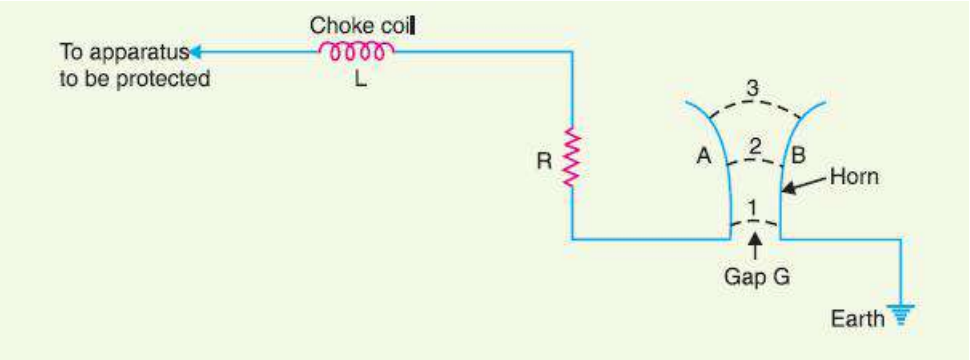
**(3)Analyse the various types of lightning arrestors and working Principle of Lightning arresters. (15 M)**

**Answer :Page: 560 - V.K.Mehta**

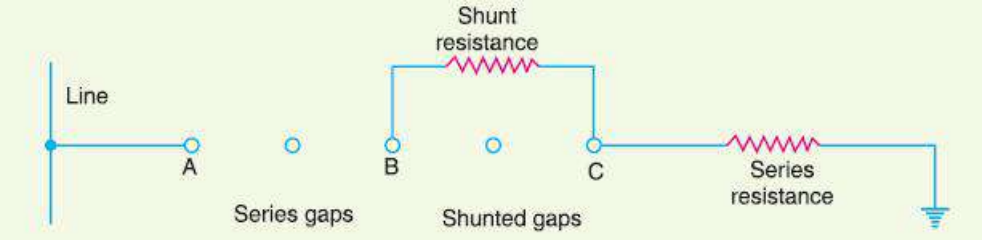
- A lightning arrester or a surge diverted is a protective device, which conducts the high voltage surges on the power system to the ground. (2 M)
- **Rod arrester** : Under normal operating conditions, the gap remains non conducting. On the occurrence of a high voltage surge on the line, the gap sparks over and the surge current is conducted to earth. In this way, excess charge on the line due to the surge is harmlessly conducted to earth. (2 M)




**Horn gap arrester:** Two horn shaped metal rods *A* and *B* separated by a small air gap. One end of horn is connected to the line through a resistance *R* and choke coil

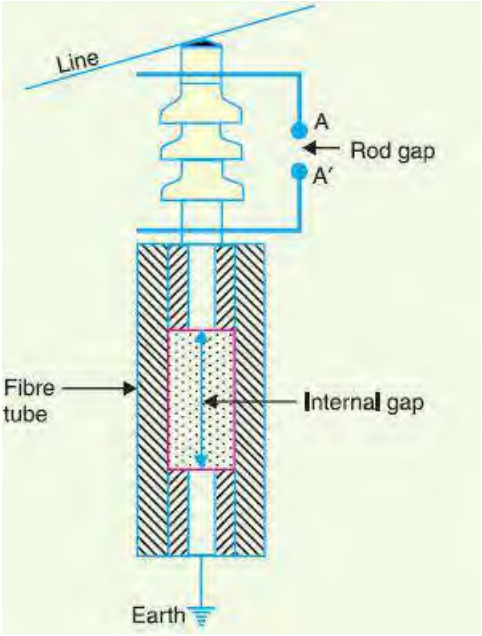



- **Multi gap arrester**



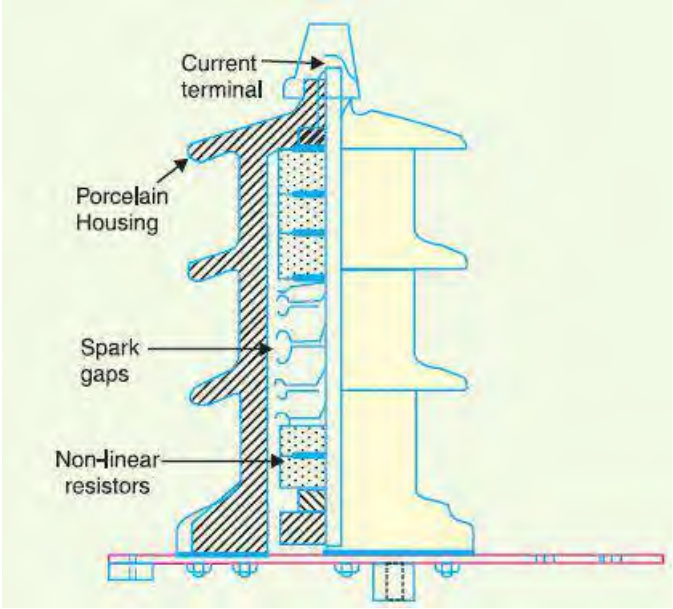

Employed where system voltage does not exceed 33 kV.( 2 M)

- **Expulsion type lightning arrester**




**Valve type lightning arrester:** Two assemblies (*i*) series spark gaps and (*ii*) non-linear resistor discs (made of material such as thyrite or metrosil) in series. The

non-linear elements are connected in series with the spark gaps.( 2 M)




(3) **A balanced 3 phase star connected load is supplied from 3 phase unbalanced supply with negligible internal impedance. Three identical star connected resistors rated for 3300 V, 500 KVA are used as a three phase load. The neutral point is not available. The line**

**voltages of supply are $E_R$= 3960<0$_0$ V, $E_Y$= 3300<-138.6$_0$ V, $E_R$= 2640<124.2$_0$ V. Find the current in R line by the method of symmetrical components. (15 M)**

**Answer :Page 2.23- Bakshi**

$E_{R1}$= 3252.48<-5.05$_0$V (2 M)

$E_{R2}$= 774.18<21.674$_0$ V(2 M)

Converting all line to phase components- (2 M)

R= 21.78 Ω (3M)

$I_R$= 68.5119<-102.879$_0$ V (6 M)

## UNIT II ELECTROMAGNETIC RELAY

Operating principles of relays - the Universal relay – Torque equation – R-X diagram – Electromagnetic Relays – Over current, Directional, Distance, Differential, Negative sequence and Under frequency relays.

### PART * A

**(1) Identify the need of relay coordination.**

The operation of a relay should be fast and selective, ie, it should isolate the fault in the shortest possible time causing minimum disturbance to the system. Also, if a relay fails to operate, there should be sufficiently quick backup protection so that the rest of the system is protected. By coordinating relays, faults can always be isolated quickly without serious disturbance to the rest of the system.

**(2)Mention the short comings of Merz Price scheme of protection applied to apower transformer.**

In a power transformer, currents in the primary and secondary are to be compared. As these two currents are usually different, the use of identical transformers will give differential current, and operate the relay under no-load condition. Also, there is usually a phase difference between the primary and secondary currents of three phase transformers. Even

CT‟s of proper turn-ratio are used, the differential current may flow through the relay under normal condition.

**(3) What are the various faults to which a turbo alternator is likely to be subjected?**

Failure of steam supply; failure of speed; over current; over voltage; unbalanced loading; stator winding fault .

**(4) Define under frequency relay.**

An under frequency relay is one which operates when the frequency of the system (usually an alternator or transformer) falls below a certain value.

**(5) Define the term pilot to power line protection.**

Pilot wires to the wires that connect the CT‟s placed at the ends of a power transmission line as part of its protection scheme. The resistance of the pilot wires is usually

less than 500ohms.

**(6 )Mention any two disadvantage of carrier current scheme for transmission line only.**

The program time (ie, the time taken by the carrier to reach the other end-upto .1% mile); the response time of band pass filter; capacitance phase-shift of the transmission line

**(7 )List the features of directional relay.**

High speed operation; high sensitivity; ability to operate at low voltages; adequate short-time thermal ratio; burden must not be excessive.

**(8 ) What are the causes of over speed and how alternators are protected from it?**

Sudden loss of all or major part of the load causes over-speeding in alternators. Modernalternatorsareprovidedwithmechanicalcentrifugaldevicesmountedontheir driving shafts to trip the main valve of the prime mover when a dangerous over-speed occurs.

**(9 )Explain the main types of stator winding faults?**

Fault between phase and ground; fault between phases and inter-turn fault involving turns of the same phase winding.

**(10) Give the limitations of Merz Price protection.**

Since neutral earthing resistances are often used to protect circuit from earth-fault currents, it becomes impossible to protect the whole of a star-connected alternator. If an earth-fault occurs near the neutral point, the voltage may be insufficient to operate the relay. Also it is extremely difficult to find two identical CT‟s. In addition to this, there always an inherent phase difference between the primary and the secondary quantities and a possibility of current through the relay even when there is no fault.

**(11) State the uses of Buchholz's relay.**

Bucholz relay is used to give an alarm in case of incipient( slow-developing) faults in the transformer and to connect the transformer from the supply in the event of severe internal faults. It is usually used in oil immersion transformers with a rating over 750KVA.

**(12)Mention any two applications of differential relay.**

Protection of generator & generator transformer unit; protection of large motors and bus bars.

**(13) Define differential relay.**

A differential relay is defined as the relay that operates when the phasor difference of two or more similar electrical quantities exceeds a predetermined value. Thus a current differential relay operates on the result of comparison between the phase angle and magnitudes of the currents entering and leaving the system to be protected.

**(14) What is biased differential bus zone reduction?**

The biased beam relay is designed to respond to the differential current in terms of its fractional relation to the current flowing through the protected zone. It is essentially an over current balanced beam relay type with an additional restraining coil. The restraining coil produces a bias force in the opposite direction to the operating force.

**(15) What is meant by directional relay?**

The directional power relay is not suitable to use as a protective relay under short circuit

conditions. This is because under short circuit conditions the voltage fril is drastically and such a reduced voltage may not be sufficient to produce the driving torque required for the relay operation.

**(16 ) Describe the features of directional relay.**

High speed operation; high sensitivity; ability to operate at low voltages; adequate short-time thermal ratio; burden must not be excessive.

**(17)Define Positive Sequence Components.**

Positive sequence components have three vectors equal in magnitude and displaced from each other by an angle 120˚ and having the phase sequence as original vectors.

**(18 ) Define Negative Sequence Component.**

It has three vectors and equal in magnitude displaced from each other by an angle 120˚and the phase sequence in opposite to its original phasor.

**(19 ) List the types of electromagnetic relay.**

Electromagnetic attraction

Attracted armature type relay

Solenoid type relay

Balanced type relay Electromagnetic Induction

Shaded pole structure

Watt – hour meter

Induction cup

**(20 ) A relay is connected to 400/5 ratio current transformer with current setting of 150%. Formulate the Plug Setting Multiplier when circuit carries a fault current of 4000A.**

Pick-up value = Rated secondary CT current × current setting

= 5 × 1.5 = 7.5A

Fault current in relay coil = 2400 x 5/ 400 = 30 A

P.S.M = Fault current in relay coil / Pick up current = 30/ 7.5= 4

**(21) Write down the universal torque equation of overcurrent relay.**

The universal relay torque equation can be given as

$$T = K_1 I^2 + K_2 V^2 + K_3 IT \cos(\phi - \tau) + K$$

where $I$ = RMS value of current in current coil

$V$ = RMS value of voltage fed to the voltage coil

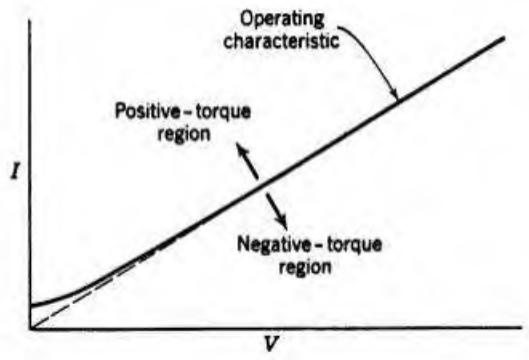
$\phi$ = Electrical angle between V and I

T = The maximum torque angle $K_1$, $K_2$

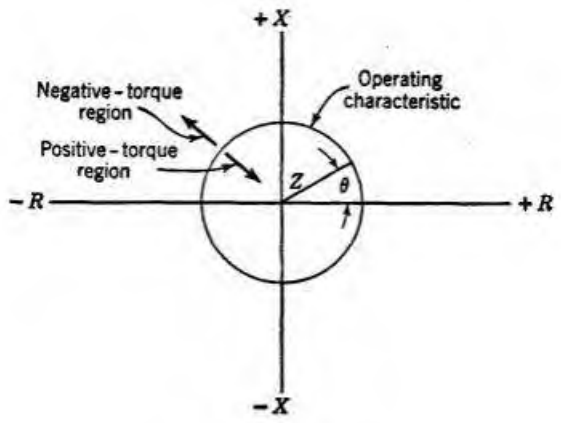
and $K_3$ = Relay constant

$K$ = Mechanical restraining torque

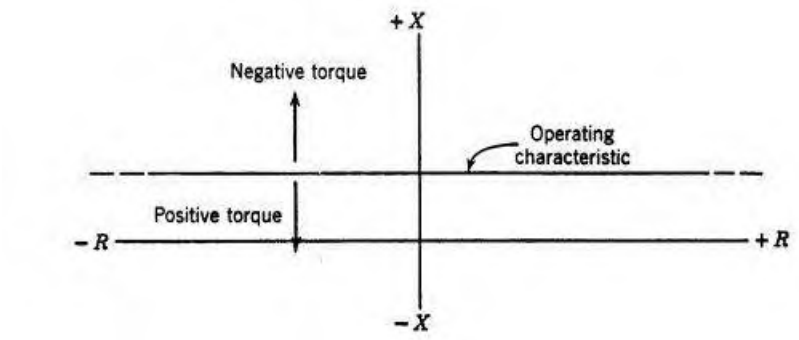
(22) **Draw the operating characteristics of impedance relay**




**(23 ) Draw the R-X diagram of impedance relay.**



**(24 )Illustrate with a diagram on the operating characteristics of reactance relay .**




**(25) Write down the torque equation of voltage restrained distance relay.**

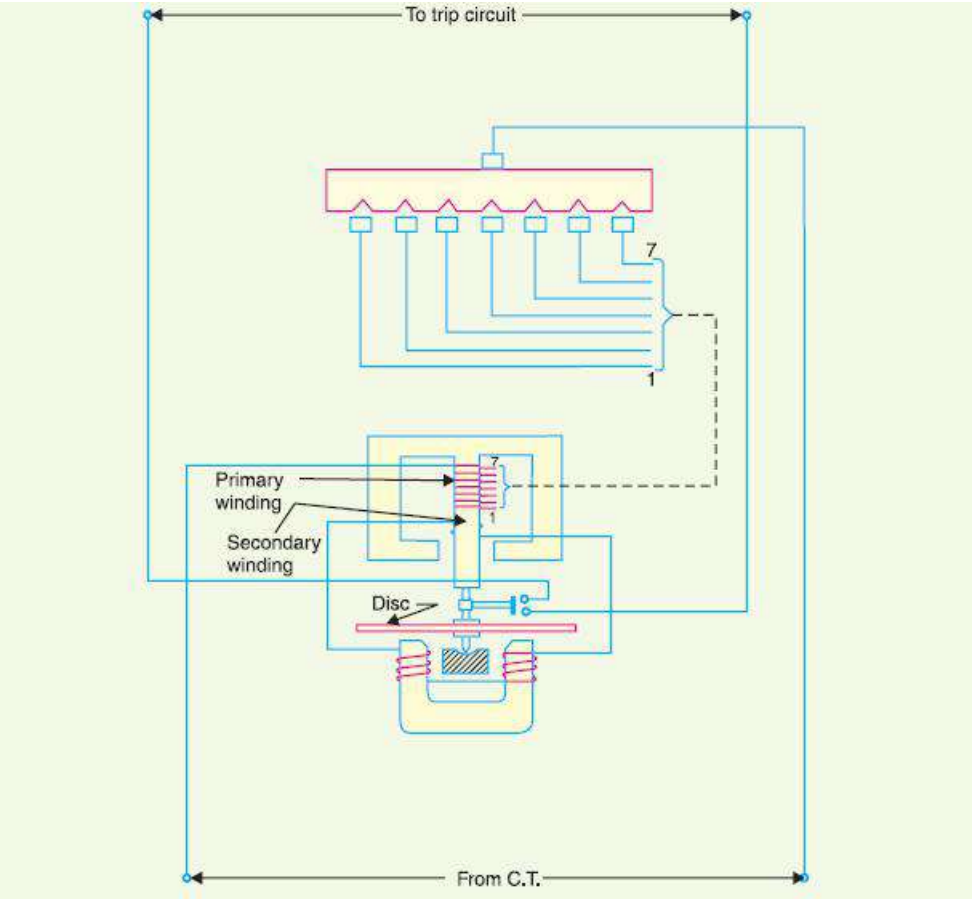
$T = K_1VI \cos(\theta - \tau) - K_2V^2 - K_3$

## PART * B

**(1)With neat Diagram explain the construction and operation of Non Directional over current relay. (13M)**

**Answer : Page 508 - V.K.Mehta**

Construction: (5 M)




- Metallic (aluminium) disc, free to rotate in between the poles of two electromagnets. The upper electromagnet, primary and a secondary winding.
- The primary connected to the secondary of a C.T. in the line to be protected, tapped at intervals. plug-setting bridge, relay operating coil, desired current setting.
- The secondary winding, energised by induction from primary series connection with

winding on the lower magnet.

