MAILAM ENGINEERING COLLEGE
Mailam(po),Villupuram(dt.) Pin: 604 304
(Approved by AICTE, New Delhi, Affiliated to Anna University Chennai & Accredited by TCS)
Department of Electrical & Electronics Engineering

SUB CODE / NAME: EE 6702 / PROTECTION AND SWITCHGEAR
YEAR / SEC : IV / A & B

SYLLABUS

UNIT I PROTECTION SCHEMES
Principles and need for protective schemes – nature and causes of faults – types of faults – faultcurrent calculation using symmetrical components – Methods of Neutral grounding – Zones ofprotection and essential qualities of protection – Protection schemes

UNIT II ELECTROMAGNETIC RELAYS
Operating principles of relays - the Universal relay – Torque equation – R-X diagram –
Electromagnetic Relays – Overcurrent, Directional, Distance, Differential, Negative sequence and Under frequency relays.

UNIT III APPARATUS PROTECTION
Current transformers and Potential transformers and their applications in protection schemes -Protection of transformer, generator, motor, busbars and transmission line.

UNIT IV STATIC RELAYS AND NUMERICAL PROTECTION
Static relays – Phase, Amplitude Comparators – Synthesis of various relays using Static comparators – Block diagram of Numerical relays – Overcurrent protection, transformer differential protection, distant protection of transmission lines.

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.

TEXT BOOKS:

1. Sunil S.Rao, 'Switchgear and Protection', Khanna Publishers, New Delhi, 2008.
2. B.Rabindranath and N.Chander, 'Power System Protection and Switchgear', New Age International (P) Ltd., First Edition 2011.
3. M.L.Soni, P.V.Gupta, U.S.Bhatnagar, A.Chakrabarti, 'A Text Book on Power System Engineering', DhanpatRai& Co.,1998.

Unit	Part - A				Part - B				Mon/Year
	Q. No	Page No.	Q. No	Page No.	Q. No	Page No.	Q. No	Page No.	
01	04	02	09	03	12	21	06	16	Dec-2017
	01	02	27	06	02	07	12	21	May-2018
					04	11			
02	25	36	26	36	01	37	04	46	Dec-2017
	27	36	23	35	16	76	08	54	May-2018
					12	63			
03	07	84	12	84	01	90	04	97	Dec-2017
	13	84	28	87	04	97	05	103	May-2018
					Prob I	120	07	111	
04	01	128	18	131	03	135	04	137	Dec-2017
	13	130	19	131	02	135	14	156	May-2018
					04	137			
05	26	171	31	172	03	176	13	189	Dec-2017
					04	177			
	32	172	23	210	03	176	15	196	May-2018
					04	177			

Prepared By	Verified By	Verified By	Approved By
Dr.S.Balasubramaniyan, Prof/EEE M.Saravana Kumar, AP/EEE	BC	HOD/EEE 21/6/18	Principal

UNIT I
PROTECTION SCHEMES

Principles and need for protective schemes – nature and causes of faults – types of faults – fault current calculation using symmetrical components – Methods of Neutral grounding – Zones of protection and essential qualities of protection – Protection schemes

PART A

1. **What are the functions of protective relays (NOV/DEC-2006,MAY/JUNE-2007) (or) Why Protection schemes are needed in power system. (Apr/May 2018)**

   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.

2. **Define protected zone. (APRIL/MAY-2015)**

   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.

3. **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.

4. **What is primary protection? (Nov/Dec 2017)**

   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.

5. **What is back up protection?**

   Is the second line of defence , which operates if the primary protectionfails to activate within a definite time delay.

6. **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.

7. **What are the major protective elements needed for power system and why?**
   It includes circuit breaker and protective relays because they isolate faulty sections of the system from healthy sections.

8. Where are the possibilities of faults to occur in a power system? What electrical quantities changes during faults?(NOV/DEC-2012, NOV/DEC-2008)

It occurs in generators, transformers, and transmission and distribution lines. Electrical quantities like current, voltage and frequency changes during fault.

9. Write types of faults? (OR) What are the different types of fault occurring in the power system? (MAY/JUNE-2014)(MAY-2017)(Nov/Dec 2017)

They are broadly classified as

- Symmetrical and unsymmetrical
- Unsymmetrical fault further classified in to
- Single phase to ground
- Two phase to ground
- Phase to phase
- Open circuit phases
- Winding faults.

10. List the common protective schemes which are used for modern power system and protection?

- Over current protection
- Distance protection
- Distance protection
- Carrier current protection
- Differential protection

11. What is the need for calculating short circuit current?

During short circuit condition the excess amount of current which causes damage to the system is determined and accordingly the breaker ratings are made to avoid damage to that zone. Thus the short circuit current is predetermined and calculated.

12. What are the various essential qualities of protective relaying? (NOV/DEC-2008, NOV/DEC-2006)

Selectivity or discrimination

- Reliability
- Sensitivity
- Stability
- Fast operation
- Speed
- Economy

13. Mention the essential features of power system protection? (NOV/DEC-2008)

- Reliability
- Sensitivity
- Stability
- Fast operation
- Selectivity or discrimination

14. Explain the need for overlapping the zones of protection? (APRIL/MAY-2008)

Adjacent protective zones must overlap each other. If no overlapping is made a fault on the boundary of the zones may not lie in any of the zones, hence no C.B would trip. Hence overlapping is needed.

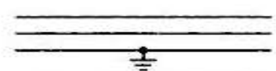
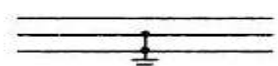
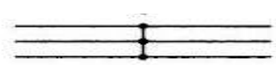
15. What is surge voltage?

A sudden sharp rise in the voltage which occurs due to lightning stroke or discharges on overhead lines. It also occurs during C.B operation particularly by breaking on inductive and closing of capacitive currents.

16. What are the causes of fault in power systems?(NOV/DEC-2007)

- Breaking of conductor,
- Failure of insulation,

17. What are the different types of fault in power systems transmission lines.(NOV/DEC-2007, APRIL/MAY-2008)

Sl.No	Type of fault	Representation	Occurrence %
1	**Line to Ground (L-G)**		85
2	**Line to Line (L-L)**		8
3	**Line to line to Ground (L-L-G)**		5
4	**Line to Line to Line (L-L-L)**		2 or less

18. List out the duties of fault limiting reactor. (NOV/DEC-2013)

A passive 3Ø air cored reactor designed for in-line operation in LV circuits, and typically installed where fault levels are found to be excessive due to reduced source impedance (eg cogeneration). The Inductance of the reactor is designed to reduce the downstream fault level to suit the fault level rating of connected equipment, and will remain constant at any current up to and including the rated short time Current. The reactance value will cause a significant voltage drop across the reactor, but due to the very high Q factor, the phase angle of this voltage drop will be such that voltage drop at the load equipment generally will be negligible.

19. Write the sources of fault power. (NOV/DEC-2013)

The generators connected to the power system are the main sources of fault currents. Under short-circuit conditions, a drop in frequency and voltage are common and under these conditions synchronous machines feed back into the system. Also, large induction motors, having considerable flywheel energy, act as generators in the event of reduced frequency. So large induction motors shall also be included in the short-circuit studies. The KVA can be assumed to be equal to the HP rating of the motor for the purpose of fault calculations.

20. Write the importance of ground wire.(MAY/JUNE-2014)

Earthing is basically a part of electrical wiring which is being done on initial level in order to connect the electrical system with general mass of earth so as to have discharge of electrical energy, fault current. Earthling is important to make the electrical fitting safe and secure from the immediate shock or thunder storm that may affect building, human being, animals etc….

21. What is the necessity of earthing? And different types.(MAY/JUNE-2015)

The necessity for earthing is to ensure that the metalwork of electrical equipment, other than current carrying parts, cannot have a potential above earth in the event of a fault which might otherwise cause danger of an electric shock. If a fault is developed, causing unearthed metalwork of a piece of electrical equipment; it is charged to a level of dangerous potential. Any person touching the metal & at the same time comes in contact with earth will receive a severe electric shock. Had the metal been effectively earthed, the very low resistance of the circuit would result in a flow of current sufficient to blow the Fuse or to operate the protective device. In an earth metalwork of a piece of electrical equipment becomes a zero potential due to this; a person does not get a shock.

22. Define term "Pick up" value in protective relay.(NOV/DEC-2014)

It is the minimum current in the relay coil at which the relay starts to operate. When the relay coil current is equal to or greater than the pickup value, the relay operates to energize the trip coil which opens the CB.

23. What is the difference between a short circuit and an overload? (NOV/DEC-2015) & (MAY/JUNE-2016)

A short circuit is an abnormal connection between two nodes of an electric circuit intended to be at different voltages.

Demand on an equipment that exceeds its capacity. Overload usually results in breakdown of the equipment or collapse of the system, sometimes beyond the possibility of repair.

24. What do you mean by dead spot? (NOV/DEC-2016)

The zone which is unprotected is called dead spot.

25. What is the difference between primary protection and back up protection? (NOV/DEC-2016)

primary protection	back up protection
The protection in which fault occurring in a line will be cleared by its own relay and circuit breaker.	It is the second line of defense, which operates if the primary protection fails to operate within a definite time

26. Give the difference between circuit breaker and switch?(May-2017)

circuit breaker	switch
It performs interruption function with relay Used to close and open a circuit along with automatic tripping	It does not protects any device Used only to isolate and close a circuit manually

27. Write down the importance of symmetrical components for fault current calculations. (Apr/May 2018)

In case of three phase's balanced system, currents and voltages are equal in magnitude and are displaced from each other by 120°. The currents and voltages are thus said to be symmetrical. The analysis of such system is easy which is done on per phase basis. But when the load is unbalanced, the analysis using normal techniques becomes difficult. Under such case, method of symmetrical components can be adopted.

PART B

Principles and need for protective schemes

1. Principle and need for Protective systems

- An electric power system consists of generators, transformers, transmission and distribution lines, etc. Short circuits and other abnormal conditions often occur on a power system.
- The heavy current associated with short circuits is likely to cause damage to equipment if suitable protective relays and circuit breakers are not provided for the protection of each section of the power system.
- Short circuits are usually called faults by power engineers.
- If a fault occurs in an element of a power system, an automatic protective device is needed to isolate the faulty element as quickly as possible to keep the healthy section of the system in normal operation. The faults must be cleared within a fraction of a second. If a short circuit persist on a system for longer , it may cause damage to some important sections of the system
- A heavy short circuit current may cause a fire
- It may spread in the system and damage a part of it
- The system may reduce to a low level and an individual generator in a power station or group of generators in different power station may lose synchronism
- Thus an un cleared heavy short circuit may cause the total failure of the system

Nature and causes of faults

2. Discuss the nature and causes of different faults in a power system.(Apr/May 2018)

Any faults in electrical apparatus are nothing but the defect in its electrical circuit which makes current path directed from its intended path. Normally due to breaking of conductors or failure of insulation, these faults occur. The other reasons for occurrence of fault include mechanical failure, accidents. Excessive internal and external stresses. The impedance of the path in the fault is low and the fault currents are comparatively large. The induction of insulation is not considered as a fault until it shows some effect such as excessive current flow or reduction of impedance between conductors or between conductors and earth.

When a fault occurs on a system, the voltage of the three phases become unbalanced. As the fault currents are large, the apparatus may get damaged. The flow of power is diverted towards the fault which affects the supply to the neighboring zone.

A power system consists of generators, transformers, switchgear, transmission and distribution circuits. There is always a possibility in such a large network that some fault will occur in some part of the system. The maximum possibility of fault occurrence is on the transmission lines due to their greater lengths and exposure to atmospheric conditions.

The faults cannot be classified according to the causes of their incidence. The breakdown may occur at normal voltage due to deterioration of insulation. The breakdown may also occur due to damage on account of unpredictable causes which include perching of birds, accidental short circuiting by snakes, kite strings, three branches etc. The breakdown may occur at abnormal voltages due to switching surges or surges caused by lighting.

Types of faults in power system

Active Faults

The "Active" fault is when actual current flows from one phase conductor to another (phase-to-phase) or alternatively from one phase conductor to earth (phase-to-earth). This type of fault can also be further classified into two areas, namely the "solid" fault and the
"incipient" fault.

Passive Faults

Passive faults are not real faults in the true sense of the word but are rather conditions that are stressing the system beyond its design capacity, so that ultimately active faults will occur.

Typical examples are:

Overloading - leading to overheating of insulation (deteriorating quality, reduced life and ultimate failure).