- The controlling torque, spiral spring, Spindle of the disc, moving contact, bridges two fixed contacts (connected to trip circuit) , disc rotates through a pre-set angle.

**Working:** (8 M)

- earth leakage induction type relay .
- The driving torque on the aluminium disc, induction principle.
- This torque, opposed by the restraining torque, provided by the spring.
- Under normal operating conditions, restraining torque is greater than the driving torque, the aluminium disc remains stationary.

If the current in the protected circuit exceeds the pre-set value, the driving torque becomes greater than the restraining torque.

- The disc rotates, moving contact bridges the fixed contacts when the disc has rotated through a pre-set angle.
- The trip circuit operates the circuit breaker which isolates the faulty section.

**(2)With neat Diagram explain the construction and operation of Directional over current relay. (13M)**

**Answer : Page 2.20- V.Thiagarajan**

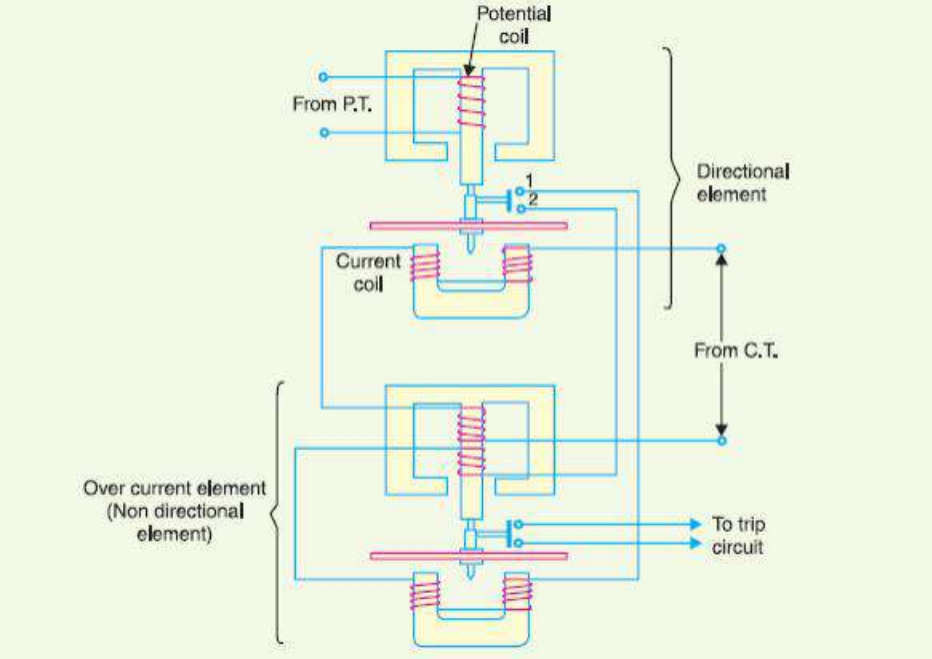



Diagram: (4 M)

**Construction:** (4 M)

- Independent of system voltage and power factor
- They elements are,

1. Directional element, directional power relay

2. Non directional element, non directional over current relay.

Directional element.

- Directional power relay which operates when power flows in a specific direction.
- The potential coil of this element connected through a potential transformer (P.T.) to the system voltage.
- The current coil energised through a C.T. by the circuit current.
- This winding carried over the upper magnet of the non-directional element.
- The trip contacts (1 and 2) of the directional element, series with the secondary circuit of the overcurrent element, the latter element cannot start to operate , secondary circuit is completed.

Non-directional element.

- The spindle of the disc, moving contact, closes the fixed contacts (trip circuit contacts) after the operation of directional element.
- Plug-setting bridge, relay for current setting, tappings, upper magnet of over current element, connected to the bridge.

**Operation:** (5 M)

- Under normal operating conditions, power flows in the normal direction directional power relay (upper element) does not operate, over current element (lower element) unenergised.
- When a short-circuit occurs, current or power flow in the reverse direction, the disc of the upper element rotates to bridge the fixed contacts 1 and 2. Completes the circuit for over current element.
- The disc of this element rotates and the moving contact attached to it closes the trip circuit. This operates the circuit breaker which isolates the faulty section.

Condition for final tripping of current:

- Current flows in a direction such as to operate the directional element.
- Current in the reverse direction exceeds the pre-set value.
- Excessive current persists for a period corresponding to the time setting of over current element.

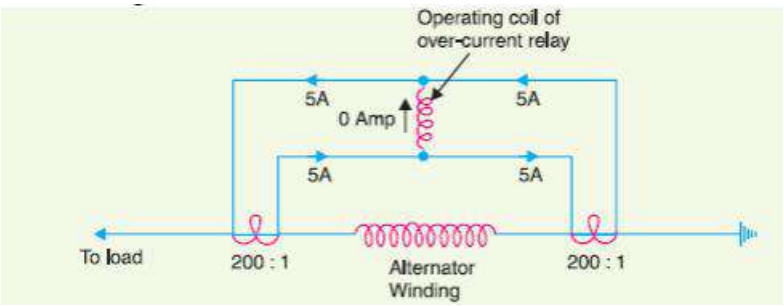
**3) Illustrate with a diagram about differential relay.**

**Answer : Page 2.40- V.Thiagarajan**

- A differential relay, operates when the phasor difference of two or more similar electrical quantities exceeds a predetermined value. current differential relay operates on the result of comparison between the phase angle and magnitudes of the currents entering and leaving the system to be protected. (2 M)

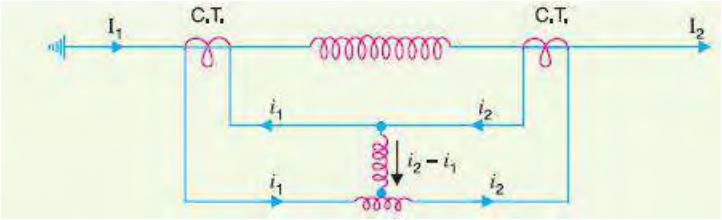
- Under normal conditions, the two currents, equal in phase and magnitude, inoperative.
- If difference current exceeds a preset value then the relay operates, opens the circuit breaker. (2 M)
- Types of Differential Relays:

Current differential relay ( 2 M)



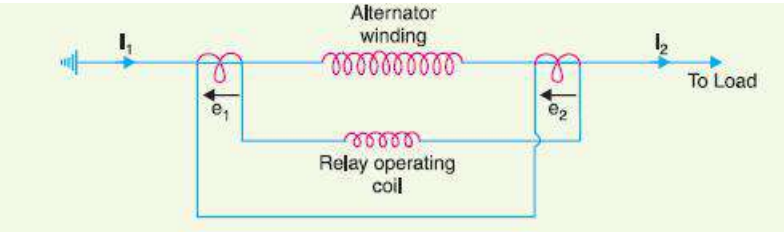

- Secondary currents of CT not equal- relay operate.

Biased beam relay or percentage differential relay (2 M)




- Operating coil proportional to $i_2 - i_1$, restraining coil proportional to ( $i_1+i_2$)/2.
- Operating current required to trip, percentage of load current.

Voltage balance differential relay (2 M)




- Under normal condition, Currents equal, secondary voltage balanced
- Voltage difference, current to flow through the operating coil of the relay, closes the trip circuit.
- Translay system- modified form of voltage balance system.

4.**Explain the working principle of under frequency relay. ( 8 M)**

Need for Frequency relay- (2 M)

Frequency Equation:

$$N_s = \frac{120f}{P}$$ : (2 M)

Working principle and diagram : (4 M)

- The frequency of induced e.m.f. of synchronous generator, maintained constant by constant speed.
- Over speeding of the generator occurs due to loss of load and under speeding occurs due to increase in load.
- In both the cases, the frequency varies from normal value. In order to avoid damage to the generator under the above two conditions, frequency relays are used.
- Under frequency relay trips the feeder on load at set value of frequency, so as to give relief to the generator, thereby saving the unit.
- Under frequency relay thus aids load shedding programme to save the grid.

5. **Explain the working principle of Negative sequence relay. (8M).**

**Answer : Page 2.49- V.Thiagarajan**

- Negative sequence relays are used to protect electrical machines against overheating due to unbalance currents in stator. (Definition: 2 M)
- Working principle and diagram: (6 M)
- Inverse square law characteristics.

6. **Derive the Universal relay torque equation. (5 M)**

- The universal torque equation explains the working of an electrical relay.
- The relay, electromagnetic.
- These electromagnetic consists current and voltage windings.
- The current through the winding produces magnetic flux. torque, produced by the interaction of the flux of the same winding or between the flux of both the windings. ( 2 M)

$$Torque\ Developed\ by\ curent\ windings = K_1 I^2$$

$$Torque\ developed\ by\ voltage\ winding = K_1 V^2$$

$$T = K_1 I^2 + K_2 V^2 + K_3 VI\cos(\theta - \tau) + K_4$$ (3 M)

7. **List the detailed classification of relays based on various parameters. ( 8 M)**

**Answer : Page 2.4- V.Thiagarajan**

According to construction: ( 2 M)

- Electromagnetic relays
- Induction relays
- Electrothermal relays
- Physico-electric relay
- Electro-dynamic relay
- Static relay
- Microprocessor relay

According to application: ( 2 M)

- Falls below specific limit or value
- Directional or reverse current relay
- Directional or reverse power relay

According to time of operation ( 2 M)

- Instantaneous relay
- Definite time lag relay
- Inverse time lag relay
- Inverse definite minimum time lag relay

According to connectivity of circuit: ( 2 M)

- Primary relay
- Secondary relay
- Auxillary relay
- Back up relay
- Reinforcing relay

## PART*C

1. **Explain the working principle of impedance relays. (15 M) (April/May 13)(Nov/Dec 2012 &15)**

**Answer : Page 2.26- V.Thiagarajan**

Distance relay general definition: (3 M)

Working principle of impedance relay: (5 M)

- Dependent on the ratio of V and I there are three types of distance relays which are, impedance relay, mho relay and reactance relay.
- Impedance relay which is based on measurement of impedance

Torque equation: (3 M)

R-X Diagram: (2 M)

Explanation- (1 M)

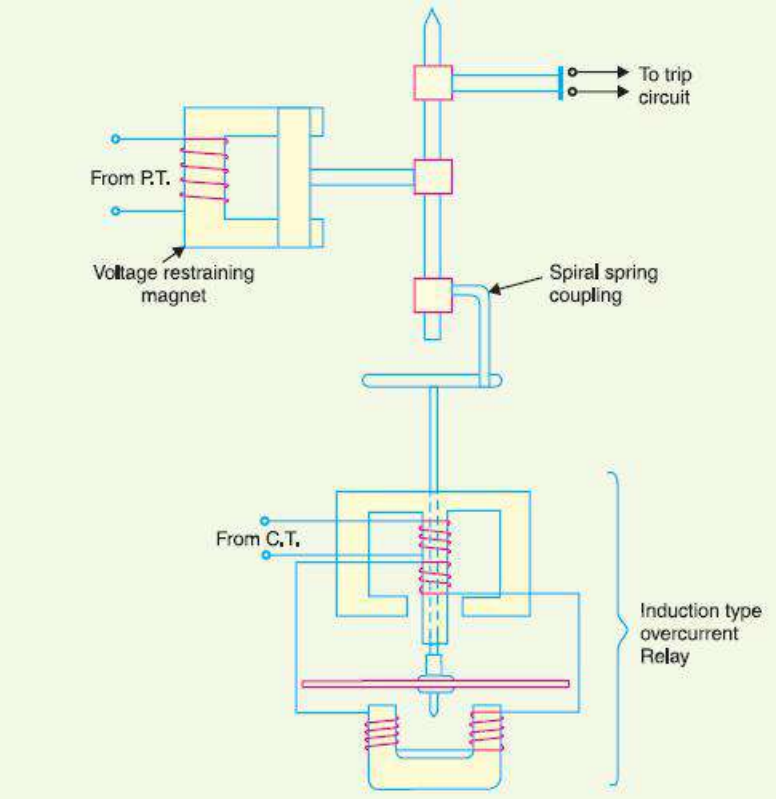
2. **With neat sketch, investigate how impedance relay is used as Time Distance. ( 13 M)**

**Answer : Page 2.27- V.Thiagarajan**

Operating time, $T \propto V/I$

$\propto Z$

$\propto$ distance (2 M)




**Construction.** (3 M)

- Current driven induction element, spindle carrying the disc, spiral spring coupling to a second spindle, bridging piece of the relay trip contacts.
- The bridge- open position by an armature, pole face of an electromagnet excited by the voltage of the circuit to be protected.

**Operation.** (4 M)

- Under normal load conditions, the pull of the armature , induction element, trip circuit

contacts remain open.

- On the occurence of a short-circuit, the disc of the induction current element , rotate at a speed depending upon the operating current. the spiral spring coupling wound up till the tension of the spring , sufficient to pull the armature away from the pole face of the voltage-excited magnet.
- the spindle carrying the armature and bridging piece moves rapidly in response to the tension of the spring and trip contacts are closed.
- This opens the circuit breaker to isolate the faulty section.
- The speed of rotation of the disc proportional to the operating current,
- Neglecting the effect of control spring. time of operation of the relay , directly proportional to the pull of the voltage-excited magnet , line voltage *V* at the point where the relay is connected.
- The time of operation of relay would vary as *V/I i.e.* as *Z* or distance.