Under frequency - causing plant to behave incorrectly.

Power swings - generators going out-of-step or synchronism with each other

Transient & Permanent Faults

Transient faults are faults which do not damage the insulation permanently and allow the circuit to be safely re-energized after a short period of time. A typical example would be an insulator flashover following a lightning strike, which would be successfully cleared on opening of the circuit breaker, which could then be automatically reclosed.

Transient faults occur mainly on outdoor equipment where air is the main insulating medium. Permanent faults, as the name implies, are the result of permanent damage to the insulation. In this case, the equipment has to be repaired and reclosing must not be entertained.

Symmetrical & Asymmetrical Faults

A symmetrical fault is a balanced fault with the sinusoidal waves being equal about their axes, and represents a steady state condition. An asymmetrical fault displays a d.c. offset, transient in nature and decaying to the steady state of the symmetrical fault after a period of time:

Faults in 3 phase system

The types of faults that can occur on a three phase A.C. system are as follows:

Types of Faults on a Three Phase System

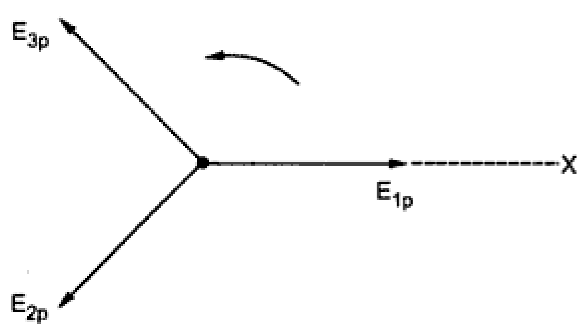
(A) Phase-to earth fault
(B) Phase-to-phase fault
(C) Phase-to-phase-to-earth fault
(D) Three phase fault
(E) Three phase-to-earth fault

Fault current calculation using symmetrical components

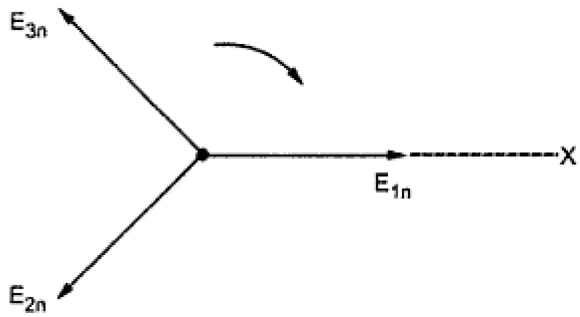
3. FAULT CURRENT CALCULATION USING SYMMETRICAL COMPONENTS (MAY/JUNE-2002, APRIL/MAY-2008, NOV/DEC-2016)(May-2017)

In case of three phase's balanced system, currents and voltages are equal in magnitude and are displaced from each other by 120°. The currents and voltages are thus said to be symmetrical. The analysis of such system is easy which is done on per phase basis. But when the load is unbalanced, the analysis using normal techniques becomes difficult. Under such case, method of symmetrical components can be adopted as suggested by fortes cue. According to his theorem, the unbalanced phasor can be resolved into three balanced systems of phasors. The balanced sets of component cane are given as (a) positive sequence component (b) negative sequence component (c) zero sequence component.

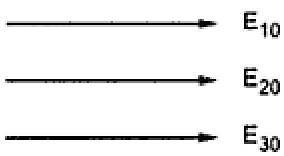
A system of vectors is having positive phase sequence when it has all vectors having same magnitude and is displaced by 120°. They have same time interval to achieve fixed axis of reference as that of generated voltage. The positive sequence is designated by use of subscript P. It is shown in the figure. The vectors come to X axis in order of 1,2and3.



A system of vector is having negative phase sequence when it has all vectors having same magnitude and is displaced by 120°. But arrive at the reference axis at a regular interval same as that of positive sequence but in reverse order i.e. in order of 1, 3, and 2. It is shown in figure suffix n is used to designate negative sequence.

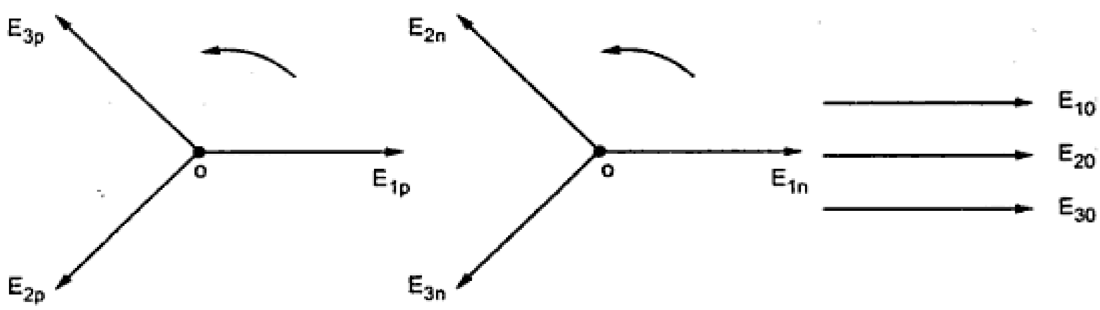


A system of vectors is having zero phase sequence if all the three vectors are not displaced in time from each other and there will be no phase sequence. In such cases the current or voltage in the 3phase circuit will vary simultaneously in all the 3 phases. Such a phase sequence is shown in the figure suffix 0 is used to designate zero sequence.



Consider a system having three vectors and it can be resolved into positive, negative and zero phase sequence components as shown in the figure. It is possible to get 3 vectors by using following equations.

$$E_1=E_{1p}+E_{1n}+E_{10}$$
$$E_2=E_{2p}+E_{2n}+E_{30}$$
$$E_3=E_{3p}+E_{3n}+E_{30}$$



i) Positive sequence of phase **ii) Negative sequence of phase** **iii) Zero sequence of phase**

Consider in general a power system network as shown in the figure suppose that fault occurs at point P in the system. Due to this current I_r, I_y, $I_b$flow out of the system while v_r,v_y,v_b are the line voltages with respect to ground.

If it is assumed that the system is operating at no load before occurring a fault, then the positive sequence voltages of all synchronous machines will be equal and has value same as pre-fault voltage at P. Let this voltage be E_r.

The voltage E_r is present only in the positive sequence network. There is no coupling between sequence network, the sequence voltages at P can be given in terms of sequence currents and Thevenin sequence impedance as

$$\begin{bmatrix} V_{rp} \\ V_{rn} \\ V_{r0} \end{bmatrix} = \begin{bmatrix} E_r \\ 0 \\ 0 \end{bmatrix} - \begin{bmatrix} Z_p & 0 & 0 \\ 0 & Z_n & 0 \\ 0 & 0 & Z_0 \end{bmatrix} \begin{bmatrix} I_{rp} \\ I_{rn} \\ I_{r0} \end{bmatrix}$$

Based on the types of fault the sequence voltages and currents are constrained resulting to a particular connection of sequence networks. The sequence currents and voltages and fault currents and fault voltages can then be easily obtained.

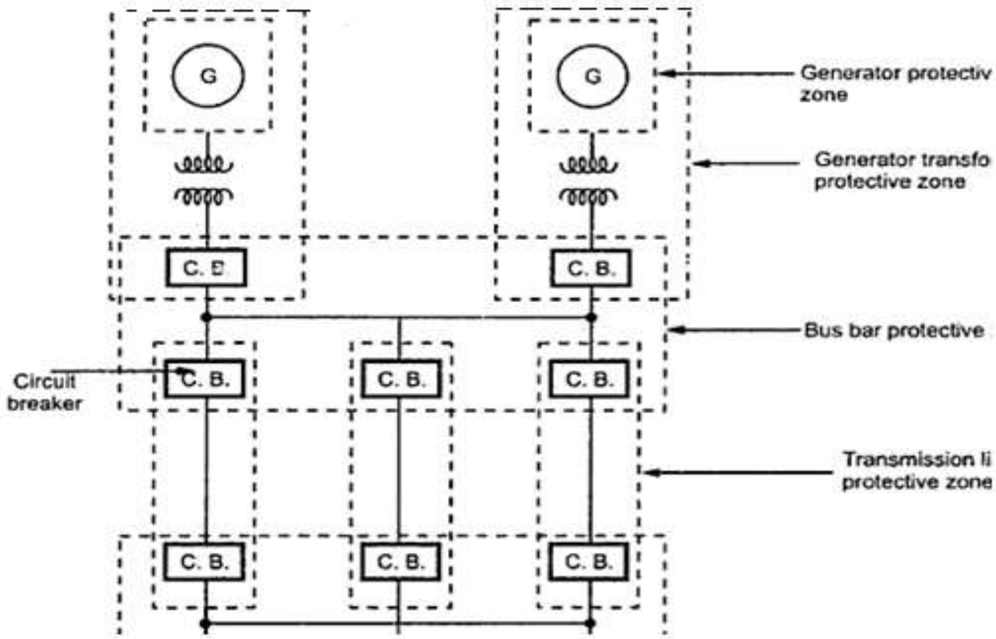
Zones of protection and essential qualities of protection

4. Explain with neat diagram the different zones of protection.(Apr/May 2018)
Explain the overlapping of protective zones with neat sketch (Dec 2015 & May 2016)

PROTECTIVE ZONES

In a protective relaying scheme, the circuit breakers are placed at the appropriate points such that any element of the entire power system can be disconnected for repairing work, usual operation and maintenance requirements and also under abnormal conditions like short circuits. Thus a protective covering is provided around each element of the system.

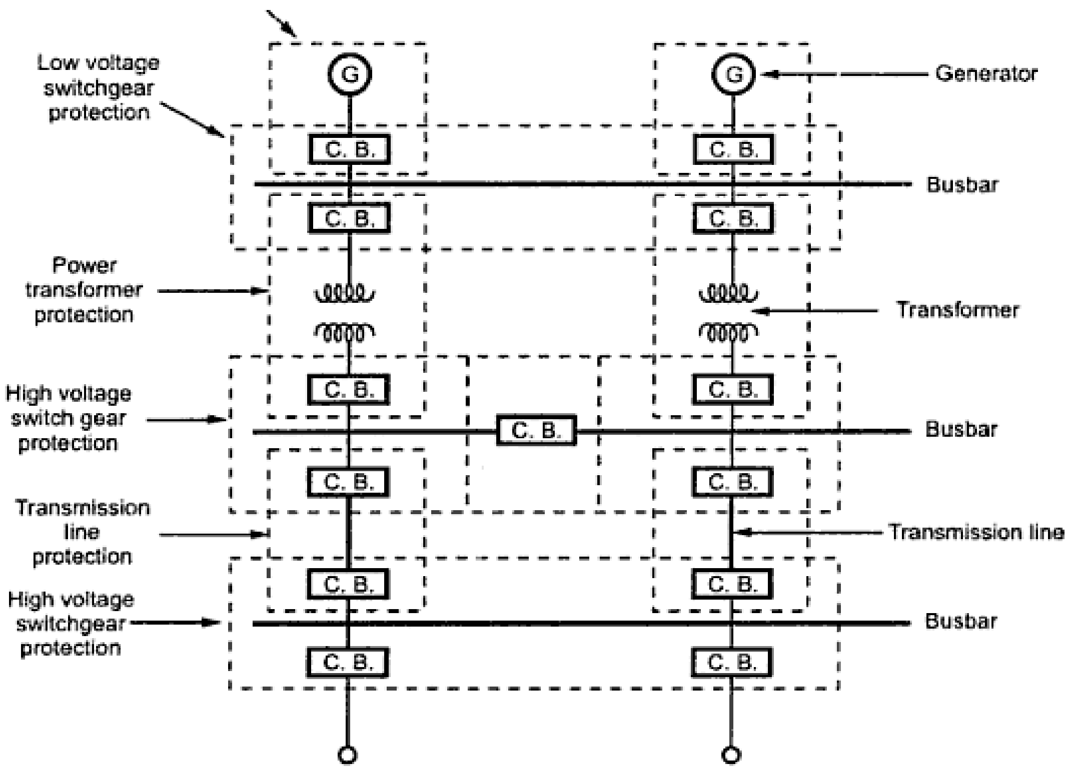
A protective zone is the separate zone which is established around each system element. The significance of such a protective zone is that any fault occurring within a given zone will cause the tripping of relays which causes opening of all the circuit breakers located within the zone. The various components which are provided with the protective zones are (1) generators, (2) transformers, (3) transmission lines, (4) bus bars, (5) cables, (6) capacitors etc. The boundaries of protective zones are decided by the locations of the current transformers.



In practice various protective zones are overlapped. **The overlapping of protective zones** is done to ensure complete safety of each and every element of the system. The zone which is unprotected is called dead spot. The zones are overlapped and hence there is no chance of existence of a dead spot in a system. For the failures within the region where two adjacent protective zones are overlapped, more circuit breakers get tripped than minimum necessary to disconnect the faulty element. If there are no overlaps, the dead spot may exist, means the circuit breakers lying within the zone may not trip even though the fault occurs. This may cause damage to the healthy system. The extent of overlapping of protective zones is relatively small. The probability of the failures in the overlapped regions is very low; consequently the tripping of too many circuit breakers will be also infrequent. The figure shows the overlapping of protective zones in the primary relaying.

It can be seen form the figure that the circuit breakers are located in the connections to each power system element. This provision makes it possible to disconnect only the faulty element form the system. Occasionally for economy in the number of circuit breakers, breakers between the two adjacent sections may be omitted but in that case both power system sections are required to be disconnected for the failure in either of the two.

Each protective zone has certain protective scheme and each scheme has number of protective systems.

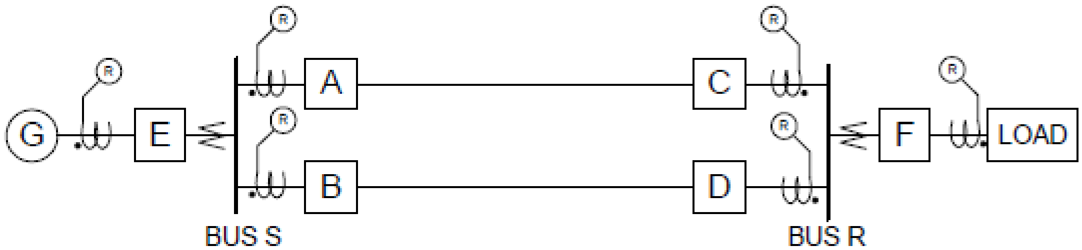


Protection schemes

5. Explain the importance of protective scheme employed in power system (APRIL/MAY-2014)(May 2017)

Power system protection is the process of making the production, transmission, and consumption of electrical energy as safe as possible from the effects of failures and events that place the power system at risk. It is cost prohibitive to make power systems 100 percent safe or 100 percent reliable. Risk assessments are necessary for determining acceptable levels of danger from injury or cost resulting from damage. Protective relays are electronic or electromechanical devices that are designed to protect equipment and limit injury caused by electrical failures. Unless otherwise noted, the generic term relay will be synonymous with the term protective relay throughout this text. Relays are only one part of power system protection, because protection practices must be designed into all aspects of power system facilities. Protective relays cannot prevent faults; they can only limit the damage caused by faults. A fault is any condition that causes abnormal operation for the power system or equipment serving the power system. Faults include but are not limited to: short- or low-impedance circuits, open circuits, power swings, over voltages, elevated temperature, off-nominal frequency operation.

Power system protection must determine from measurements of currents and/or voltages whether the power system is operating correctly. Three elements are critical for protective relays to be effective: measurements, data processing, and control. Figure below shows a typical application of relays to a power system. This example system contains a single source that is connected to bus S through a step-up transformer,



two

Breakers A through F provide the control to isolate faulted sections of the power system. Breaker F would not be required for this example except that customer-owned generation is becoming more common and a load can change to a source. The current transformers attached to the relay is at strategic points in the power system provide the necessary instrumentation for relays to determine the presence of faults. Voltage instrumentation for protection systems may also be required, depending on the relaying scheme used. Any number of relay devices may use any

Single-voltage or current instrumentation device. It is important that the load or burden the relay devices create does not adversely affect the quality or accuracy of the measurements by these or other devices.

Maintain the Ability to Deliver Electric Power

Power systems is consist of generation plants, transmission facilities, distribution lines, and customer loads, all connected through complex electrical networks. In the United States, electrical energy is generated and distributed by a combination of private and public utilities that operate in interconnected grids, commonly called power pools, fore liability and marketing. Elsewhere in the world, generation is tied to load through national or privatized grids. Either way, power flows according to electrical network theory.

Interconnection improves the reliability of each pool member utility because loss of generation is usually quickly made up from other utilities. However, interconnection also increases the complexity of power networks. Power pool reliability is a function of the reliability of the transmission in the individual members. Protection security and dependability is significant in determining the reliability of electrical service for both individual utilities and the interconnected

Power system pool.

Public Safety

Relays are designed to de energize faulted sections as quickly as possible, based on the premise that the longer the power system operates in a faulted condition, the greater the chance that people will be harmed and / or equipment damaged. In some cases power system stability and government regulatory commissions set the speed requirements of extra high voltage (EHV) systems. Because of cost constraints, relays are not designed to prevent the deaths of people or animals that make direct contact with high voltage lines. Instead, designers use physical.

separation and insulation to prevent direct contact. Still, the faster a faulted system element can be detected, isolated, and reenergized, the lower the probability that anyone will encounter hazardous voltages.

Equipment Protection

The primary function of power system protection is to limit damage to power system apparatus. Whether the fault or abnormal condition exposes the equipment to excessive voltages or excessive currents, shorter fault times will limit the amount of stress or damage that occurs. The challenge for protective relays is to extract information from the voltage and current instrumentation that indicates that equipment is operating incorrectly. Although different faults require different fault detection algorithms, the instrumentation remains the same, namely voltages and currents.

Power System Integrity

Properly operating relay systems isolate only the portions on the network directly involved with the fault. If relays operate too quickly or fail to operate, the fault-affected area expands and some circuits can be de energized. Parts of the power system can become isolated or islanded from the rest of the network. A large mismatch between generation and load can put an islanded network in jeopardy of losing the generation control that holds frequency and voltage within acceptable limits. Without generation control, the isolated systems will eventually be tripped off by other relays. Widespread outages caused by cascading relay operations due to voltage or frequency excursions require many work hours to restore power, which is costly from both a labor and a lost revenue perspective.

Power Quality

The factors measured to determine the quality of power are voltage amplitude, frequency, and waveform purity. Voltage amplitude quality takes into account persistent RMS value, flicker, and intermittent dips and peaks, as well as momentary and long-term outages. Frequency changes at most a few hundredths of a hertz, unless the power system has lost generation control. Induction motors have the most sensitivity to power system frequency. Waveform purity is largely a function of harmonic content and is predominantly influenced by load.

The quality of electrical power is an issue for loads that are sensitive to momentary outages and harmonics. In the past, when loads were primarily resistive and inductive, harmonics were either inconsequential or nonexistent. Also, momentary outages had little effect on residential customers. Commercial and industrial customers compensated for momentary outages either with multiple feeds from the utility power sources or with local generation.

Today, every residential customer knows that there was an outage whether she or he was home to experience it. Outages affect home computers and the digital clocks on VCRs, microwave ovens, and other numerous appliances. Although the inconvenience may seem trivial to the relay engineer and perhaps the actual number of outages is even less than in years past, the customer may perceive that the power system is not as reliable today. Good relay selectivity is key to reducing the number of outages and faster relaying minimizes the duration of power dips a substantial component of poor quality is not tripping unnecessarily.

6. Explain the essential qualities of protection and explain them in detail. (NOV/DEC-2016, MAY/JUNE-2014) (Nov/Dec 2017)

OR

Basic functional requirements of protective relaying (APRIL/MAY-2008, NOV/DEC-2014)

A Protective relaying scheme should have certain important qualities. Such an essential qualities of protective relaying are,

1. Reliability
   Protective relaying must be ready to function, reliable and correct in operation at all times under any kind of fault and abnormal conditions of power system for which it has been designed.
2. Selectivity and Discrimination
   It is ability of the protective systems to determine the point at which the fault occurs and select the nearest of the circuit-breakers tripping of which will lead to clearing of fault which minimum or no damage to the system.
3. Speed and Time

- Protective relaying should disconnect a faulty element as quickly as possible.
- Improve the power system stability,
- Decreases the amount of damage incurred,
- Lessens annoyance to power consumers and decreases total outage time for power consumer,
- Decreases the likelihood of development of any one type of fault in to other more severe type,
- Permit use of rapid re-closure of CB to restore service to customers.

4. Sensitivity
   It is capacity of the relaying to operate reliably under the actual conditions that produce the least operating tendency. There may be abnormalities in the normal operating conditions or the fault for which the protection has been designed it is desirable to have protection as sensitive as possible in order that it shall operate for low values of actuating quantity is more complex and use more equipment and circuitry and therefore more expansive. Such protection is used only in that case where simpler arrangement cannot be applied because of low degree of sensitivity.
5. Stability-it should be stable operation in normal operation.
6. Adequateness
7. Simplicity and Economy.

Simplicity of construction and good quality of relay, corrections of design and installation qualified maintenance and supervision, the main factor which influence protective reliability. As a rule, the simple the protective scheme and the lesser number of relays, circuits, contacts it contains, the greater will be reliability.

As with good engineering design, economics play a major rule. It is futile to achieve all important general requirements together, so compromises become necessary. Too much protection is as bad as too little and the relay engineer must strike a sensible compromise with due regard to practical situation considered

7. What are the METHODS OF BACKUP PROTECTION?

The various methods used for the backup protection are classified as,

a) RELAY BACKUP PROTECTION: In this scheme a single breaker is used by both primary as well as backup protection but the two protective systems are different.
b) BREAKER BACKUP PROTECTION: In this method separate breakers are provided for primary and backup protection. Both the types of breakers are at the same station.
c) REMOTE BACKUP PROTECTION: In this method, separate breakers are provided form primary and backup protection. The two types of breakers are at the different stations and are completely isolated and independent of each other.
d) CENTRALLY CO-ORDINATED BACKUP PROTECION: In this method, primary protection is at various stations. There is a central control room and backup protection for all stations is at central control room. Central control continuously inspects the load flow and frequency in the system. If any element of any part of the system fails, load flow gets affected which is sensed by the control room. The control source consists of digital computers which decide the proper switching action. The method is also called centrally controlled backup protection.

8. Explain the different methods of backup protection.(MAY/JUNE-2007)

PRIMARY AND BACKUP PROTECTION:

The protection provided by the protective relaying equipment cane is categorized into two types as:

1. Primary protection
2. Backup protection

The primary protection is the first line of defense and is responsible to protect all the power system elements from all the types of faults. The backup protection comes into play only when the primary protection fails.

The backup protection is provided as the main protection can fail due to many reasons like,

1. Failure in circuit breaker
2. Failure in protective relay
3. Failure in tripping circuit
4. Failure in D.C. tripping voltage
5. Loss of voltage or current supply to the relay

Thus if the backup protection is absent and the main protection fails then there is a possibility of severe damage to the system.

When the primary protection is made inoperative for the maintenance purpose, the backup protection acts like a main protection. The arrangement of backup protective scheme should be such that the failure in main protection should not cause the failure in back up protection as well. This is satisfied if back up relaying and primary relaying do not have anything common. Hence generally backup protection is located at different stations from the primary protection. From the cost and economy point of view, the backup protection is employed only for the protection against short circuit and not for any other abnormal conditions.

CONCEPT OF BACKUP RELAYING:

Consider the backup relaying employed for the transmission line section EF as shown in the figure

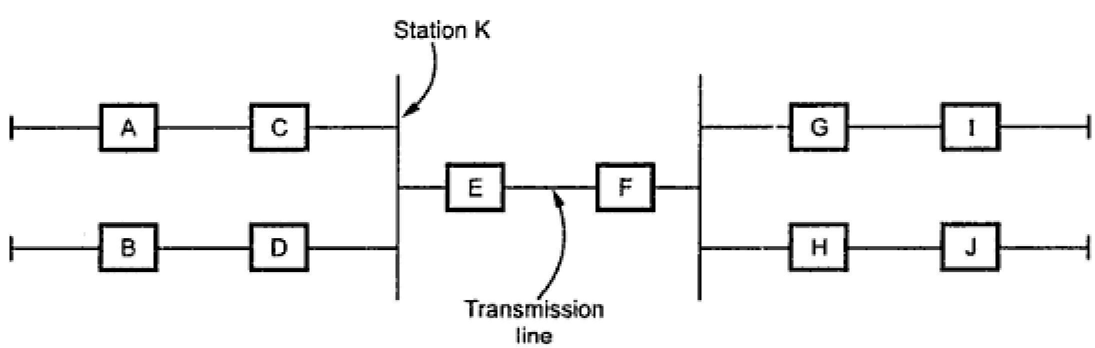


Fig. 1.3 Backup relaying

The relays C, D, G and H are primary relays while A, B, I and J are the backup relays.