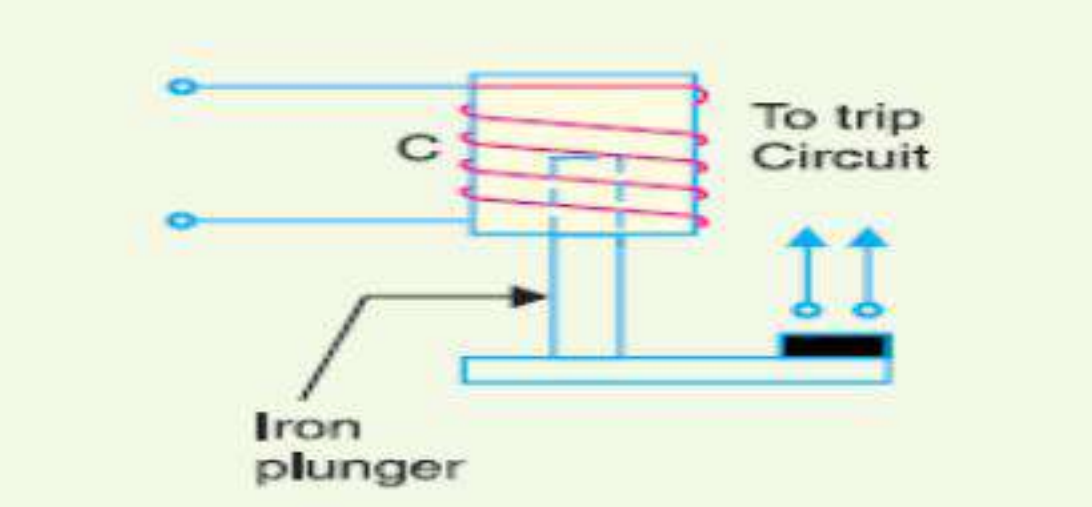
3. **What are the Classification of Electromagnetic Relays? Explain about Electromagnetic Attraction Type Relays.**

**Answer : Page 2.7- V.Thiagarajan**

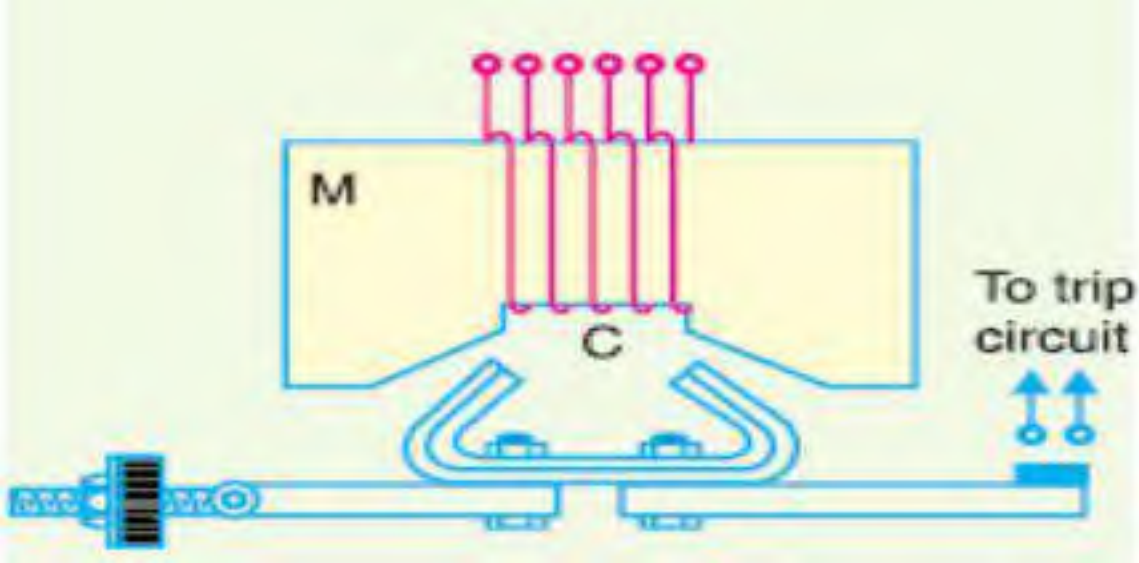
- All the relays consist of one or more elements which gets energized and actuated by the electrical quantities of the circuit.
- On-no-mechanical type which work on the principles of electromagnetic attraction and electromagnetic induction

The various types of these relays are,

➢Solenoid Type



➢Attracted armature type




➢ Balanced beam type relay:

## UNIT III APPARATUS PROTECTION

1) **What are the types of graded used in line of radial relay feeder?**
Definite time relay and inverse-definite time relay.

**2)What are the various faults that would affect an alternator?**
a) Stator faults
1. Phase to phase faults 2. Phase to earth faults 3. Inter turn faults
b) 1. Earth faults 2. Fault between turns 3. Loss of excitation due to fuel failure
c) 1. Over speed 2. Loss of drive 3. Vacuum failure resulting in condenser pressure rise, resulting in shattering of the turbine low pressure casing
d) 1. Fault on lines 2. Fault on busbars

**3)Why neutral resistor is added between neutral and earth of an alternator?**
In order to limit the flow of current through neutral and earth a resistor is introduced between them.

**4)What is the backup protection available for an alternator?**
Over current and earth fault protection is the backup protections.

**5)What are faults associated with an alternator?**
External fault or through fault
Internal fault
1, Short circuit in transformer winding and connection
2, Incipient or slow developing faults

6) **What are the main safety devices available with transformer?**
Oil level guage, sudden pressure delay, oil temperature indicator, winding temperature indicator .

**7)What are the limitations of Buchholz relay?**

Only fault below the oil level are detected.

Mercury switch setting should be very accurate, otherwise even for vibration, there can be a false operation.

The relay is of slow operating type, which is unsatisfactory.

**8)What are the problems arising in differential protection in power transformer and how are they overcome?**

Difference in lengths of pilot wires on either sides of the relay. This is overcome by connecting adjustable resistors to pilot wires to get equipotential points on the pilot wires.

Difference in CT ratio error difference at high values of short circuit currents that makes the relay to operate even for external or through faults. This is overcome by introducing bias coil.

Tap changing alters the ratio of voltage and currents between HV and LV sides and the relay will sense this and act. Bias coil will solve this.

Magnetizing inrush current appears wherever a transformer is energized on its primary side producing harmonics. No current will be seen by the secondary.

CT‟s as there is no load in the circuit. This difference in current will actuate the differential relay. A harmonic restraining unit is added to the relay which will block it when the transformer is energized.

**9) What is REF relay?**

10) It is restricted earth fault relay. When the fault occurs very near to the neutral point of the transformer, the voltage available to drive the earth circuit is very small, which may not be sufficient to activate the relay, unless the relay is set for a very low current. Hence the zone of protection in the winding of the transformer is restricted to cover only around 85%. Hence the relay is called REF relay.

**10)What is over fluxing protection in transformer?**

If the turns ratio of the transformer is more than 1:1, there will be higher core loss and the capability of the transformer to withstand this is limited to a few minutes only. This phenomenon is called over fluxing.

**11)What are the uses of Buchholz's relay?**

Buchholz relay is used to give an alarm in case of incipient( slow-developing) faults in the transformer and to connect the transformer from the supply in the event of severe internal faults. It is usually used in oil immersion transformers with a rating over 750KVA.

**12)Why busbar protection is needed?**

a)Fault level at busbar is high

b) The stability of the system is affected by the faults in the bus zone.

(c) A fault in the bus bar causes interruption of supply to a large portion of the system network.

**13 )What are the merits of carrier current protection?**

Fast operation, auto re-closing possible, easy discrimination of simultaneous faults .

**14)What is field suppression?**

When a fault occurs in an alternator winding even though the generator circuit breaker is tripped, the fault continues to fed because EMF is induced in the generator itself. Hence the field circuit breaker is opened and stored energy in the field winding is discharged through another resistor. This method is known as field suppression.

**15)What are the causes of bus zone faults?**

Failure of support insulator resulting in earth fault

Flashover across support insulator during over voltage
Heavily polluted insulator causing flashover
Earthquake, mechanical damage etc.

**16 ) What are the problems in bus zone differential protection?**

Large number of circuits, different current levels for different circuits for external faults.
Saturation of CT cores due to dc component and ac component in short circuit currents. The saturation introduces ratio error.
Sectionalizing of the bus makes circuit complicated.
Setting of relays need a change with large load changes.

**17)What is meant by relay operating time?**

It is defined as the time period extending from the occurrence of the fault through the relay detecting the fault to the operation of the relay.

**18 )Give the limitations of Merz Price protection.**

Since neutral earthing resistances are often used to protect circuit from earth- fault currents, it becomes impossible to protect the whole of a star-connected alternator. If an earth-fault occurs near the neutral point, the voltage may be insufficient to operate the relay. Also it is extremely difficult to find two identical CT‟s. In addition to this, there always an inherent phase difference between the primary and the secondary quantities and a possibility of current through the relay even when there is no fault.

**19)List the different faults that may occur in transformer.**

External fault
Internal fault
Short circuit in transformer winding and connection.
Incipient or slow developing fault.

**20) What are the uses of Buchholz's relay?**

Buchholz relay is used to give an alarm in case of incipient( slow-developing) faults in the transformer and to connect the transformer from the supply in the event of severe internal faults. It is usually used in oil immersion transformers with a rating over 750KVA.

**21)Discuss the most severe fault in transmission line.**

The most severe fault is L-L-L-G fault . (Symmetrical fault)

**22) Why secondary of CT should not be left open?**

During normal operation of CT, the primary and secondary winding produces mmf which by lenze‟s law opposes each other. As the secondary mmf is slightly less than the primary mmf, the net mmf is small. This net mmf is the working / magnetizing mmf of the core of CT. Now, in case secondary winding is kept open then secondary current will be zero while the primary current of CT will remain same. Therefore the opposing mmf of secondary will no longer exist. Hence the net mmf is due to primary current only i.e. $N_1I_1$ which is very large. This large mmf will produce large flux in the core and will saturate the core. Again, due to large flux in the core the flux linkage of secondary winding will be large which in turn will produce a large voltage across the secondary terminals of the CT. This large voltage across the secondary terminals will be very dangerous and will lead to the insulation failure and there is a good chance that the person who is opening the CT secondary while primary is energized will die due to shock.

**23)Define the term pilot with reference to power line protection.**

Pilot wire is a communication cable between DC and primary substation, a communication cable between two relays whenever a transmission line or equipment is to be protected by

using distance relay or by differential relay or price protection. A wire is connected between the CT which is located in different ends of the protection zone. This wire provides the path for the circulating current produce in abnormal condition, which is sensed by the relay and therefore is tripped.

**24 )What is burden in Current Transformer?**

The actual burden is formed by the resistance of the pilot conductors and the protection relay(s).

**25) Define feeder protection.**

Feeder protection is defined as the protection of the feeder from the fault so that the power grid continually supply the energy. The feeder injects the electrical energy from the substation to the load end. So it is essential to protect the feeder from the various type of fault.

## PART * B

1. **Briefly explain about transformer protection using Differential protection scheme (Merz-price protection scheme) (13M)**

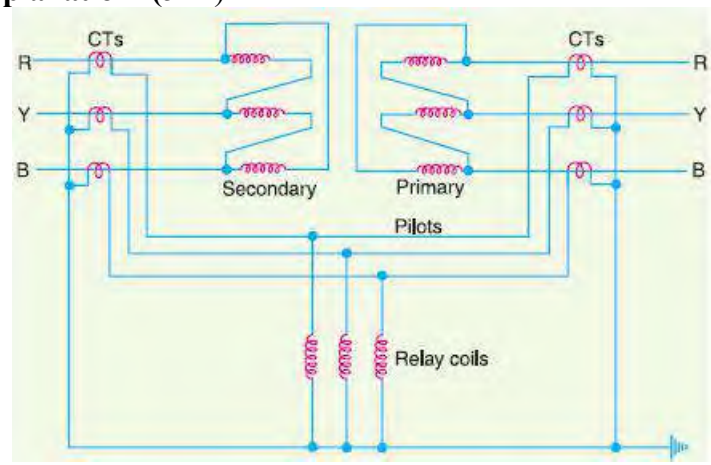
**Answer: Page 3.5- Thiagarajan**

- **Differential protection**

Differential protection, compares currents entering and leaving the protected zone and operates when the differential current between these currents exceed a pre determined level. (3 M)

- Under internal fault conditions (i.e. faults between the CTs) the relay operates, since both the CT secondary currents add up and pass through the relay.
- This protection is also called unit protection, as it only operates for faults on the unit it is protecting, which is situated between the CTs.

**Diagram- (**5 M) **and explanation- (**5 M)




- Difference in magnitude of currents in the primary and secondary of power transformer is compensated by different turns ratio of CTs.

2. **What is meant by Buchholz Relay? Explain its operation with neat sketch. (13M)**

**Answer: Page 3.36- Thiagarajan**

**Construction: (**4 M)

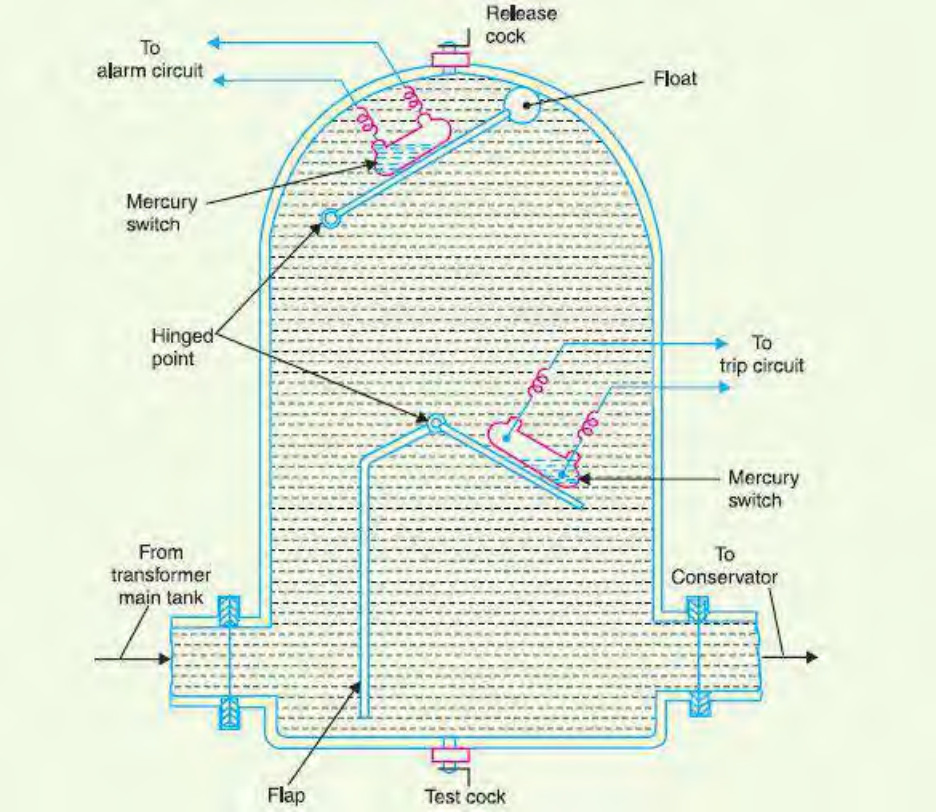
Alarm circuit, conservator, main tank, float, hinge, mercury switch.

**Working: (**5 M)

- Failure of the winding insulation will result in some form of arcing, which can decompose the oil into hydrogen, acetylene, methane, etc. Localized heating can also precipitate a breakdown of oil into gas.

➢ Severe arcing will cause a rapid release of a large volume of gas as well as oil vapor. The action can be so violent that the build-up of pressure can cause an oil surge from the tank to the conservator.

**Diagram: (**4 M)




3. **Explain about the faults occuring in generator (13M)**

**Answer: Page 3.6- Thiagarajan**

➢ The various faults which can occur associated with a generator can be classified as,

➢ Stator faults: The faults associated with the stator of the generator

➢ Rotor faults: The faults associated with the rotor of the generator.

➢ Abnormal running conditions: This includes number of abnormal conditions which may occur in practice, from which the generator must be protected. ( 3 M)

➢ Stator Faults

The main types of stator faults are.

**Phase to phase faults**

**Phase to Earth Faults**

**Stator Inter-Turn Faults**

**Rotor Faults**

**Abnormal Running Conditions**

These abnormal conditions include, I. Overloading 2. Over speeding 3. Unbalanced loading 4. Over voltage 5. Failure of prime mover (Arc of excitation (Field failure) 7. Cooling system failure ( Explanation: Each 2 M)

**Failure of prime-mover.** Input, prime-mover fails, the alternator runs as a synchronous motor draws some current from the supply system, “inverted running”.

**Failure of field:** No immediate damage , permitting the alternator to run without a field for a

short-period, rely on the control room attendant to disconnect the faulty alternator manually from the system bus-bars.

**Over current.** Due to partial breakdown of winding insulation or due to overload on the supply system. Reasons.

**Over speed.** Sudden loss of all or the major part of load on the alternator.

**Over-voltage.** Speed of the prime-mover increases due to sudden loss of the alternator load. relays are so arranged that when the generated voltage rises 20% above the normal value, they operate to

- trip the main circuit breaker to disconnect the faulty alternator from the system
- disconnect the alternator field circuit

**Unbalanced loading.** There are different phase currents in the alternator.

Unbalanced loading arises from faults to earth or faults between phases on the circuit external to the alternator.

The unbalanced currents, if allowed to persist, may either severely burn the mechanical fixings of the rotor core or damage the field winding.

**(*vii*) Stator winding faults.** These faults occur mainly due to the insulation failure of the stator windings. The main types of stator winding faults, in order of importance are :

**(*a*)** fault between phase and ground

**(*b*)** fault between phases

**(*c*)** inter-turn fault involving turns of the same phase winding

The stator winding faults- most dangerous- cause considerable damage to the expensive machinery. Differential method of protection (also knows as Merz-Price system)- due to its greater sensitivity and reliability.

4. **A star-connected, 3-phase, 10-MVA, 6·6 kV alternator has a per phase reactance of 10%. It is protected by Merz-Price circulating-current principle which is set to operate for fault currents not less than 175 A. Calculate the value of earthing resistance to be provided in order to ensure that only 10% of the alternator winding remains unprotected. ( 10 M)**

**Answer: Page 529- V.K. Mehta**

Voltage per phase, Vph= 3810 V

Full-load current, I= 875 A ( 2 M)

Reactance per phase x = 0·436 Ω ( 3 M)

r = 2·171Ω ( 5 M)

5. **A star-connected, 3-phase, 10 MVA, 6·6 kV alternator is protected by Merz- Price circulating-current principle using 1000/5 amperes current transformers. The star point of the alternator is earthed through a resistance of 7·5 Ω . If the minimum operating current for the relay is 0·5 A, calculate the percentage of each phase of the stator winding which is unprotected against earth-faults when the machine is operating at normal voltage. ( 8 M)**

**Answer: Page 530- V.K. Mehta**

Voltage per phase, Vph= 3810 V

Minimum fault current which will operate the relay = 1000/5 * 0.5 = 100 A ( 2 M)

E.M.F. induced in *x*% winding = 38·1 *x* volts ( 2 M)

19·69% of alternator winding is left unprotected. ( 4 M)

6 )**A 3-phase transformer of 220/11,000 line volts is connected in star/delta. The protective transformers on 220 V side have a current ratio of 600/5. What should be the CT ratio**

**on 11,000 V side ? ( 8 M)**

**Answer: Page 538- V.K. Mehta**

Phase current of star connected *CT*s on 11,000 V side = 5 √3 A ( 2 M)

Diagram: ( 2 M)

Primary apparent power = Secondary apparent power

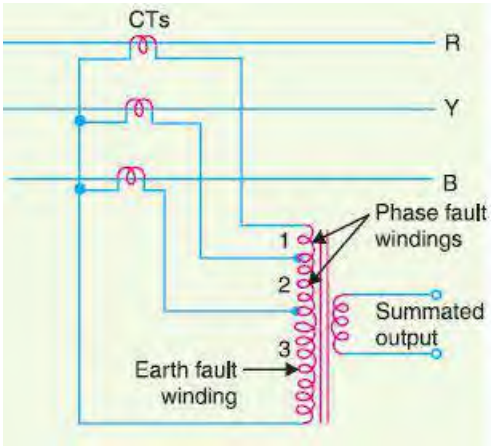
I= 12A ( 2 M)

Turn-ratio of *CT*s on 11000 V side= 12 : 5√ 3 = **1·385 : 1** ( 2 M)

**7. Explain differential pilot wire protection using translay scheme. (13 M)**

**Answer: Page 548- V.K. Mehta**

- Similar to voltage balance system except balance or opposition is between the voltages induced in the secondary windings wound on the relay magnets and not between the secondary voltages of the line current transformers.
- This permits to use current transformers of normal design and eliminates one of the most serious limitations of original voltage balance system, namely; its limitation to the system operating at voltages not exceeding 33 kV. ( 3 M)
- Diagram: ( 3 M)

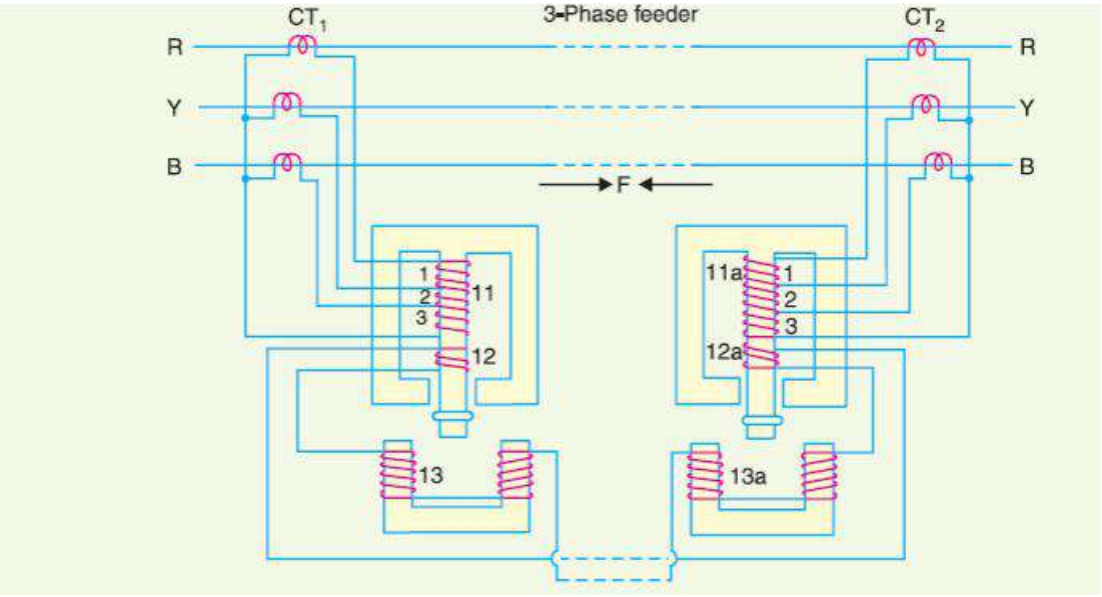



- Construction and working: (7 M)

Summation transformer, poly phase quantity into single phase quantity. Three CTs connected to tapped primary of summation transformer.

Advantages:

- primary windings 1 and 2 can be used for phase faults whereas winding 3 can be used for earth fault
- The number of pilot wires required is only two.



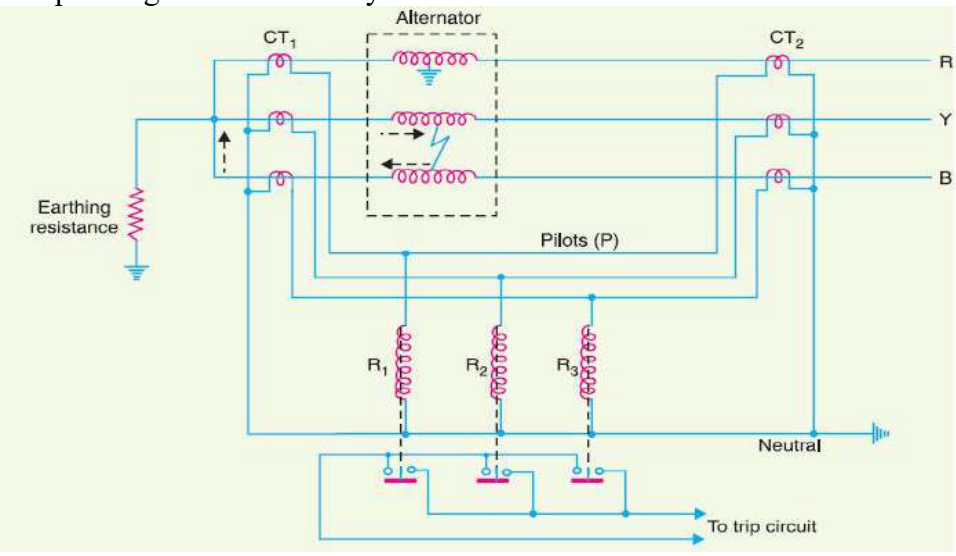

## PART*C

1. **Breifly explain about Merz-price protection of a generator with neat sketch. (15 M)**

**Answer: Page 3.6- Thiagarajan**

Diagram- (4 M)
Merz-price protection- (3 M)
Working: (4 M)
Advantages and disadvantages: (4 M)

- In this method, the currents at the two ends of the protected section are sensed using current transformers.
- The wires connecting relay coils to the current transformer secondary‟s arc called pilot wires.
- Under normal conditions, when there is no fault in the windings, the currents in the pilot wires fed C.T. secondary are equal.
- When fault occurs inside the protected section to the stator windings, the differential current I, flows through the operating coils of the relay.



**2) Explain about Motor protection (15 M)**

**Answer: Page 3.24- Thiagarajan**

**Ground fault protection : (8 M)**

- Phase Fault Protection (**7 M)**

This protection is also called short circuit protection.

- Attracted armature type relay

**Main requirements**

- In the event of fault, or short circuit the breaker close to the fault should open and all other breakers are to remain in closed position, except in case of grid lines.
- In case the nearest breaker to the fault to open, back-up protection should be provided by the adjacent breakers.
- The relay operating time should be as short as possible in order to pressure system stability.
- Protection of transmission line has quite a different problem, compared to protection of generators, transformers, motors etc.

3. **Explain transmission system protection schemes with neat sketch. (15 M) .**

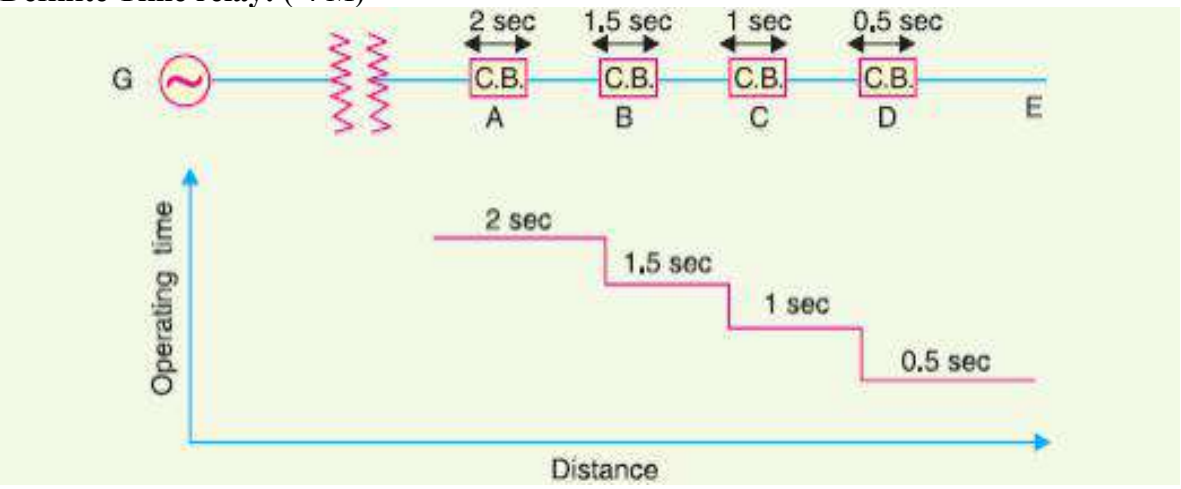
**Answer: Page 3.57- Thiagarajan**

- A transmission system may use one or more of the following types of protection.
- Over current protection non directional time and current graded scheme (3M)
- Directional time and current graded scheme (3M)
- Distance protection using high speed distance relays. (3M)
- Pilot wire protection (3M)
- Carrier current pilot protection
- Micro wave pilot protection
- Distance protection of lines (3M)

4. **Discuss with neat diagram, time graded overcurrent protection and distance protection of transmission lines. (13 M)**

**Answer: Page 544-V.K.Mehta**

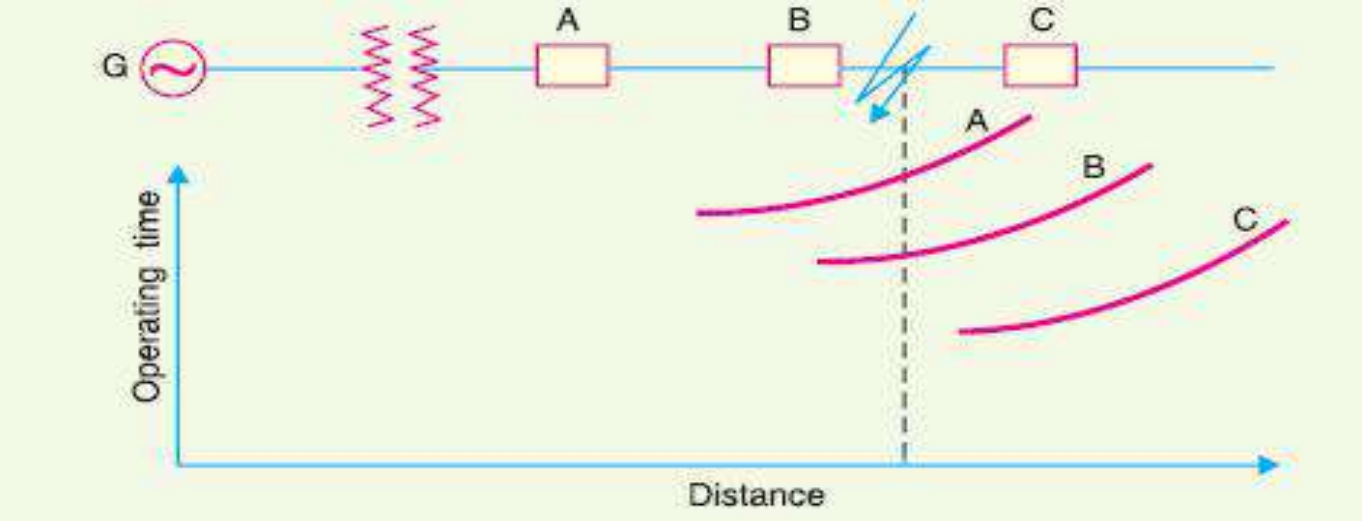
**Definite Time relay:** ( 4 M)




- Time of operation is fixed.
- Is independent of the operating current.
- Disadvantage: If there are a number of feeders in series, the tripping time for faults

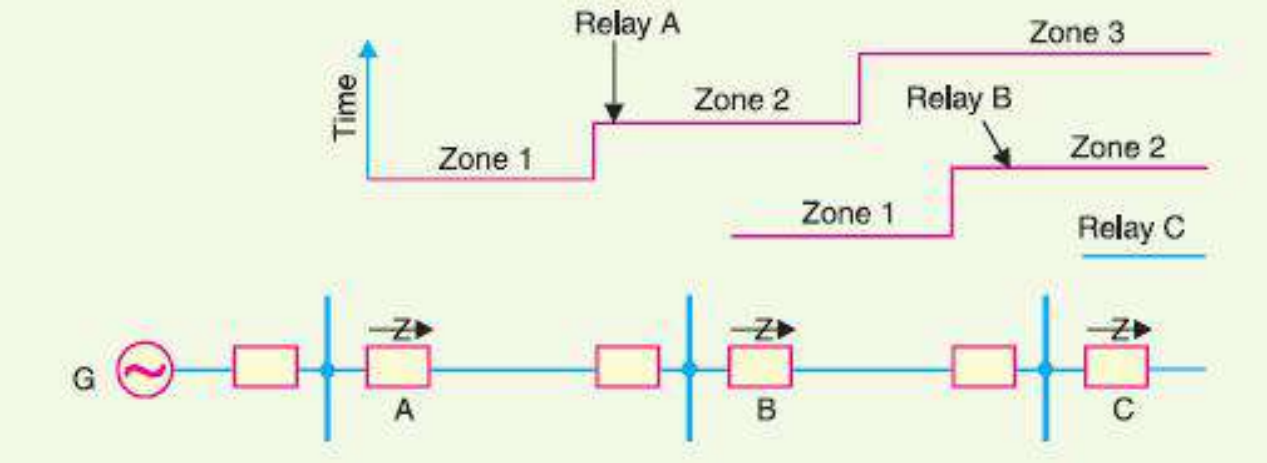
near the supply end becomes high.