Normally backup relays are tripped if primary relay fails. So if the primary relay E fails to trip, then backup relays A and B get tripped. The backup relays and associated backup relaying equipment are physically apart from the faulty equipment.

The backup relays A and B provide backup protection for fault at station K. Also the backup relays at A and F provide the backup protection for the faults in line DB.

The backup relaying often relay operates, the larger part of the system is disconnected.

It is obvious that when the backup relay operates, the larger part of the system is disconnected.

The important requirement of backup relaying is that it must operate with sufficient time delay so that the primary relaying is given a chance to operate. When fault occurs, both the type of relays operations but primary is expected to trip first and backup will then reset without having had time to complete its relaying operation.

When the given set of relays provides the backup protection for several adjacent system elements then the slowest primary relaying of any of those will determine the necessary time delay of the given backup relays.

9. Write notes on various principles of power system protection.

Fundamental Principles of Power System Protection are:

- Fault Calculations and Sequence Components
- Over Current and Earth Fault Protection
- Voltage and Current Transformers
- Distance Protection : Fundamental Considerations
- Protection Signaling
- High Impedance Differential Protection
- Transformer Protection
- Low Impedance Bus bar Differential Protection
- Feeder Differential Protection
- Auto Reclosing Concepts
- Protection of Capacitor Banks

10. Write notes on power system earthing.

There are several important reasons why a grounding system should be installed. But the most important reason is to protect people! Secondary reasons include protection of structures and equipment from unintentional contact with energized electrical lines. The grounding system must ensure maximum safety from electrical system faults and lightning.

A good grounding system must receive periodic inspection and maintenance, if needed, to retain its effectiveness. Continued or periodic maintenance is aided through adequate design, choice of materials and proper installation techniques to ensure that the grounding system resists deterioration or inadvertent destruction. Therefore, minimal repair is needed to retain effectiveness throughout the life of the structure.

The grounding system serves three primary functions which are listed below.

(i) Personnel Safety

Personnel safety is provided by low impedance grounding and bonding between metallic equipment, chassis, piping, and other conductive objects so that currents, due to faults or lightning, do not result in voltages sufficient to cause a shock hazard. Proper grounding facilitates the operation of the overcurrent protective device protecting the circuit.

(ii) Equipment and Building Protection.
Equipment and building protection is provided by low impedance grounding and bonding between electrical services, protective devices, equipment and other conductive objects so that faults or lightning currents do not result in hazardous voltages within the building. Also, the proper operation of Overcurrent protective devices is frequently dependent upon low impedance fault current paths.

(iii) Electrical Noise Reduction.
Proper grounding aids in electrical noise reduction and ensures:
1. The impedance between the signal ground points throughout the building is minimized.
2. The voltage potentials between interconnected equipment are minimized.
3. That the effects of electrical and magnetic field coupling are minimized.
Another function of the grounding system is to provide a reference for circuit conductors to stabilize their voltage to ground during normal operation. The earth itself is not essential to provide a reference function. Another suitable
Conductive body may be used instead. The function of a grounding electrode system and a ground terminal is to provide a system of conductors which ensures electrical contact with the earth.

Methods of Neutral grounding

11. Explain Power system earthing. What are neutral earthing and its objectives?

Neutral earthing Process of connecting the natural point of a supply system on a non-current carrying part of a supply system and on the non-current carrying parts of electrical apparatus to the ground mass of earth in such a manner. That all time an immediate discharge of electrical energy takes place without danger. It's called earthling.

Earthling means connecting earth terminals to electrode installed solidly in the mass of earth. A wire connecting from ground 2.5 to 3 m deep from an electrode is called earthing. Earthing will give low resistance to flow of heavy current of a circuit. Double earth is used to give minimum resistance to flow of current of the apparatus in the case of short circuit to leakage or any other fault occurs. If one earth is out of order the second will do the work. The earth resistance for copper wire is 1 ohm for G.I wire .it should not be more than 3 ohms. Earth resistance should be kept as low as possible.

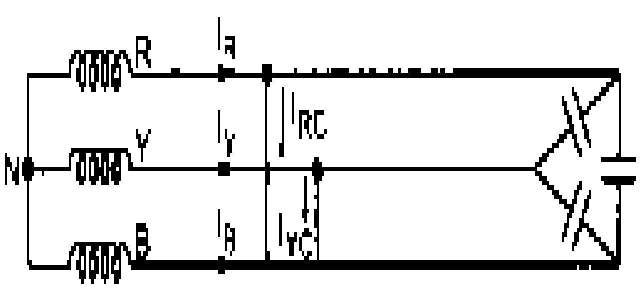
OBJECTS OF EARTHING OR OBJECTIVES OF EARTHING

- To same human life from shock or death by blowing the corresponding fuse of an apparatus.
- To protect m/c which are fed from OHT lines from lighting
- To maintain line voltage constant (since neutral of every alternator and transformer is earthed).

Advantages of earthing

- Persisting arcing ground is eliminated.
- Over voltage due to re striking is minimized.
- Ground faults can be located and isolated fast.
- Steady state voltage stress to earth is minimized.
- Sensitive protective apparatus can be used.
- Maintenance expenditure can be reduced.
- Better safety is ensured.
- Service reliability is improved.
- Earthing provide improved lighting protection.

Necessity of neutral earthing.



$$I_F = \frac{V_{ph}}{X_L};\ I_C = \frac{3V_{ph}}{X_C}$$

More insulation of a system is likely to be overstressed due to over voltage.
Such a system cannot be adequately protected for faults to earth.

Methods of Neutral grounding

12. **Discuss and compare the various methods of neutral earthing. (Nov/Dec 2017)**
Explain different types of earthing the neutral point of the power system (Dec-15 , May-16)
Explain in detail about the need and different types of earthing schemes?(NOV/DEC 2016)(Apr/May 2018)
Types of Neutral Earthing in Power Distribution:

Introduction:

In the early power systems were mainly Neutral ungrounded due to the fact that the first ground fault did not require the tripping of the system. An unscheduled shutdown on the first ground fault was particularly undesirable for continuous process industries. These power systems required ground detection systems, but locating the fault often proved difficult. Although achieving the initial goal, the ungrounded system provided no control of transient over-voltages.

A capacitive coupling exists between the system conductors and ground in a typical distribution system. As a result, this series resonant L-C circuit can create over-voltages well in excess of line-to-line voltage when subjected to repetitive re-strikes of one phase to ground. This in turn, reduces insulation life resulting in possible equipment failure.

Neutral grounding systems are similar to fuses in that they do nothing until something in the system goes wrong. Then, like fuses, they protect personnel and equipment from damage. "Damage comes from two factors, how long the fault lasts and how large the fault current is. Ground relays trip breakers and limit how long a fault lasts and Neutral grounding resistors limit how large the fault current is".

Importance of Neutral Grounding:

There are many neutral grounding options available for both Low and Medium voltage power systems. The neutral points of transformers, generators and rotating machinery to the earth ground network provides a reference point of zero volts. This protective measure offers many advantages over an ungrounded system, like,

1. Reduced magnitude of transient over voltages
2. Simplified ground fault location
3. Improved system and equipment fault protection
4. Reduced maintenance time and expense
5. Greater safety for personnel
6. Improved lightning protection
7. Reduction in frequency of faults.

Method of Neutral Earthing:

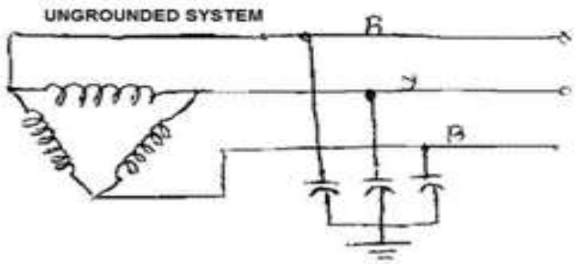
There are five methods for Neutral earthing.

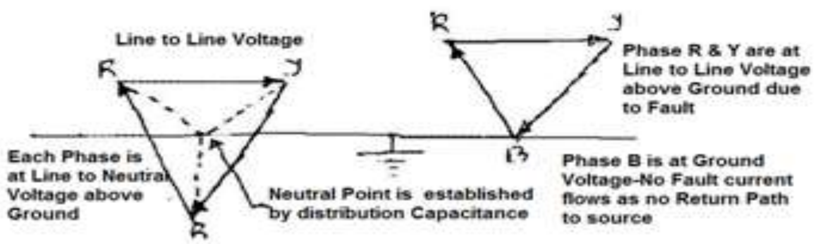
1. Unearthed Neutral System
2. Solid Neutral Earthed System.
3. Resistance Neutral Earthing System.
    1. Low Resistance Earthing.
    2. High Resistance Earthing.
4. Resonant Neutral Earthing System.
5. Earthing Transformer Earthing.

(1) Ungrounded Neutral Systems:

- In ungrounded system there is no internal connection between the conductors and earth. However, as system, a capacitive coupling exists between the system conductors and the adjacent grounded surfaces. Consequently, the “ungrounded system” is, in reality, a “capacitive grounded system” by virtue of the distributed capacitance.

- Under normal operating conditions, this distributed capacitance causes no problems. In fact, it is beneficial because it establishes, in effect, a neutral point for the system; As a result, the phase conductors are stressed at only line-to-neutral voltage above ground.
- But problems can rise in ground fault conditions. A ground fault on one line results in full line-to-line voltage appearing throughout the system. Thus, a voltage 1.73 times the normal voltage is present on all insulation in the system. This situation can often cause failures in older motors and transformers, due to insulation breakdown.





Advantage:

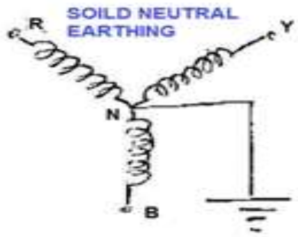
1. After the first ground fault, assuming it remains as a single fault, the circuit may continue in operation, permitting continued production until a convenient shut down for maintenance can be scheduled.

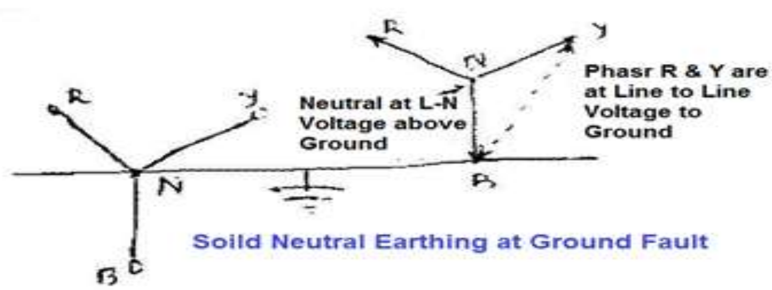
Disadvantages:

1. The interaction between the faulted system and its distributed capacitance may cause transient overvoltage (several times normal) to appear from line to ground during normal switching of a circuit having a line-to ground fault (short). These over voltages may cause insulation failures at points other than the original fault.
2. A second fault on another phase may occur before the first fault can be cleared. This can result in very high line-to-line fault currents, equipment damage and disruption of both circuits.
3. The cost of equipment damage.
4. Complicate for locating fault(s), involving a tedious process of trial and error: first isolating the correct feeder, then the branch, and finally, the equipment at fault. The result is unnecessarily lengthy and expensive down downtime.

(2) Solid Neutral Earthed System:

- Solidly grounded systems are usually used in low voltage applications at 600 volts or less.
- In solidly grounded system, the neutral point is connected to earth.
- Solidly Neutral Grounding slightly reduces the problem of transient over voltages found on the ungrounded system and provided path for the ground fault current is in the range of ***25 to 100% of the system three phase fault current.*** However, if the reactance of the generator or transformer is too great, the problem of transient over voltages will not be solved.
- While solidly grounded systems are an improvement over ungrounded systems, and speed up the location of faults, they lack the current limiting ability of resistance grounding and the extra protection this provides.
- To maintain systems health and safe, Transformer neutral is grounded and grounding conductor must be extend from the source to the furthest point of the system within the same raceway or conduit. Its purpose is to maintain very low impedance to ground faults so that a relatively high fault current will flow thus insuring that circuit breakers or fuses will clear the fault quickly and therefore minimize damage. It also greatly reduces the shock hazard to personnel





- If the system is not solidly grounded, the neutral point of the system would "float" with respect to ground as a function of load subjecting the line-to-neutral loads to voltage unbalances and instability.
- The single-phase earth fault current in a solidly earthed system may exceed the three phase fault current.
- The magnitude of the current depends on the fault location and the fault resistance. One way to reduce the earth fault current is to leave some of the transformer neutrals unearthed.