**Inverse Time relay:** ( 4 M)




- Inverse time characteristics.

**Distance Protection of transmission lines:** (13 M)




Zone 1 covers 90% of the line and is arranged to trip instantaneously for faults in this portion.

Zone 2 element trips the fault in the remaining 10 % of the line.

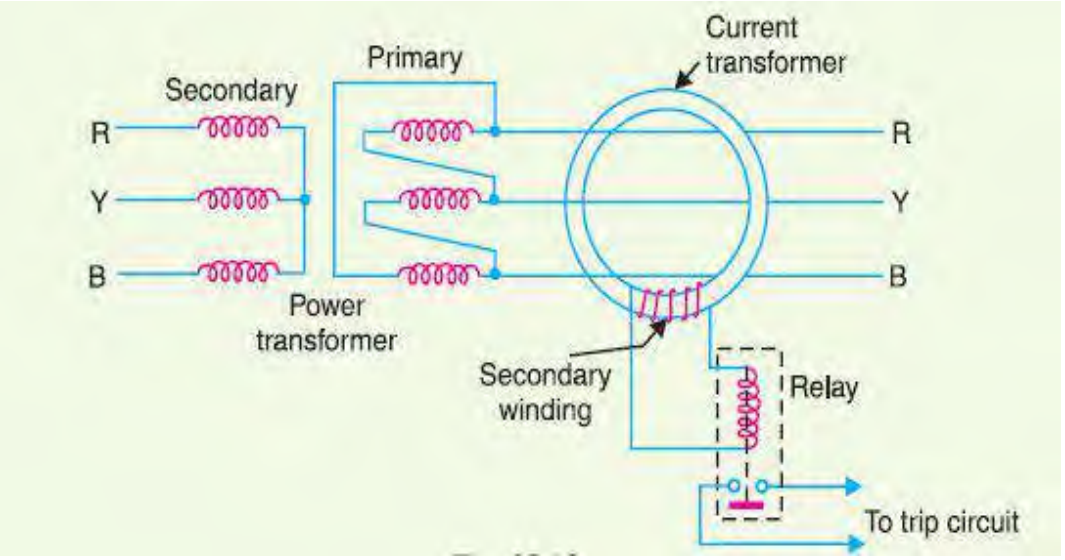
Zone 3- back up protection.

## 4. Differentiate between CT and PT. (6).

| S. No | Current Transformers (CT) | Potential/Voltage Transformers (PT/VT) |
|---|---|---|
| 1 | The Primary winding of a C.T have smallernumber of turns than secondary. | The Primary winding of a P.T have larger number of turns than secondary. |
| 2 | The secondary of a C.T cannot be open circuited on any circumstance when it is under service. | The secondary of a P.T can be open circuited without any damage being caused either to the operator or the transformer. |
| 3 | A CT may be considered as a series transformer. | P.T may be considered as a parallel transformer. |
| 4 | The primary current in a C.T is independent of the secondary circuit conditions (burden/load). | The primary current of a P.T depends upon the secondary circuit conditions (burden/load). |
| 5 | The primary winding of the CT is connected in series with the line carrying the current to be measured. Hence it carries of the full line current. | The primary winding P.T is connected across the line of voltage to be measured. Hence the full line voltage is impressed across its terminal. |
| 6 | With the help of CT, a 5A ammeter can be used measure a high current like 200A. | With the help of P.T, a 120V voltmeter can be used to measure very high voltages like 11KV. |

## 5.Explain earth fault protection of transformers. (8 M)

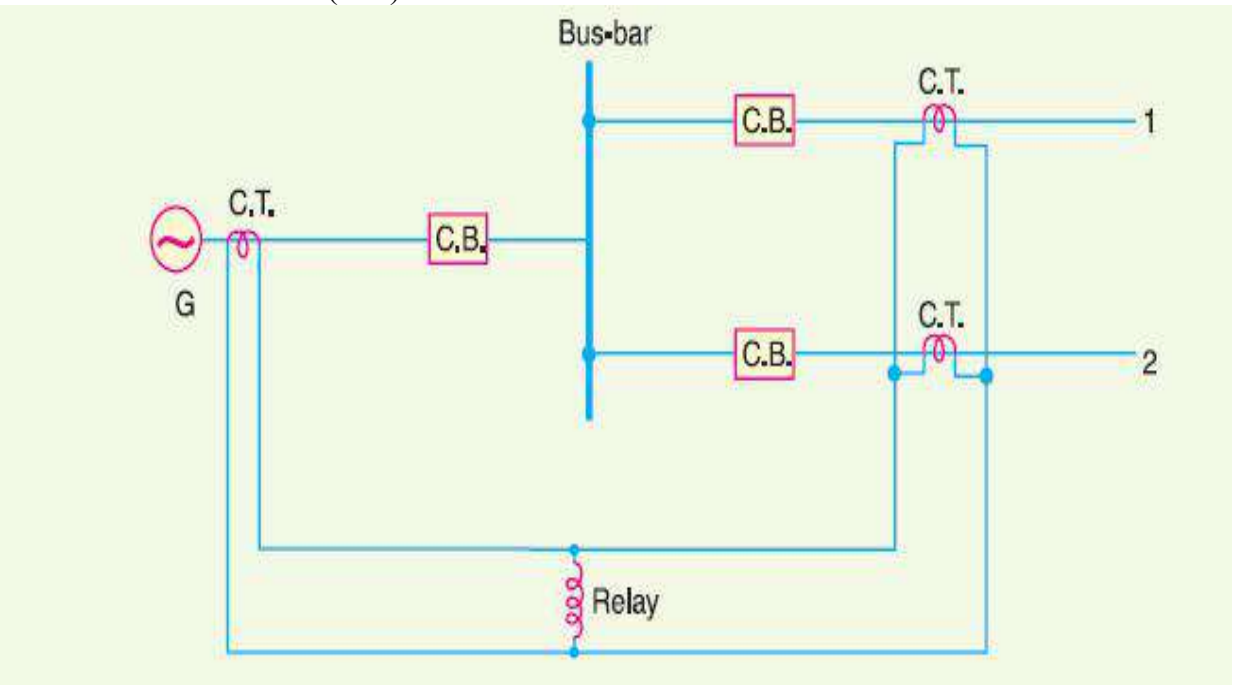
**Answer: Page 535- V.K.Mehta**




➢ The three leads of the primary winding of power transformer are taken through the core of a current transformer which carries a single secondary winding.

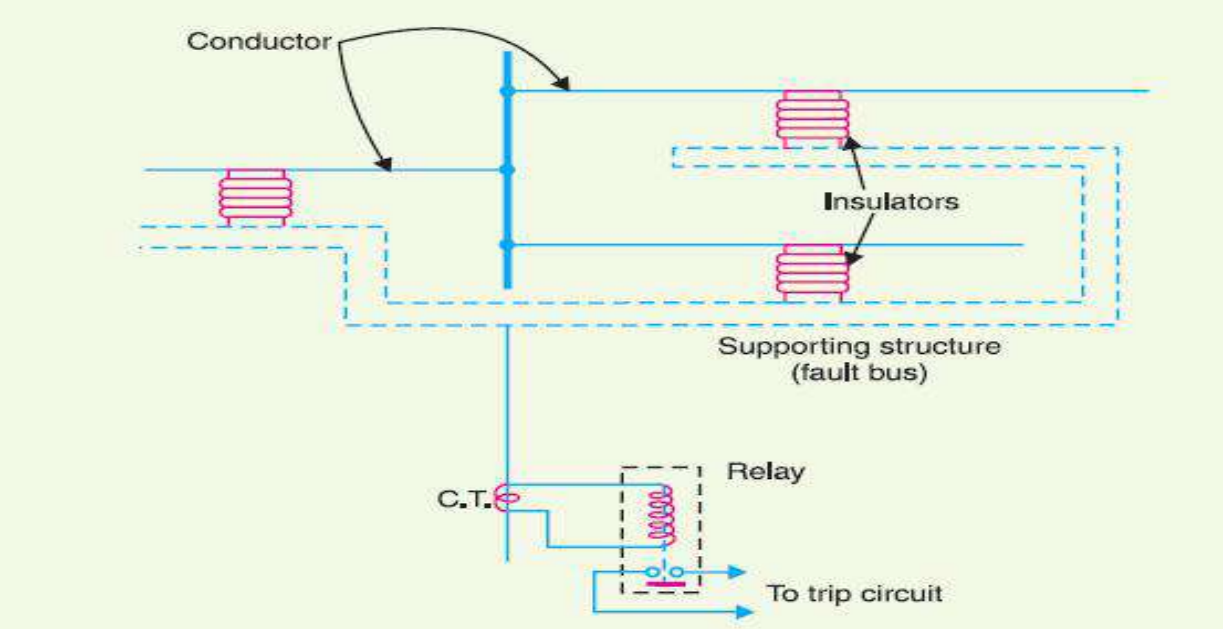
- The operating coil of a relay- connected to this secondary.
- Under normal conditions (i.e. no fault to earth), the vector sum of the three phase currents is zero and there is no resultant flux in the core of current transformer
- No current flows through the relay and it remains inoperative.
- Occurrence of an earth-fault, the vector sum of three phase currents - no longer zero. The resultant current sets up flux in the core of the C.T. which induces e.m.f. in the secondary winding.
- Energizes the relay to trip the circuit breaker and disconnect the faulty transformer from the system. (4 M)

**6. Briefly explain about busbar protection schemes with neat diagram. (15 M)**
**Answer: Page 542- V.K. Mehta**
**Differential Protection:** (7 M)




- All CTs must be of same ratio.
- Under normal condition or during external fault condition- the sum of current entering the bus is equal to sum of current leaving it.
- Fault condition- difference current flows and cause opening of generator circuit breaker and each of the line circuit breakers.

**Fault Bus Protection:** (8 M)




- It is possible to design a station so that the faults that develop are mostly earth-faults.
- This can be achieved by providing earthed metal barrier (known as *fault bus*) surrounding each conductor throughout its entire length in the bus structure.
- Every fault that might occur must involve a connection between a conductor and an earthed metal part.
- By directing the flow of earth-fault current, it is possible to detect the faults and determine their location. This type of protection is known as fault bus protection.

## UNIT IV STATIC RELAYS AND NUMERICAL PROTECTION

Static relays – Phase, Amplitude Comparators – Synthesis of various relays using Static comparators – Block diagram of Numerical relays – Over current protection, transformer differential protection, distant protection of transmission lines.

## PART * A

**Q.No. Questions**

**1) What is a programmable relay?**

A static relay may have one or more programmable units such as microprocessors or microcomputers in its circuit.

**2) What is CPMC?**

It is combined protection, monitoring and control system incorporated in the static system.

**3)What are the advantages of static relay over electromagnetic relay?**

- Low power consumption as low as 1mW
- No moving contacts; hence associated problems of arcing, contact bounce, erosion, replacement of contacts
- No gravity effect on operation of static relays. Hence can be used in vessels i.e., ships, aircrafts etc.
- 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.

- Static relay is compact
- Superior operating characteristics and accuracy
- Static relay can think , programmable operation is possible with static relay

Effect of vibration is nil, hence can be used in earthquake-prone areas Simplified testing and servicing.

- Can convert even non-electrical quantities to electrical in conjunction with transducers.

**4) Define static relay.**

A static relays to a relay in which measurement or comparison of electrical quantities is done in a static network which is designed to give an output signal, when a threshold condition is passed, which operates a tripping device.

**5)List the types of static relays.**

Electronic relays 2. Transducer relays 3. Rectifier bridge relays 4.Transistor relays 5. Hall effect relays 6. Guass effect relays

**6) What are the limitations of a static relay?**

- Auxiliary voltage requirement for Relay Operation.
- Static relays are sensitive to voltage transients which are caused by operation of breaker and isolator in the primary circuit of CTs and PTs.
- Serious over voltage is also caused by breaking of control circuit, relay contacts etc.
- Temperature dependence of static relays: The characteristics of semiconductor devices are affected by ambient temperature. Highly reliable power supply circuits are required.

**7 )Define comparator.**

Comparator is a part of a static relay which receives two inputs to be compared and gives output based on comparison. Types are amplitude comparator, phase comparator, Hybrid comparator.

**8)What are the types of electronic circuits used in a static protection system?**

Analog circuits – For simple functions

Digital circuits – For complex functions Hybrid circuits – For highly complex functions

**9)How does a numerical over current relay work?**

Numerical over current protection algorithm first reads all the setting such as the type of characteristics to be implemented, the pickup value $I_{perunit}$, the time multiplier setting in case of inverse time over current relay or the time delay in case of DTOC relay. Using a multiplexer, the microprocessor can sense the faults currents. If fault current exceeds a pickup value, microprocessor sends a tripping signal to the C.B of the faulty circuit.

**10)Define hybrid comparator.**

It is a comparator which compares both magnitude and phase of the input quantities. Hence amplitude and phase comparators are used. Inputs are given to phase comparator and output of phase comparator is given to amplitude comparator.

**11)What is digital filtering?**

Digital filtering is performed using analog filters consisting of RLC circuits and active filters using operational amplifiers which is the most needed operation in numerical relaying

**12)Define sampling theorem.**

It states that in order to preserve the information contained in a signal of frequency it must be sampled at a frequency at least equal to or greater than twice the signal frequency.

$\omega_{sampling,min} \geq 2\omega signal$

**13) What are the Limitations of Numerical Relay?**

- Numerical Relay offers more functionality, and greater precision. Numerical Relay can make faster decisions. Numerical Relay protection often relies on non proprietary software, exposing the system to potential risk of hacking.
- Numerical Relay protection sometimes has exposure to externally-sourced transient interference that would not affect conventional technology.
- Numerical Relay protection shares common functions. This means that there are common failure modes that can affect multiple elements of protection.

**15 )What are the two types of Phase comparators?**

Phase comparators are of two types: the cosine type and the sine type.

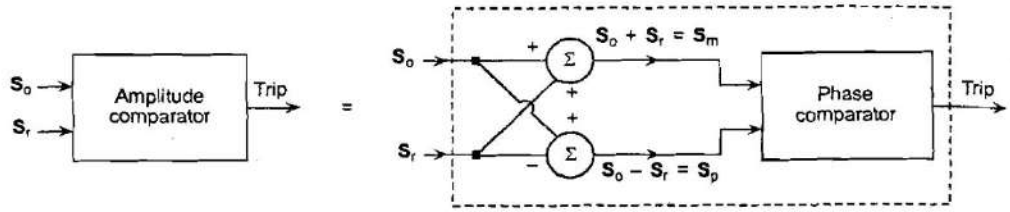
**16) What is the trip condition for Sine comparators?**

If $0_0 < \text{Arg}\ (S_m/S_p) < 180_0$ then trip; else restrain where $S_m$ and $S_p$ are the inputs to the sine comparator.

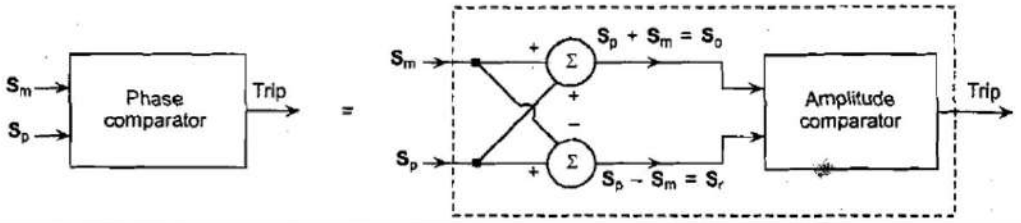
**17 )What is the trip condition for Cosine comparators?**

If $-90_0 < \text{Arg}\ (S_m/S_p) < +90°$ then trip; else restrain where Sm and Sp are the inputs to the cosine comparator.

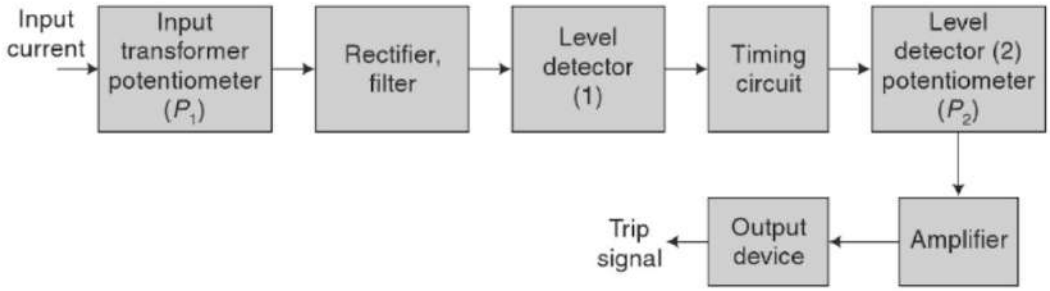
**18)Draw the duality between amplitude and phase comparators.**



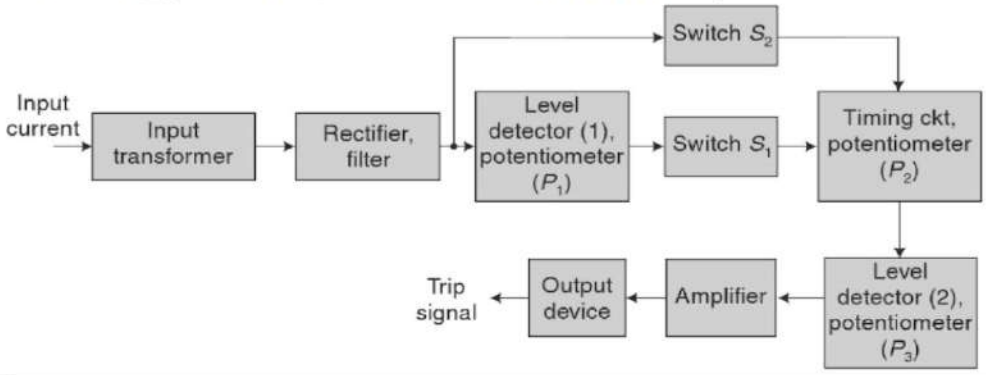

**19** **Draw the duality between phase and amplitude comparators.** BTL 3




**20** **Draw the block diagram of static instantaneous over current relay.** BTL 3




**21** **Draw the block diagram of static inverse time over current relay.** BTL 3




**22) What are the types of Numerical Over current relays?**

- Microprocessor based over current relays
- Microcontroller based over current relays
- Digital Signal Processor based over current relays

**23) What are the types of Numerical Over current relays?**

- Microprocessor based over current relays
- Microcontroller based over current relays
- Digital Signal Processor based over current relays

- FPGA based over current relays
- ANN over current relays

**23 )What is meant by under reach of distance relay?**

A distance relay is said to under reach when the impedance seen by relay due to fault is more than the relay setting value even though the fault point is within the protected zone of line. This means that reach of relay has decreased from the setting value.

**24)What is meant by over reach of distance relay?**

The tendency of a distance relay to operate eve when the fault is beyond its preset reach is known as over reach.

**25)State the reason for overreach of distance relays.**

Presence of DC offset in the fault current wave.

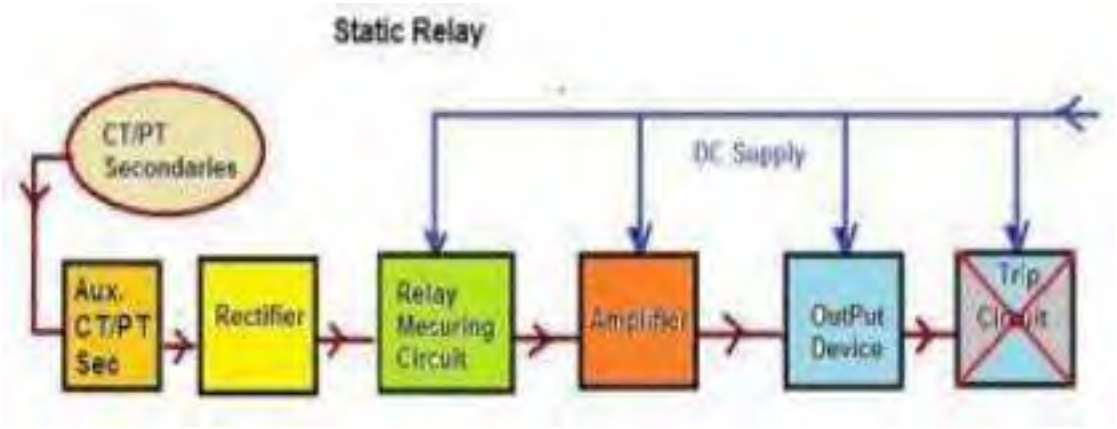
## PART * B

**1)Explain with neat block diagram of the solid state relays. (13M)**

**Static relay introduction:** (3 M)

- Measurement or comparison of electrical quantities is done in a static network which is designed to give an output signal, when a threshold condition is passed, which operates a tripping device.

**Block diagram:**




**Working:** (6 M)

- A relay using combination of both static and electro-magnetic units is also called a static relay provided that static units accomplish the response.
- The performance of static relay is better than electromagnetic relays as they are fast acting and accuracy of measurement is better than electromagnetic relay.
- The rectified output supplied to a measuring unit comprising of comparators, level detectors, filters, logic circuits. Output - actuated when the dynamic input (i.e., the relaying quantity) attains the threshold value.
- This output of the measuring unit amplified by amplifier and fed to the output unit device, which is usually an electro-magnetic one. The output unit energizes the trip coil only when relay operates.

**2 )Explain the block diagram of numerical relay with neat sketch. (13M)**

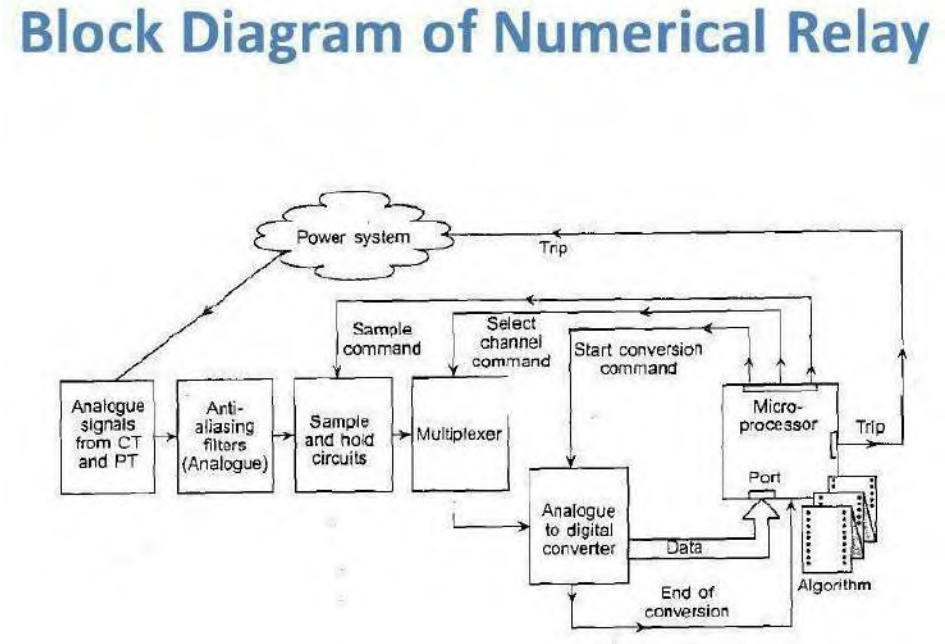
**Answer:**

**Numerical relay introduction** (3 M)

Numeric relays are programmable relays. The characteristics and behavior of the relay can be programmed.

First generation numerical relays to meet the static relay protection characteristic, modern numeric protection devices capable of providing complete protection with added functions like control and monitoring.
Numerical protection devices offer several advantages in terms of protection, reliability, and trouble shooting and fault information.

**Block diagram:**




**Working:** (6 M)

- These are microprocessor - based relays in contrast to other relays that are electromechanically controlled.
- Function of Relay: Modern power system protection devices are built with integrated functions. Multifunction like protection, control, monitoring and measuring are available today in numeric power system protection devices. Also, the communication capability of these devices facilitates remote control, monitoring and data transfer.
- Numerical protection devices are available for generation, transmission and distribution systems
- Numerical relays are micro processor based relays
- These relays provide great precision and convenience in application in the sophisticated electronic products.

Advantages of Numerical relays:

- Compact Size
- Flexibility:
- Reliability
- Multi Function Capability
- Modular frame:
- Low burden.
- Sensitivity:
- Speed & Fast Resetting

**3)Describe with neat block diagram about the working of numerical over current protection. (13M).**

**Answer:**
**Diagram**

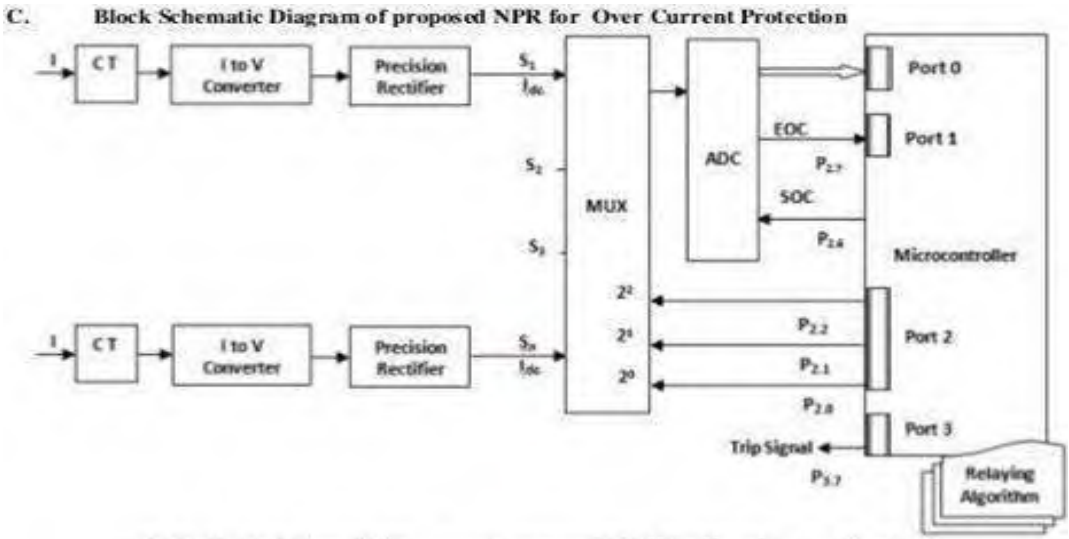



Fig.1: Block Schematic Diagram of proposed NPR for Over Current Protection

**Working:**

- The output of the rectifier fed to the multiplexer.
- The microcomputer sends a command to switch on desired channel of the multiplexer to obtain the rectified voltage proportional to the current in a particular circuit.
- The output of the multiplexer is fed to the A/D converter to obtain the signal in digital form.
- The A/D converter ADC 0800 has been used for this purpose.
- The microcomputer reads the end of conversion signal to examine whether the conversion is over or not.
- As soon as the conversion is over, the microcomputer reads the current signal in digital form and then compares it with the pickup value.

**3) Explain about amplitude comparators and phase comparators in detail. ( 13 M)**

**Answer:**

Amplitude comparators- (3 M)

Amplitude comparator compares the magnitude of two input quantities irrespective of the angle between them. One – operating quantity, Two- restraining quantity. Amplitude of operating quantity greater than the restraining quantity, relay trips.

Phase comparators- (3 M)

Compares two input quantities in phase angle, irrespective of their magnitudes and operates if the phase angle between them is <=$90_0$

Synthesis of relays using static comparators- (7 M)

**4) Draw the flowchart for numerical over current relay. ( 8 M)**

**Answer: Page 99 - Notes**

**Flowchart:**

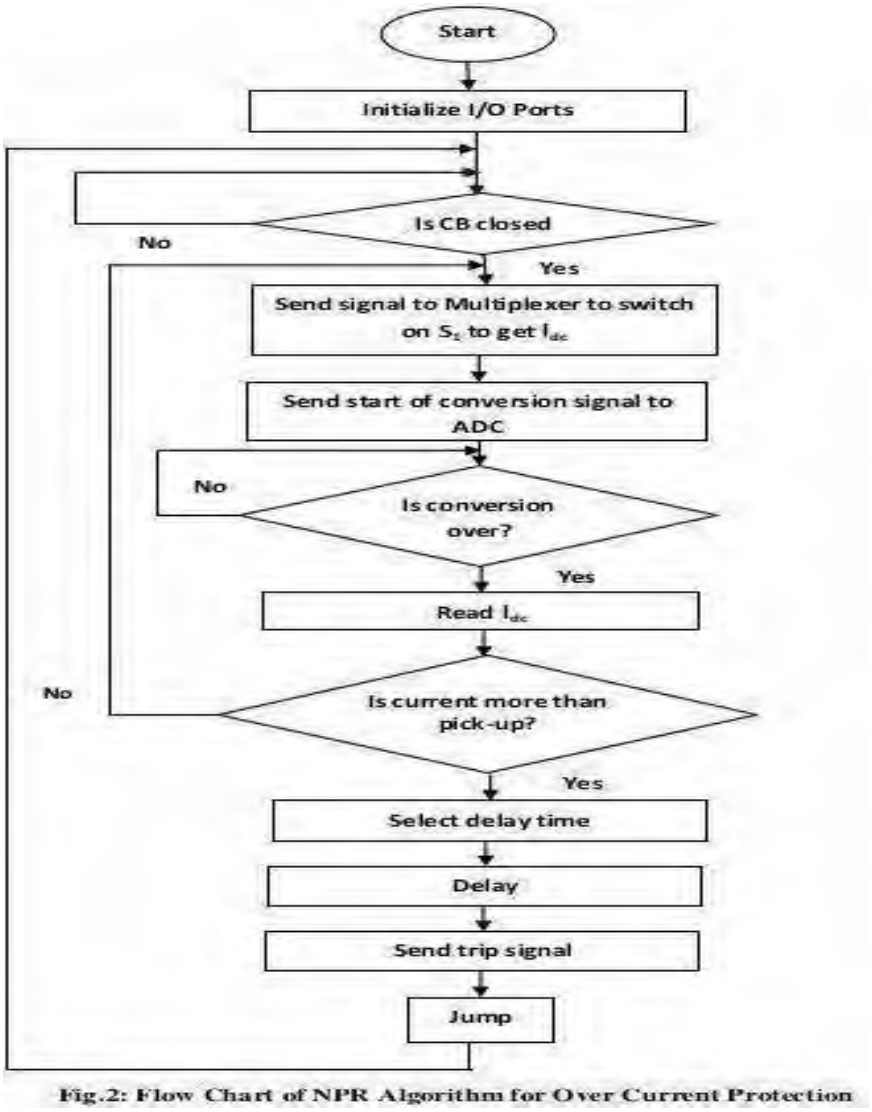



Fig.2: Flow Chart of NPR Algorithm for Over Current Protection

Explanation: (3 M)