Advantage:

1. The main advantage of solidly earthed systems is low over voltages, which makes the earthing design common at high voltage levels (HV).

Disadvantage:

1. This system involves all the drawbacks and hazards of high earth fault current: maximum damage and disturbances.
2. There is no service continuity on the faulty feeder.
3. The danger for personnel is high during the fault since the touch voltages created are high.

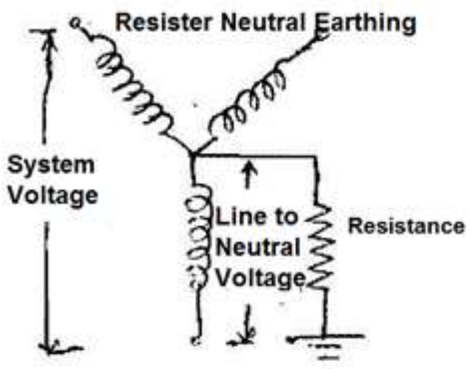
Applications:

1. Distributed neutral conductor.
2. 3-phase + neutral distribution.
3. Used when the short-circuit power of the source is low.

3) Resistance earthed systems:

- Resistance grounding has been used in three-phase industrial applications for many years and it resolves many of the problems associated with solidly grounded and ungrounded systems.
- Resistance Grounding Systems limits the phase-to-ground fault currents. The reasons for limiting the Phase to ground Fault current by resistance grounding are:
    - To reduce burning and melting effects in faulted electrical equipment like switchgear, transformers, cables, and rotating machines.
    - To reduce mechanical stresses in circuits/Equipments carrying fault currents.
    - To reduce electrical-shock hazards to personnel caused by stray ground fault.
    - To reduce the arc blast or flash hazard.
    - To reduce the momentary line-voltage dip.
    - To secure control of the transient over-voltages while at the same time.
    - To improve the detection of the earth fault in a power system.
- Grounding Resistors are generally connected between ground and neutral of transformers, generators and grounding transformers ***to limit maximum fault current as per Ohms Law to a value which will not damage the equipment*** in the power system and allow sufficient flow of fault current to detect and operate Earth protective relays to clear the fault.
- Therefore, it is the most common application to limit single phase fault currents with low resistance Neutral Grounding Resistors to approximately rated current of transformer and / or generator.
- In addition, limiting fault currents to predetermined maximum values permits the designer to selectively coordinate the operation of protective devices, which minimizes system disruption and allows for quick location of the fault.
- There are two categories of resistance grounding:
  (1) Low resistance Grounding. (2) High resistance Grounding
- Ground fault current flowing through either type of resistor when a single phase faults to ground will increase the phase-to-ground voltage of the remaining two phases. As a result, ***conductor insulation and surge arrestor ratings must***

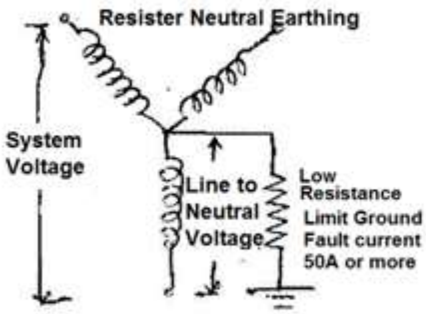
be based on line-to-line voltage. This temporary increase in phase-to ground voltage should also be considered when selecting two and three pole breakers installed on resistance grounded low voltage systems.



- Neither of these grounding systems (low or high resistance) reduces arc-flash hazards associated with phase-to-phase faults, but both systems significantly reduce or essentially eliminate the arc-flash hazards associated with phase-to-ground faults. Both types of grounding systems limit mechanical stresses and reduce thermal damage to electrical equipment, circuits, and apparatus carrying faulted current.
- The difference between Low Resistance Grounding and High Resistance Grounding is a matter of perception and, therefore, is not well defined. ***Generally speaking high-resistance grounding refers to a system in which the NGR let-through current is less than 50 to 100 A. Low resistance grounding indicates that NGR current would be above 100 A.***
- A better distinction between the two levels might be alarm only and tripping. An alarm-only system continues to operate with a single ground fault on the system for an unspecified amount of time. In a tripping system a ground fault is automatically removed by protective relaying and circuit interrupting devices. Alarm-only systems usually limit NGR current to 10 A or less.

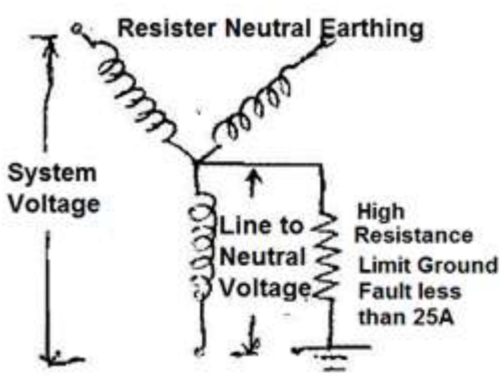
(A).Low Resistance Grounded:

Low Resistance Grounding is used for large electrical systems where there is a high investment in capital equipment or prolonged loss of service of equipment has a significant economic impact and it is not commonly used in low voltage systems because the limited ground fault current is too low to reliably operate breaker trip units or fuses. This makes system selectivity hard to achieve. Moreover, low resistance grounded systems are not suitable for 4-wire loads and hence have not been used in commercial market applications



(B).High Resistance Grounded:

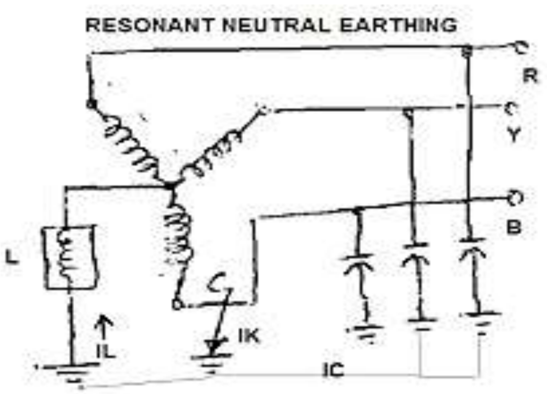
- High resistance grounding is almost identical to low resistance grounding except that the ground fault current magnitude is typically limited to ***10 amperes or less***. High resistance grounding accomplishes two things.
- The first is that the ***ground fault current magnitude is sufficiently low enough such*** that no appreciable damage is done at the fault point. This means that the faulted circuit need not be tripped off-line when the fault first occurs. Means that once a fault does occur, we do not know where the fault is located. In this respect, it performs just like an ungrounded system.
- The second point is it can ***control the transient overvoltage phenomenon*** present on ungrounded systems if engineered properly.



4) Resonant earthed system:

- Adding inductive reactance from the system neutral point to ground is an easy method of limiting the available ground fault from something near the maximum 3 phase short circuit capacity (thousands of amperes) to a relatively low value (200 to 800 amperes).
- To limit the reactive part of the earth fault current in a power system a neutral point reactor can be connected between the transformer neutral and the station earthing system.
- A system in which at least one of the neutrals is connected to earth through an
    1. Inductive reactance.
    2. Petersen coil / Arc Suppression Coil / Earth Fault Neutralizer.

- The current generated by the reactance during an earth fault approximately compensates the capacitive component of the single phase earth fault current, is called a resonant earthed system.
- The system is hardly ever exactly tuned, i.e. the reactive current does not exactly equal the capacitive earth fault current of the system.
- A system in which the inductive current is slightly larger than the capacitive earth fault current is over compensated. A system in which the induced earth fault current is slightly smaller than the capacitive earth fault current is under compensated
- However, experience indicated that this inductive reactance to ground resonates with the system shunt capacitance to ground under arcing ground fault conditions and creates very high transient over voltages on the system.
- To control the transient over voltages, the design must permit at least 60% of the 3 phase short circuit current to flow underground fault conditions.
- Example. A 6000 amp grounding reactor for a system having 10,000 amps 3 phase short circuit capacity available. Due to the high magnitude of ground fault current required to control transient over voltages, inductance grounding is ***rarely used within industry.***



Petersen Coils:

Petersen Coil is connected between the neutral point of the system and earth, and is rated so that the capacitive current in the ***earth fault is compensated by an inductive current passed by the Petersen Coil***. A small residual current will remain, but this is so small that any arc between the faulted phase and earth will not be maintained and the fault will extinguish. Minor earth faults such as a broken pin insulator, could be held on the system without the supply being interrupted. Transient faults would not result in supply interruptions.

- Although the standard 'Peterson coil' does not compensate the entire earth fault current in a network due to the presence of resistive losses in the lines and coil, it is now possible to apply 'residual current compensation' by injecting an additional 180° out of phase current into the neutral via the Peterson coil.
- The fault current is thereby reduced to practically zero. Such systems are known as 'Resonant earthing with residual compensation', and can be considered as a special case of reactive earthing.

- Resonant earthing can reduce EPR to a safe level. This is because the Petersen coil can often effectively act as a high impedance NER, which will substantially reduce any earth fault currents, and hence also any corresponding EPR hazards (e.g. touch voltages, step voltages and transferred voltages, including any EPR hazards impressed onto nearby telecommunication networks).

Advantages:

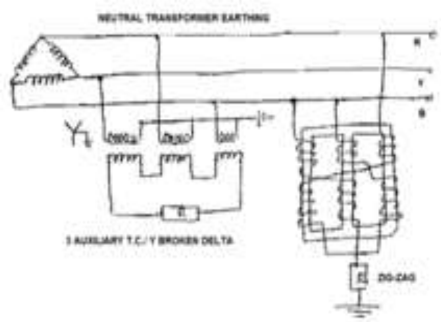
1. Small reactive earth fault current independent of the phase to earth capacitance of the system.
2. Enables high impedance fault detection.

Disadvantages:

1. Risk of extensive active earth fault losses.
2. High costs associated.

(5) Earthing Transformers:

For cases where there is no neutral point available for Neutral Earthing (e.g. for a delta winding), an earthing transformer may be used to provide a return path for single phase fault currents In such cases the impedance of the earthing transformer may be sufficient to act as effective earthing impedance. Additional impedance can be added in series if required. A special 'zig-zag' transformer is sometimes used for earthing delta windings to provide a low zero-sequence impedance and high positive and negative sequence impedance to fault currents.

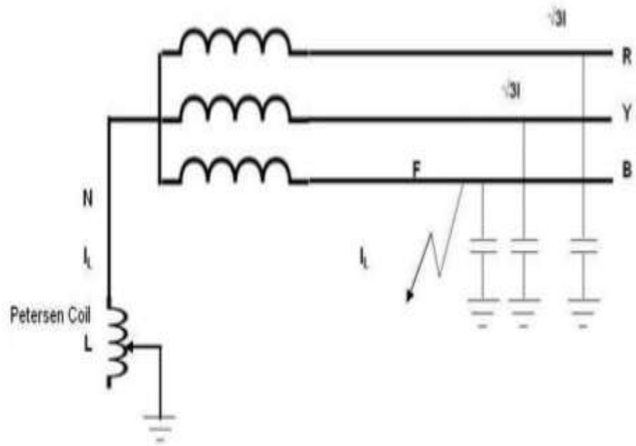


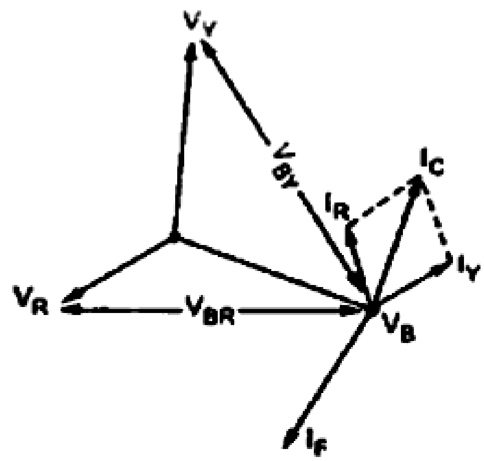
13. Explain about the Peterson coil and derive its inductance value. (NOV/DEC-2006,NOV/DEC-2007)

Discuss in detail about the Peterson coil? List protective function performed by this device. (APRIL/MAY-2015)
Derive an expression for the reactance of the Peterson coil in terms of capacitance of the protected line. (Dec 2015 & May 2016)
Explain arc suppression coil earthing with neat diagram.(May-2017)

This coil is known as ground fault neutralizer or arc suppressor coil.
It's an iron cored reactor connected between the neutral point and the ground and capable of behind turned with the capacitance of the healthy phase.to produce resonance when a L-G fault occurs.