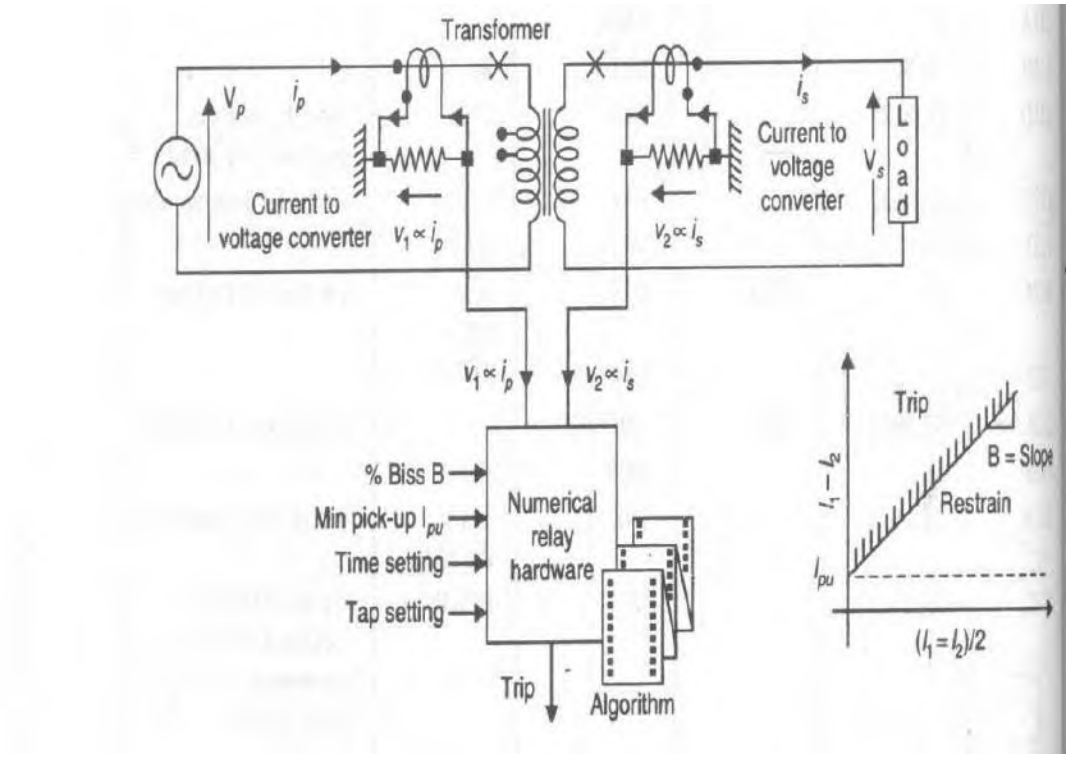
- When the fault current exceeds the pickup value, the fault current - measured once again by the microprocessor to confirm whether - fault current or transient.
- In case of any transient of short duration, the measured current above pick up value will not appear in the second measurement.
- But if there is an actual fault, it will again appear in the second measurement also and then the microprocessor will issue the tripping signal to disconnect the faulty part of the system.

## PART*C

**1)Describe with neat block diagram, the working of numerical transformer differential protection. (15 M)**

**Answer:**

**Diagram**




**Working:** (5 M)

The idea is to estimate the phasor value of the current on both sides of the transformer and find the phasor difference between the two. If magnitude of this difference -substantial, internal fault indicated and the trip signal should be issued.

**Algorithm for percentage differential relay**:

- Read percentage bias B and the minimum pick up $I_{pu}$.
- Read $i_p$ samples. Estimate phasor $I_p$ using any technique.
- Read is samples. Estimate phasor Is using any technique.
- Compute spill current $I_{spill} = I_p - I_s$.
- Compute circulating current $I_{circulating} = (I_p + I_s) / 2$
- If $I_{spill} > (BI_{circulating} + I_{pu})$ then trip, else restrain.

**2)Describe with neat block diagram, the working of static instantaneous over current protection relay.(15 M)**

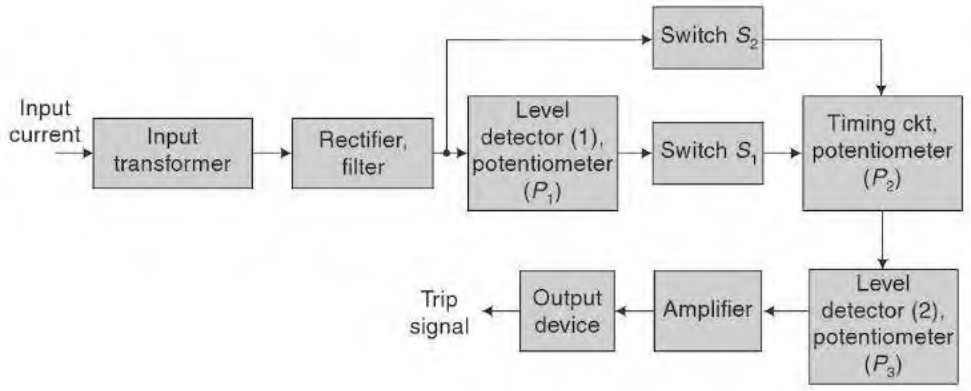
**Answer:**

**Over current relay-** (3 M)

Numerical over current protection algorithm first reads all the setting such as the type of characteristics to be implemented, the pickup value $I_{perunit}$, the time multiplier setting in case of inverse time over current relay or the time delay in case of DTOC relay. Using a multiplexer,, the microprocessor can sense the faults currents. If fault current exceeds a

pickup value,, microprocessor sends a tripping signal to the C.B of the faulty circuit.

**Block diagram:**




**Explanation:** (8 M)

- The current derived from the C.T is fed to the input transformer which gives a proportional output voltage.
- The input transformer has an air gap in the iron core and is provided with tappings on its secondary winding to obtain different current settings.
- The output voltage of the transformer is rectified through a rectifier and then filtered at a single stage.
- A fixed portion of the rectified and filtered voltage (through a potential divider) is compared against a preset pick up by a level detector and if it exceeds the pickup value, a signal through an amplifier is given to the output device which issues the trip signal.
- The output may either be a static thyristor circuit or an electromagnetic slave relay.

**3 )Explain the types of amplitude comparators in detail. (15 M)**

**Answer: Page: 66- Badri Ram**

**Types:** (2 M)

- Circulating current type rectifier bridge comparators
- Phase splitting type comparators
- Sampling comparators

**Circulating current type rectifier bridge comparators**- used for over current and distance relay characteristics. Operating and restraining quantities are rectified and then applied to a slave relay or thyristor circuit. Two full wave rectifiers- one for operating quantity and the other for restraining quantity.

Bridges- DC polarized relay.

Operating quantity exceeds restraining quantity, relay operates. Diagram. ( 5 M)

**Phase splitting type comparators-** Input split into six components $60_0$ apart, output after rectification smoothens within 5%, a continuous output signal is obtained. The operating time depends on the time constant. Diagram. ( 5 M)

**Sampling comparators-** One of the inputs is rectified and it is compared with the other input at the particular moment. Diagram.

# UNIT V CIRCUIT BREAKERS

Physics of arcing phenomenon and arc interruption - DC and AC circuit breaking – re-striking voltage and recovery voltage - rate of rise of recovery voltage - resistance switching - current chopping - interruption of capacitive current - Types of circuit breakers – air blast, air break, oil, SF6 and vacuum circuit breakers – comparison of different circuit breakers – Rating and selection of Circuit breakers.

## PART * A

**Q.No. 1 What is resistance switching?**

It is the method of connecting a resistance in parallel with the contact space(arc). The resistance reduces the restriking voltage frequency and it diverts part of the arc current. It assists the circuit breaker in interrupting the magnetizing current and capacity current.

**2) What do you mean by current chopping?**

When interrupting low inductive currents such as magnetizing currents of the transformer, shunt reactor, the rapid deionization of the contact space and blast effect may cause the current to be interrupted before the natural current zero. This phenomenon of interruption of the current before its natural zero is called current chopping.

**3 )What are the methods of capacitive switching?**

Opening of single capacitor bank

Closing of one capacitor bank against another

**4 )What is an arc?**

Arc is a phenomenon occurring when the two contacts of a circuit breaker separate under heavy load or fault or short circuit condition.

**5) Give the two methods of arc interruption.**

High resistance interruption:-the arc resistance is increased by elongating, and splitting the arc so that the arc is fully extinguished _ Current zero method:-The arc is interrupted at current zero position that occurs100 times a second in case of 50Hz power system frequency in ac.

**6 )What is restriking voltage?**

It is the transient voltage appearing across the breaker contacts at the instant of arc being extinguished.

**7)What is meant by recovery voltage?**

The power frequency rms voltage appearing across the breaker contacts after the arc is extinguished and transient oscillations die out is called recovery voltage.

**8)What is RRRV?**

RRRV is the rate of rise of restriking voltage, expressed in volts per microsecond. It is closely associated with natural frequency of oscillation.

**9 )What is circuit breaker?**

Circuit breaker is a piece of equipment used to break a circuit automatically under fault conditions. It breaks a circuit either manually or by remote control under normal conditions and under fault conditions.

**10)Write the classification of circuit breakers based on the medium used for arc extinction.**

- Air break circuit breaker
- Oil circuit breaker
- Minimum oil circuit breaker
- Air blast circuit breaker

- SF6 circuit breaker
- Vacuum circuit breaker

**11)What is the main problem of the circuit breaker?**

When the contacts of the breaker are separated, an arc is struck between them. This arc delays the current interruption process and also generates enormous heat which may cause damage to the system or to the breaker itself. This is the main problem.

**12)Write the demerits of MOCB.**

- Short contact life
- Frequent maintenance
- Possibility of explosion
- Larger arcing time for small currents
- Prone to restricts

**14) What are the advantages of oil as arc quenching medium?**

• It absorbs the arc energy to decompose the oil into gases, which have excellent cooling properties

• It acts as an insulator and permits smaller clearance between line conductors and earthed components

**15)What are the hazards imposed by oil when it is used as an arc quenching medium?**

There is a risk of fire since it is inflammable. It may form an explosive mixture with arc. So oil is p:red as an arc quenching medium.

**16)What are the advantages of MOCB over a bulk oil circuit breaker?**

• It requires lesser quantity of oil
• It requires smaller space
• There is a reduced risk offire
• Maintenance problem are reduced

**17) What are the disadvantages of MOCB over a bulk oil circuit breaker?**

The degree of carbonization is increased due to smaller quantity of oil There is difficulty of removing the gases from the contact space in time The dielectric strength of the oil deteriorates rapidly due to high degree of carbonization

**18)What are the types of air blast circuit breaker?**

Arial-blast type
Cross blast
Radial-blast

**19)What are the advantages of air blast circuit breaker over oil circuit breaker?**

- The risk of fire is diminished
- The arcing time is very small due to rapid buildup of dielectric strength between contacts
- The arcing products are completely removed by the blast whereas oil deteriorates with successive operations.

**20) What are the demerits of using oil as an arc quenching medium?**

• The air has relatively inferior arc quenching properties

• The air blast circuit breakers are very sensitive to variations in the rate of rise of restriking voltage

• Maintenance is required for the compression plant which supplies the airblast

**21)What is meant by electro negativity of SF6gas?**

SF6 has high affinity for electrons. When a free electron comes and collides with a neutral

gas molecule, the electron is absorbed by the neutral gas molecule and negative ion is formed. This is called as electro negativity of SF6 gas.

**22)What are the characteristic of SF6gas?**

It has good dielectric strength and excellent arc quenching property. It is inert, non- toxic, noninflammable and heavy. At atmospheric pressure, its dielectric strength is 2.5 times that of air. At three times atmospheric pressure, its dielectric strength is equal to that of the transformer oil.

**23)Write the classifications of test conducted on circuit breakers.**

- Type test
- Routine test
- Reliability test
- Commissioning test

**24)What are the indirect methods of circuit breaker testing?**

- Unit test
- Synthetic test
- Substitution testing
- Compensation testing
- Capacitance testing

**25)What are the advantages of synthetic testing methods?**

• The breaker can be tested for desired transient recovery voltage and RRRV.
• Both test current and test voltage can be independently varied. This gives flexibility to the test
• The method is simple
• With this method a breaker capacity (MVA) of five time of that of the capacity of the test plant can be tested.

**26)How does the over voltage surge affect the power system?**

The over voltage of the power system leads to insulation breakdown of the equipment‟s. It causes the line insulation to flash over and may also damage the nearby transformer, generators and the other equipment connected to the line.

## PART * B

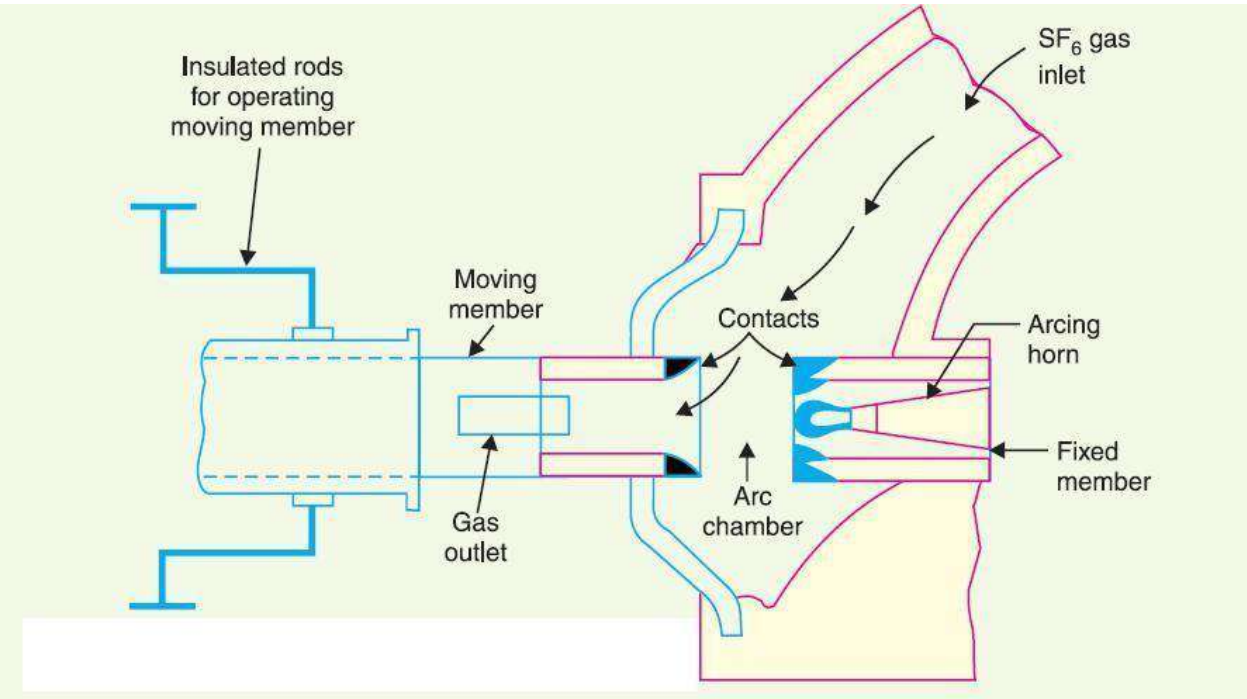
1.**Explain about the SF6 circuit breaker in detail. (13M)**

**Answer: Page 5.25- V.Thiagarajan**

**Diagram: (5 M)**

**Explanation: (8 M)**

➢ SF6 gas has high dielectric strength which is the most important quality of a material for use in electrical equipments and in particular for breaker it is one of the most desired properties. It has high Rate of Rise of dielectric strength after arc extinction.

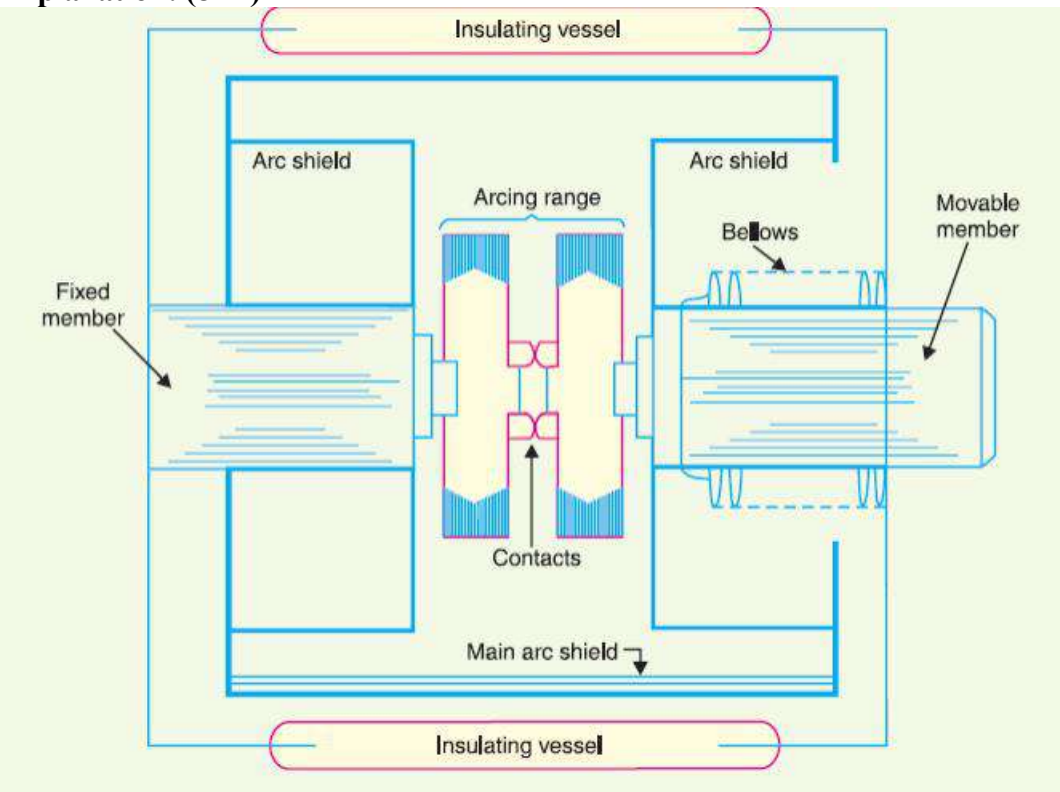



2. **Explain about the vacuum circuit breaker in detail. (13M)**

**Answer: Page 5.23- V.Thiagarajan**

**Diagram: (5 M)**

**Explanation: (8 M)**



**Principle.** The arc is quickly extinguished because the metallic vapours, electrons and ions produced during arc rapidly condense on the surfaces of the circuit breaker contacts, resulting in quick recovery of dielectric strength.

3. **Explain about the oil circuit breakers in detail.(13M)**

**Answer: Page 5.9- V.Thiagarajan**

**Costruction: ( 5 M)**

There are two compartments separated from each other but both filled with oil. The upper chamber is the circuit breaking chamber while the lower one is the supporting chamber.

*Circuit-breaking chamber.* It is filled with oil and has the following parts

**(*a*)** upper and lower fixed contacts

**(*b*)** moving contact

**(*c*)** turbulator

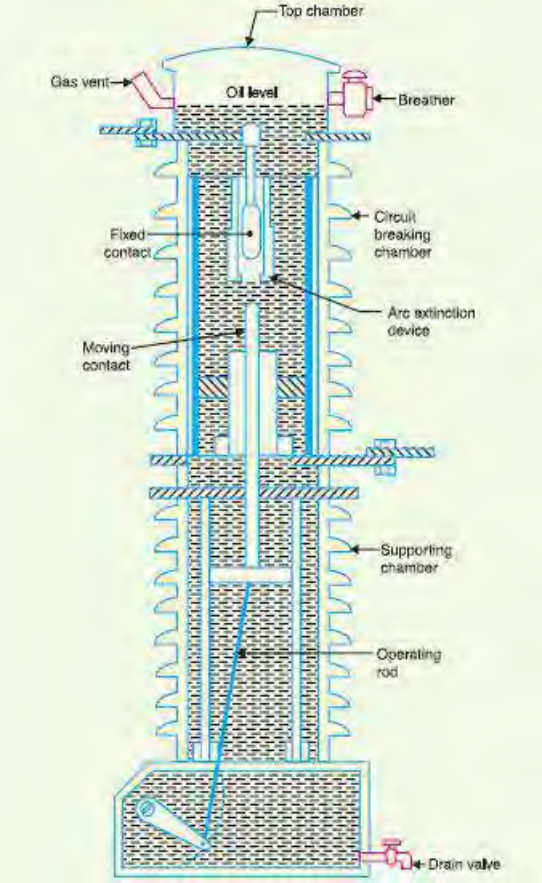



**Diagram: (5 M)**

Top chamber. It is a metal chamber and is mounted on the circuit-breaking chamber.

**Operation: (5 M)**

Under normal operating conditions, the moving contact remains engaged with the upper fixed contact. When a fault occurs, the moving contact is pulled down by the tripping springs and an arc is struck. The arc energy vaporises the oil and produces gases under high pressure.

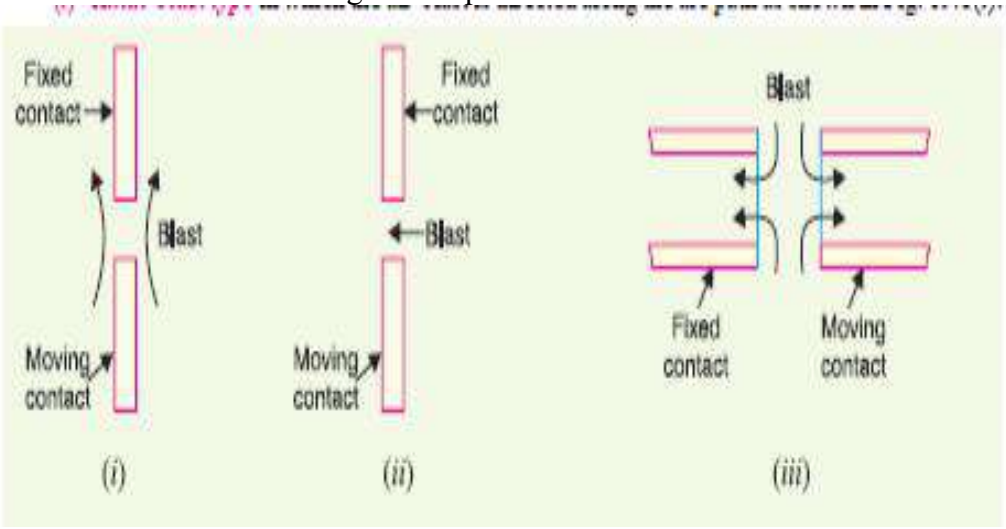
## PART*C

1)**Explain about the air blast circuit breakers in detail.**

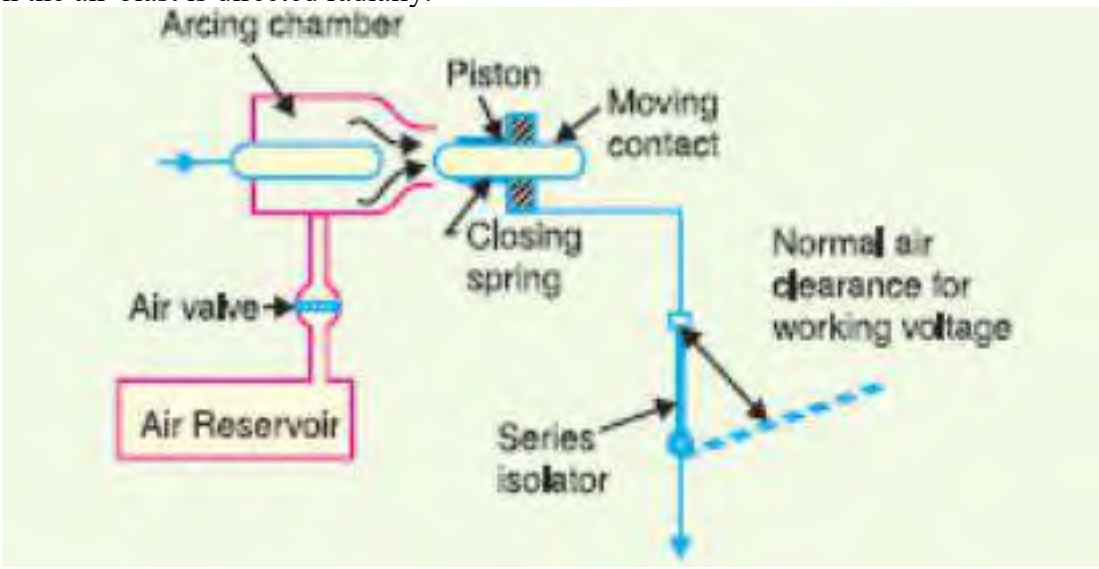
**Answer: Page 5.19- V.Thiagarajan**

**Principle: (3 M)**

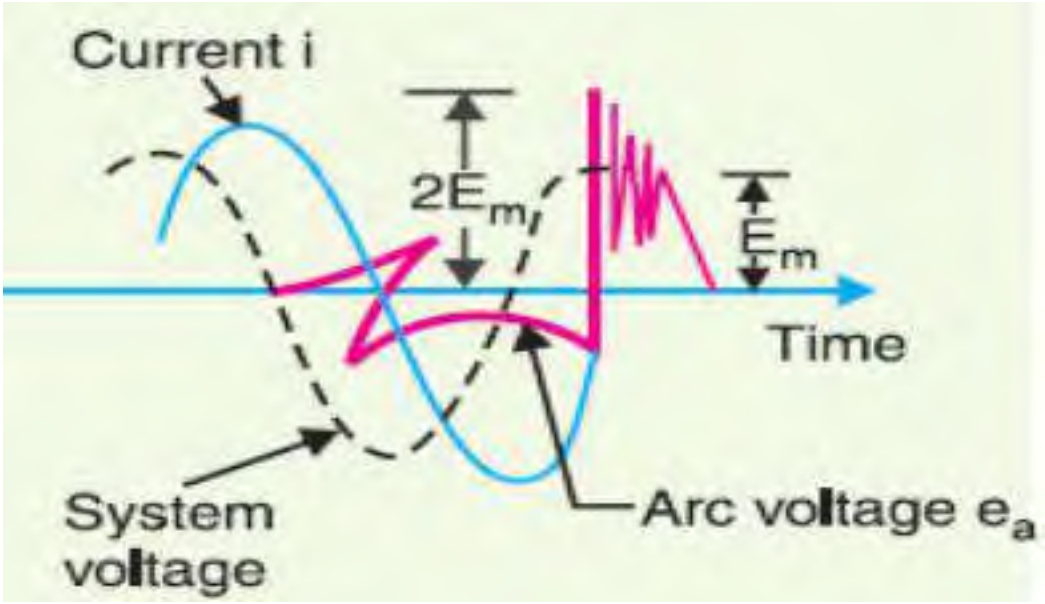
**Construction with diagram: (7 M)**
**Working: (5 M)**
Depending upon the direction of air-blast in relation to the arc, air-blast circuit breakers are classified into :
**(*i*)** Axial-blast type in which the air-blast is directed along the arc path




Cross-blast type in which the air-blast is directed at right angles to the arc path.
Radial-blast type in which the air-blast is directed radially.




**2.Explain about Rate of rise of recovery voltage (15M)**
**Answer: Page 4.17- V.Thiagarajan**
**Diagram: (4 M)**
**Explanation: (6 M)**



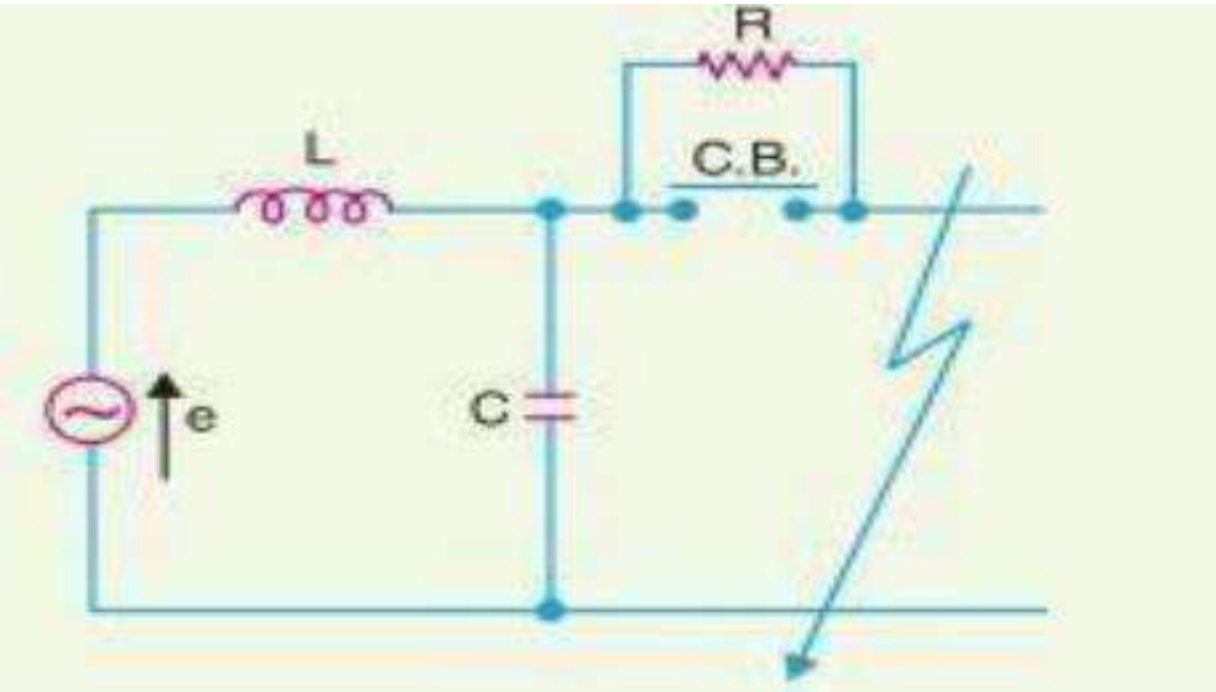

Before current interruption, the capacitance *C* is short-circuited by the fault and the short-circuit current through the breaker is limited by inductance *L* of the system only
When the contacts are opened and the arc finally extinguishes at some current zero, the generator voltage *e* is suddenly applied to the inductance and capacitance in series.
Transient frequency :$fn = 1/2\ \pi\sqrt{LC}$
The value of R.R.R.V. depends upon :
**(*a*)** recovery voltage
**(*b*)** natural frequency of oscillations **(3 M)**
For a short-circuit occuring near the power station bus-bars, *C* being small, the natural frequency
$f_n (= 1/ 2\ \pi\ \sqrt{LC})$ will be high. Consequently, R.R.R.V. will attain a large value.
Thus the worst condition for a circuit breaker would be that when the fault takes place near the bus-bars.

**3. Write short notes on Resistance switching (15M)**

**Answer: Page:4.22- V.Thiagarajan**

**Resistance switching: (4 M)**
**Diagram: (4 M)**
**Derivation: (4 M)**
**Explanation: (3 M)**

To reduce the restriking voltage, RRRV and severity of the transient oscillations, a resistance is connected across the contacts of the circuit breaker.




This is known as resistance switching.
The analysis of resistance switching can be made to find out the critical value of the shunt resistance to obtain complete damping of transient oscillations.