It's mainly used to prevent arcing ground which lead to overvoltage on system with an under grounded neutral.
Peterson coil make arcing ground fault self-extinguishing and in case of sustained ground faults on one of the lines it reduces the faults current to a very low value so that the healthy phases can be kept in a select the proper value of inductive reactance Peterson coil is provided with toppings.





In an undergrounded system when a ground fault occurs on any one line the voltage of the healthy phases is increased by √3 times. √3Vp.when Vp phase voltage hence the charging current of √3I / Phase. Where is the charging current of the line to ground of one phase, the phase sum of the charging current of the healthy phases because three time s the normal line to neutral charging current of one phase has shown in pharos diagram of above1 .hence,

$$Charging\ current, I_C = 3\mathrm{I} = \frac{3V_p}{X_c} = \frac{3V_p}{(1/\omega C)} = 3V_p\omega C$$

Where Ic is the resultant charging current and I is the charging current of line to ground of one phase.
If L is the inductance of the Peterson coil connected between the neutral and the ground, then

$$I_L = \frac{V_p}{X_L} = \frac{V_p}{\omega L}$$

In order to obtain satisfactory cancellation of arcing ground. The fault current I_l following through the Peterson coil should be equal to the resultant charging ground I_c.
Therefore for balance condition $I_L = I_c$

$$\frac{\cancel{V_p}}{\omega L} = 3\cancel{V_p}\omega C$$

Inductance of the Peterson coil.

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

14. A 132KV, 3 phase , 50 cycles, OHT line , 50 km long as a capacitance to earth for each line of 0.0157µF/Km. Determine the inductance and KVA rating of the arc suppression coil?(NOV/DEC 2016)

Given data:

$V_p = 132KV$; f=50Hz ; l=50km ; C=0.0157 × 10^{-6} ×50 F = 0.785µF

Formula used

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

Solution:

$$L = \frac{1}{3(2\pi f)^2 c} = \frac{1}{3(2\pi \times 50)^2 \times 0.785 \times 10^{-6}} = 4.3H$$

$$I_C = \frac{V_p/\sqrt{3}}{X_L} = \frac{132 \times 10^3}{\sqrt{3} \times 2\pi \times 50 \times 4.3} = 56.4\ A$$

$$Rating = \frac{56.4 \times 132}{\sqrt{3}} = 4300KVA$$

UNIT II
ELECTROMAGNETIC RELAYS

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

PART-A

1. **What purpose distance relay is used? (Dec-2006)**

   Distance protection is used for the protection of transmission or sub-station lines, usually 33KV, 66KV, and 132KV.

   A distance relay measures the distance between the relay location and the point of fault in terms of impedance, reactance etc...

2. **Define the terms (a) pick up value (b) plug setting multiplier.(June-2007)**

   Pick up value:

   It is the minimum current in the relay coil at which the relay starts to operate. when the relay coil current is equal to or greater than the pick up value ,the relay operate to energize the trip coil which open the CB.

   Plug setting multiplier:

   Plug setting is used to change the number of turns of the operating coil to get a particular pick up value.

   It is the ratio of fault current in relay coil to the pick up current.

$$\text{PSM} = \frac{\text{fault current in relay coil}}{\text{pick up current}}$$

3. **What type of relay is best suited for long distance very high voltage transmissionline? (Dec-2007)**

   Impedance relay is best suited for long distance very high voltage transmission line

4. **What are advantages of over current relay over electromagnetic types? (May-2008)**
   - The below points is over come in electromagnetic relay.
   - Larger difference between their pick up and reset values.
   - Relay armature vibrates at denote the power supply frequency. This vibration will lead to sparking between the contacts, so relay will be damaged.

5. **Give any two application of electro magnetic relay (Dec-2008)**
   - The protection of various A.C and D.C equipments.
   - The over/ under current and over/voltage production of various A.C and D.C equipments.

6. **Define pick up value and current setting as applied to protective relaying.(June-2009)**

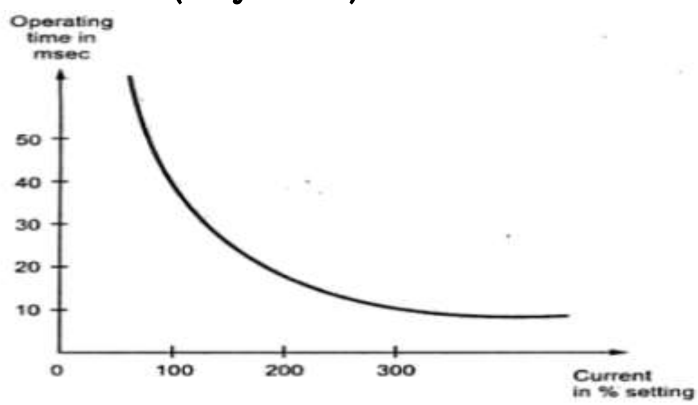
Pick up value:

It is the minimum current in the relay coil at which the relay starts to operate. When the relay coil current is equal to or greater than the pick up value, therelay operates to energize the trip coils which open the CB.

Current setting:

Current setting is the actual value of energizing current at which the relay is designed to operate order of conditions.

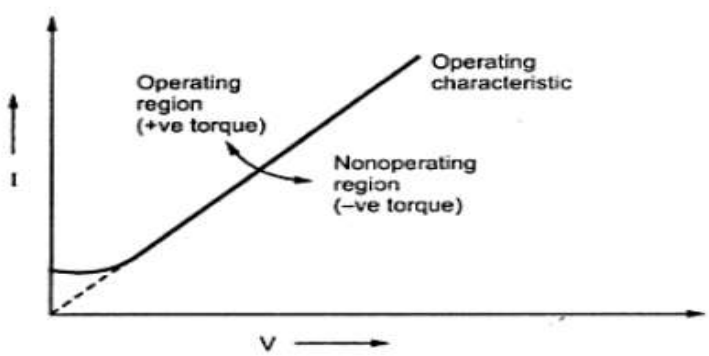
7. **Classify the different types of over current relay based on the inverse time characteristics.(May-2010)**



- Static instantaneous over current relay.
- Directional static over current relay.
- Inverse time over current relay.

8. **Derive and draw characteristics of impedance relay.(May-2010)**

Time of operation of relay $\alpha \frac{V}{I} Z \quad \alpha$ distance.



V=Voltage in Volts; I =current in amps; Z=impedance in ohms

9. **Mention different types of over current relay.(Dec-2010)**

Directional induction type over current relay 2.Nondirectional induction type over current relay

10. Mention the application of differential relay.(May-2011)

- It can be differentiate the heavy load conditions and minor load condition.
- Fault current can be easily identify the relay.
- Protection of generator and generator transformer unit protection of large motors and bus-bars.

11. What are the features of directional relay?(May-2011)

A directional power relay which operates when the power in the circuit flows in a particular direction. It requires sensing the system voltage as well as system current.

12. Define burden of relay?

It is the power consumed by the relay circuitary at the rated current.

13. Why the shading ring is provided in an induction disc relay?(May-2017)

The shading ring is provided to produce flux in the shaded portion of the magnet which is displaced in phase and space from flux in the remaining portion of the same magnet.

14. What is mean by differential relay?(June-13)

- In a differential protection scheme if the currents on both sides of the equipment are compared.
- Under normal conditions, or for a fault outside of the protected zone, current I_1 is equal to current I_2. Therefore the currents in the current transformers secondary's are also equal, i.e. $i_1 = i_2$ and no current flows through the current relay.
- If a fault develops inside of the protected zone, currents I_1 and I_2 are no longer equal, therefore i_1 and i_2 are not equal and there is a current flowing through the current relay.

15. What are the necessary conditions for two alternating fluxes acting on a common rotor?(a) To produce same torque,(b) To produce maximum torque.(June-13)

1. Two alternating fluxes which a phase shift are needed for torque protection, i.e a single alternating flux would not produce torque.
2. Maximum torque is produced when two alternating fluxes are shifted in phase by 90°.
3. The resultant torque is study, i.e.it is not a function of time, as time t is not involved in the expression for torque.

16. What Are The Function Of Under Frequency Relay? (DEC-2013,Dec-14)

It rapidly disconnects the generator in the case of failure in the connected power system.

17. List the different types of distance relay (MAY-2014)

a. Impedance Relay
b. Admittance Relay (mho) relay
c. Reactance Relay

18. Distance relay divided in to two types

- Definite – distance relay
- Definite – time relay

19. What is the principle of differential relay(MAY-15)

Allow us to assume an easy example of an influence power transformer with transformation magnitude (ratio) relation 1:1 and (Y/Y) connection and therefore the CT_1 and CT_2 ensure a similar transformation magnitude relation as shown. The current flows within the primary side and secondary side of power transformer are equal, presumptuous ideal power transformer. The secondary current I_1 and I_2 are same in magnitude and reverse in direction. Therefore, the net current within the differential coil is nil at load situation (without any fault), and therefore the relay won't operate.

20. What are functions of protective relay.(MAY-15)

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.

21. Where is negative phase sequence relay employed? (Dec 2015)

Used in generators

22. What is the significance of PSM and TSM?(Dec-2016)

TSM:(Time setting multiplier)
it is multiplier of various time current characteristics curves(i.e. Normalinverse,extremeinverse,longinverse,very long inverse,..etc)
PSM(plug setting multiplier)
The relay's primary winding is supplied from the power systems current transformer via a plug bridge, which is also commonly known as the plug setting multiplier (psm)

23. A relay is connected to 400/5 ratio current transformer with current setting of 150%. Calculate the plug setting multiplier when circuit carries a fault current of 4000A (Dec-2016) (Apr/May 2018)

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

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

Fault current in the relay coil =4000 X 5 /400

= 50

PSM = 50/(5 X 1.5) = 6.66

24. What are the difficulties of differential protection? (May-2017)

This relay suffers from the following disadvantages,

1. The current transformers are connected through cables called pilot cables. The impedance of such pilot cables generally causes a slight difference between the currents at the ends of the section to be protected. A sensitive relay can operate to a very small difference in the two currents, though there is no fault existing.
2. The relay is likely to operate inaccurately with heavy through current flows.
3. Under severe through fault conditions, the current transformers may saturate and cause unequal secondary currents. The difference between the currents may approach the pick value to cause the inaccurate operation for the relay.
4. Under heavy current flows, pilot cable capacitances may cause inaccurate operation of the relay.

25.Write the torque equation of Universal relay.(Nov/ Dec 2017)

$$T=K_1I^2+K_2V^2+K_3\,VI\cos(\theta-\tau)+K_4$$

This equation is called universal torque equation the term k4 can be restraing torque due to springs or gravity.

26.Give the principle of negative sequence relay.(Nov/ Dec 2017)

The network consist of four impedances Z_1,Z_2,Z_3,Z_4 of equal magnitude connected in a bridge formation. Z_1 and Z_2 are non inductive resistances while Z_3 and Z_4 are composed of both resistance and reactance. The values of Z_2 and Z_4 are also adjusted that the current flowing in these lag behind those in the impedances Z_1 and Z_2 by 60°.the relay is assumed to have a negligible impedance.

27.What is the principle of distance relay? (Apr/May 2018)

A distance relay measures the distance between the relay location and the point of fault in terms of impedance, reactance etc...

PART B

1. Explain the types and working principle with neat diagram Electromagnetic attraction relay.(Dec-2010,)(May 2017) (Nov/Dec 2017)

Electromagnetic Attraction Relays

In these relays, there is a coil which energizes an electromagnet . When the operating current becomes large, the magnetic field produced by an electromagnet is so high that it attracts the armature or plunger, making contact with the trip circuit contacts. These are simplest type of relays. The various types of electromagnetic attraction type relays are,

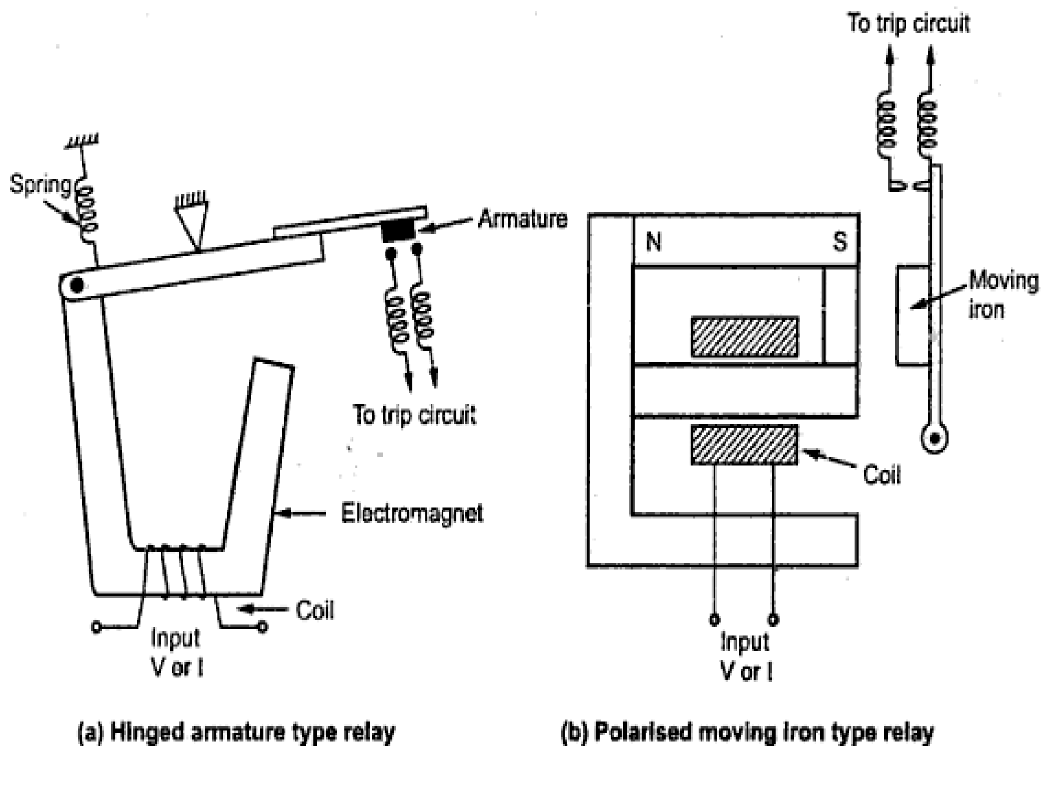
- Attracted armature relay
- Solenoid and plunger type relay

Attracted Armature Type Relay

There are two types of structures available for attracted armature type relay which are,

- Hinged armature type
- Polarised moving iron type

The two types of attracted armature type relays are shown in the Fig



(a) Hinged armature type relay (b) Polarised moving iron type relay

In attracted armature type, there exists a laminated electromagnet which carries a coil. The coil is energized by the operating quantity which is proportional to the circuit voltage or current. The armature or a moving iron is subjected to the magnetic force produced by the operating quantity. The force produced is proportional to the square of current hence these relays can be used for a.c. as well as d.c. The spring is **used** to produce restraining force. When the current through coil increases beyond the limit under fault conditions, armature gets attracted. Due to this it makes contact with contacts of a trip circuit, which results in an opening of a circuit breaker.

The minimum current at which the armature gets attracted to close the trip circuit is called pickup current.

Generally the number of tappings is provided on the relay coil with which its turns can be selected as per the requirement. This is used to adjust the set value of an operating quantity at which relay should operate.

An important advantage of such relays is their high operating speed. In modern relays an operating time as small as 0.5 msec is possible. The current-time characteristic of such relays is hyperbolic, as shown in the Fig. 2.6.

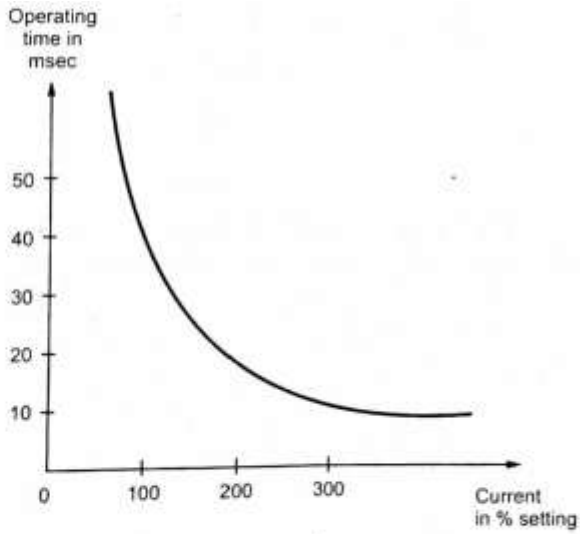


Fig. 2.6 Current-time characteristics

Solenoid and Plunger Type Relay

- The Fig. 2.7 shows the schematic arrangement of solenoid and plunger type relay which works on the principle of electromagnetic attraction.
- It consists of a **solenoid** which is nothing but an electromagnet. It also consists a movable iron plunger. Under normal working conditions, the spring holds the plunger in the position such that it cannot make contact with trip circuit contacts.
- Under fault conditions when current through relay coil increases, the solenoid draws the plunger upwards. Due to this, it makes contact with the trip circuit contacts, which results in an opening of a circuit breaker.

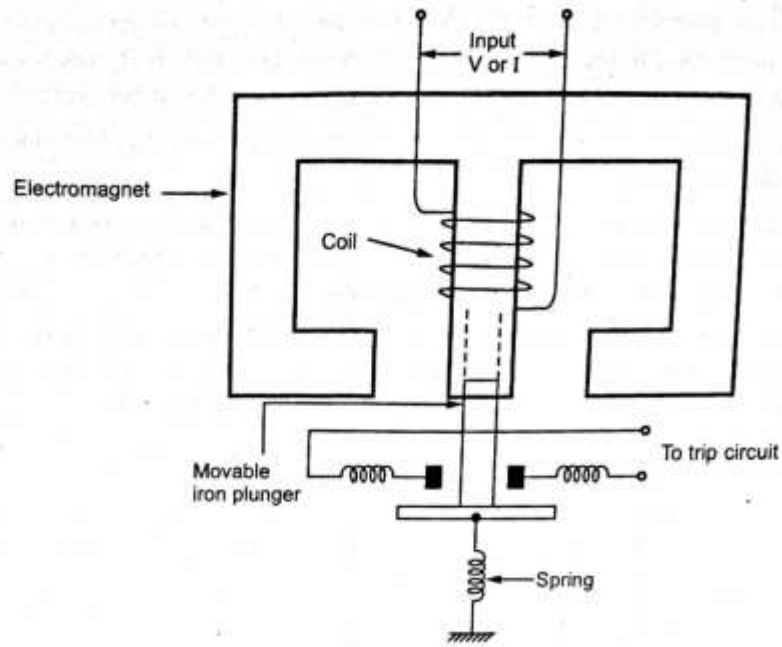


Fig. 2.7 Solenoid and plunger type relay

Operating Principle *of* Electromagnetic Attraction Relays

The electromagnetic force produced due to operating quantity which is exerted on armature, moving iron or plunger is proportional to the square of the flux in the air gap. Thus neglecting the saturation effect, the force is proportional to the square of the operating current. Hence such relays are useful for a.c. and d.c. both.

For d.c.operation : In d.c. operation, the electromagnetic force is constant. When this force exceeds the restraining force, the relay operates.

$$Now \qquad F_e = K_1 I^2$$

$$F_e = Electromagnetic\ force$$
$$K_1 = constant$$
$$I = operating\ current\ in\ a\ coil$$
$$And \qquad F_r = K_2$$

Where $F_r = Restraining\ force\ due\ to\ spring\ including\ friction$

$$K_2 = constant$$

.

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

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

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

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

This is the current at which relay operates in case of d.c. operation.

For a.c. operation: In a.c. electromagnetic relays, the electromagnetic force is proportional to square of the current but it is not constant. It is given by,

$$F_e = K_1 I^2 = \frac{1}{2} K I_m^2 - \frac{1}{2} K I_m^2 \cos 2\omega t$$

where I_m = Maximum value of the operating current
K = constant

It shows that the electromagnetic force consists of two components,

- Constant, independent of time.
- Pulsating at double the frequency of applied voltage.

Advantages of Electromagnetic Relays

The various advantages of electromagnetic relays are,

- Can be used for both a.c. and d.c.
- They have fast operation and fast reset.
- These are almost instantaneous. Though instantaneous, the operating time varies with current. With extra arrangements like dashpot, copper ring etc. slow operating and resetting times can be obtained.
- High operating speed with operating time in few milliseconds also can be achieved.
- The pickup can be as high as 90-95% for d.c. operation and 60 to 90% for the d.c. operation.
- Modern relays are compact, simple, reliable and robust.

Disadvantages of Electromagnetic Relays

The few disadvantages of these relays are,

- The directional feature is absent.
- Due to fast operation the working can be affected by the transients. As transients contain d.c. as well as pulsating component, under steady state value less than set value, the relay can operate during transients.

Applications of Electromagnetic Relays

The various applications of these relays are,

- The protection of various a.c. and d.c.equipments.
- The over/under current and over/under voltage protection of various a.c. and d.c.equipments.

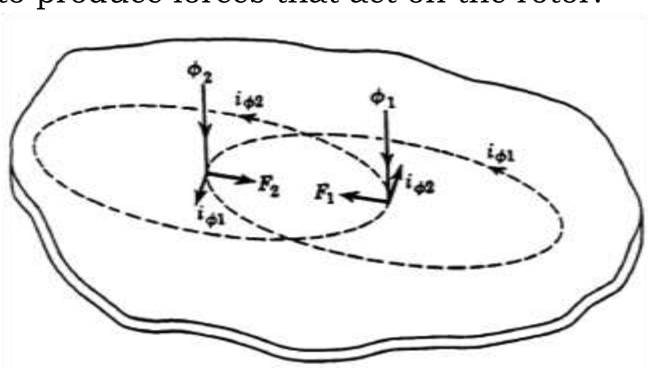
- In the definite time lag over current and earth fault protection along with definite time lag over current relay.
- For the differential protection.
- Used as auxiliary relays in the contact systems of protective relaying schemes.

2. Derive the torque equation for induction type relay.(May-2010,2011)

Induction-type relays are the most widely used for protective-relaying purposes involving ac quantities. They are not usable with d-c quantities, owing to the principle of operation. An induction-type relay is a split-phase induction motor with contacts. Actuating force is developed in a movable element that may be a disc or other form of rotor of non-magnetic current conducting material by the interaction of electromagnetic fluxes with eddy currents that are induced in the rotor by these fluxes.

The Production of Actuating Force

Figure shows how force is produced in a section of a rotor that is pierced by two adjacent a-c fluxes. Various quantities are shown at an instant when both fluxes are directed downward and are increasing in magnitude. Each flux induces voltage around itself in the rotor, and currents flow in the rotor under the influence of the two voltages. The current produced by one flux reacts with the other flux, and vice versa, to produce forces that act on the rotor.



The quantities involved in Fig. above may be expressed as follows:

$$\phi_1 = \Phi_1 \sin \omega t$$

$$\phi_2 = \Phi_2 \sin (\omega t + \theta),$$

Where q is the phase angle by which I_2 leads I_1. It may be assumed with negligible error that the paths in which the rotor currents flow have negligible self-inductance, and hence that the rotor currents are in phase with their voltages.

$$i\phi_1 \;\alpha\; \frac{d\phi_1}{dt} \;\alpha\; \Phi_1 \cos \omega t$$

$$i\phi_2 \;\alpha\; \frac{d\phi_2}{dt} \;\alpha\; \Phi_2 \cos(\omega t + \theta)$$

We note that Fig. shows the two forces in opposition, and consequently we may write the
Equation for the net force (F) as follows:

$$F = (F_2 - F_1) \;\alpha\; (\phi_2 i_{\phi 1} - \phi_1 i_{\phi 2}) \text{-------- (1)}$$

Substituting the values of the quantities into equation (1) we get:

$$F \;\alpha\; \Phi_1\Phi_2 [\sin(\omega t + \theta)\cos\omega t - \sin\omega t \cos(\omega t + \theta)] \text{ ------- (2)}$$

This reduces to.

$$F \;\alpha\; \Phi_1\Phi_2 \sin\theta \text{ ------------- (3)}$$

Since sinusoidal flux waves were assumed, we may substitute the rms values of the fluxes for the crest values in equation 3.

It is important to note that the net force or torque acting on the disc is same at every instant. The action of relay under such a force is free from vibrations.

It can be observed from equation (3) if θ is zero than net force is zero and disc cannot rotate. Hence there must exists a phase difference between the two fluxes .the torque is maximum when phase difference θ is 90^{deg}.

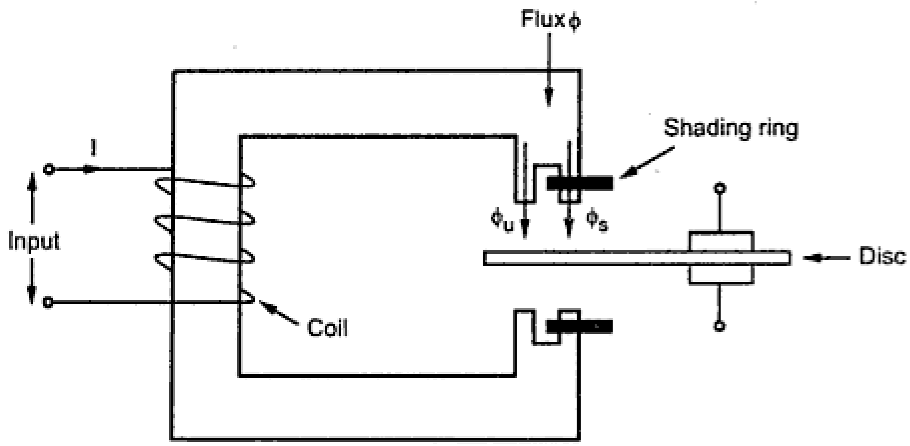
The direction of net force which decides the direction of rotation of disc depends on which flux is leading the other.

3. Explain with neat diagram of (1) shaded pole region, (2) what hour meter type, (3) induction cup type induction relay.

The different types of structure that have been used are commonly called: (1) the "shaded pole" structure; (2) the "watt-hour-meter" structure; (3) the "induction-cup" and the"double-induction-loop" structures; (4) the "single-induction-loop" structure.

Shaded-Pole Structure.

The shaded-pole structure, illustrated in Fig. is generally actuated by current flowing in a single coil on a magnetic structure containing an air gap. The air gap flux produced by this current is split into two out-of-phase components by a so-called “shading ring," generally of copper, that encircles part of the pole face of each pole at the Air gap.



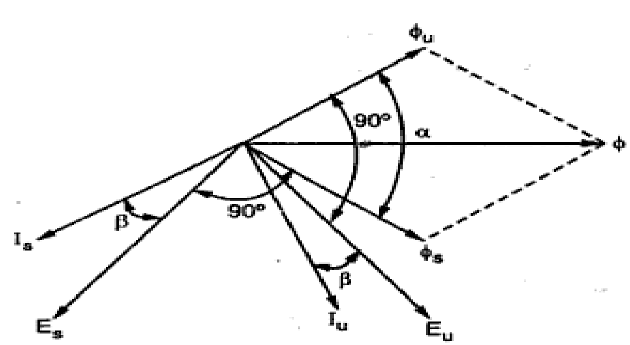
Shaded pole induction relay

The rotor shown edgewise in Fig. is a copper or aluminum disc, pivoted so as to rotate in the air gap between the poles. The phase angle between the fluxes piercing the disc is fixed by design, and consequently it does not enter into application considerations. The shading rings may be replaced by coils if control of the operation of a shaded-pole relay is desired. If the shading coils are short-circuited by a contact of some other relay, torque will be produced; but, if the coils are open-circuited, no torque will be produced because there will be no phase splitting of the flux. Such torque control is employed where "directional control" is desired.

Due to the alternating flux, E.M.F gets induced in the shading ring. This E.M.F drives the current causing the flux to exist in shaded portion. This flux lags behind the flux in the unshaded portion by an angle α.

φ_s= flux in the shaded portion
φ_u= flux in the unshaded portion
E_s=E.M.F induced in the disc due to φ_s
E_u= E.M.F induced in the disc due to φ_u
I_S=Induced current due to E_s
I_u= Induced current due to E_u.

$E_u$lagsbehindφ_u by 90˚ while E_s lags behind φ_s by 90˚.the current I_S lags $E_s$by small angle β while I_u lags E_u by small angle β. This angle is generally neglected and I_S and I_u are assumed to be in phase with E_s and E_u respectively. The phasor diagram shown in below.



The torque equation

$T \propto \varphi_s \varphi_u \sin\alpha$

T=Torque

Assuming the fluxes φ_s and $\varphi_u$to be proportional to the current I tn the relay coil we can write,

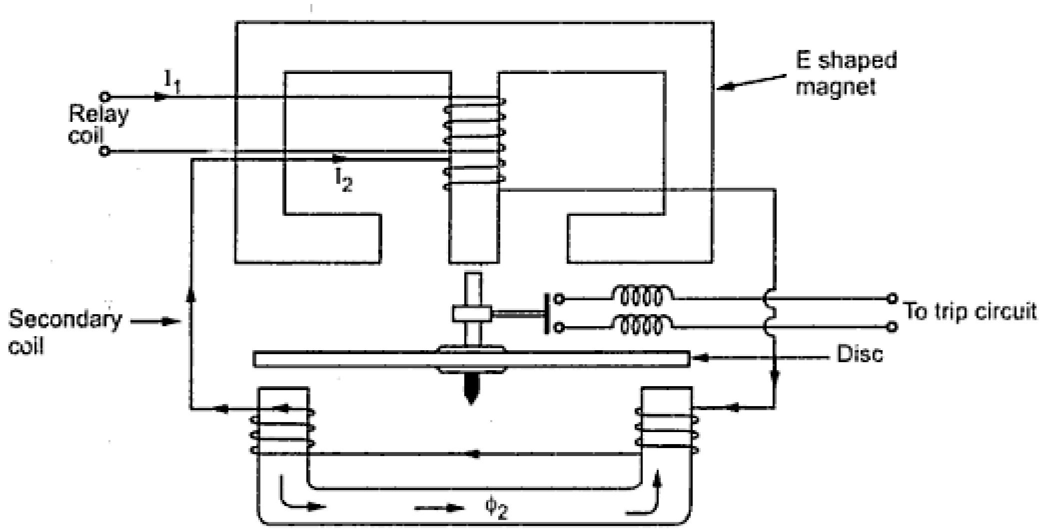
$T \propto I^2 \sin\alpha$

$T = kI^2$

As α is constant for the given design. Thus the torque is proportional to the square of the current through the coil.

Watthour-Meter Structure.

This structure gets its name from the fact that it is used for watthour meters. As shown in Fig. this structure contains two separate coils on two different magnetic circuits, each of which produces one of the two necessary fluxes for driving the rotor



It consists of two magnets, one E shaped magnet and other U shaped magnet. The disc is free to rotate in between these magnets. The upper E shaped magnet carries both primary winding which is relay coil and secondary winding. The primary carries the relay current I_1 which produces the flux φ_1. The E.M.F gets induced in the secondary due to this flux. This drives current I_2, flux φ_2 gets produced in the lower magnet. This flux lags behind the main flux φ_1 by an angle α. Due to the interaction of two fluxes, the torque is exerted on the disc and disc rotates.

Assuming that the entire flux φ_1 enters the disc from upper magnet and entire flux φ_2 enters the disc from lower magnet, we can write the torque equation.

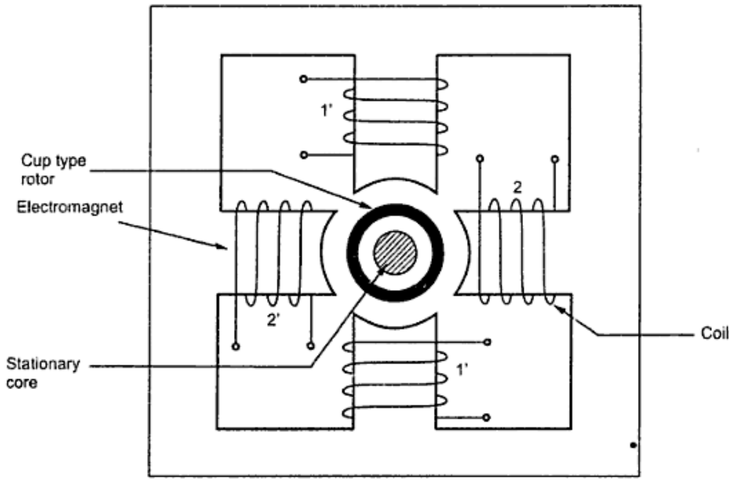
$T \propto \varphi_1 \varphi_2 \sin\alpha$

In this relay, the tapping can be provided on the primary. With the help of this suitable number of primary turns can be selected and hence current setting can be adjusted.

An important feature is that its operation can be controlled by opening or closing of secondary winding .it can be open, no current can flow through secondary hence flux φ_2 cannot be produced and hence no torque can be produced. Thus relay can made inoperative opening the secondary winding.

INDUCTION CUP TYPE RELAY

The construction of this type of relay is very similar to an induction motor. The arrangement shown in fig.



The stator consists of two, four or more poles. These are energized by the relay coils the four pole structure and two pair of coil. The coil1 and 1' are connected while coil2 and 2' are connected to form two pairs of coils. The rotor is hollow cylindrical cup type in structure. Compared to induction motor the difference is that in this relay the rotor core is stationary and only rotor conductor portion is free to rotate its axis.

The current and respective fluxes produced by the two pairs of coils are displaced from each other by an angleα. This is the resultant flux in the air gap is rotating. So rotating magnetic field is produced by two pairs of coils. Due to this, eddy currents are induced in the cup type rotor. This current produces the flux. The interaction of two fluxes produce the torque and rotor rotates in the same direction as that of rotating magnetic field. A control spring and back stop carried on an arm attached to the spindle of cup are responsible to prevent continuous rotation.

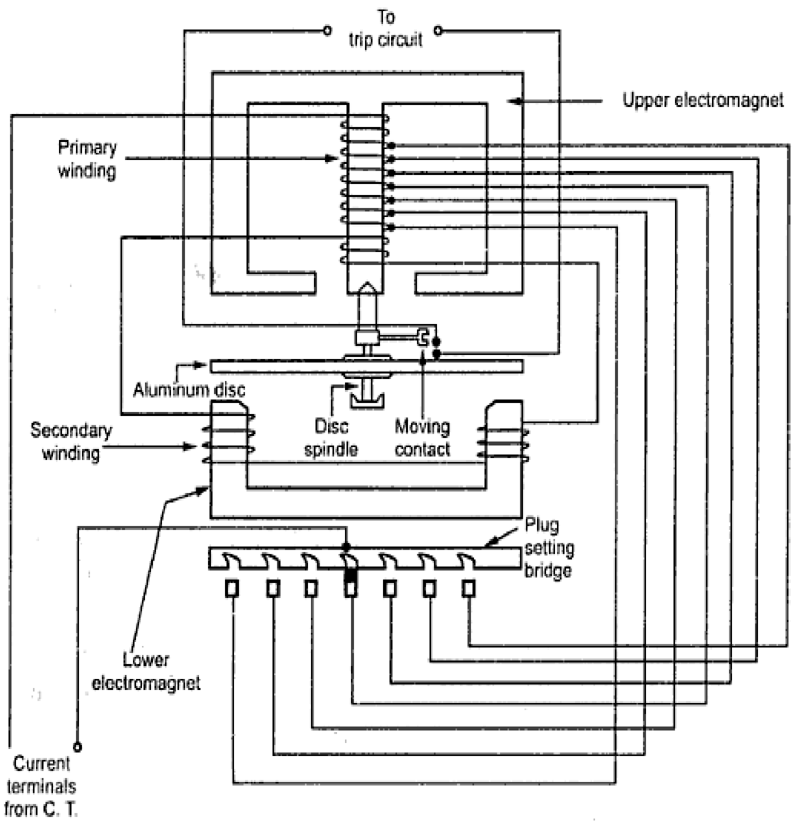
These relay are very fast in operation. The operating time of the other of 10ms is possible with this type. This is because the rotor is light having very low moment of inertia. The induction cup structure can be used for two quantity or single quantity relay.

Asingle quantity relay means both coils are fed by the same actuating quantity with fixed phase angle shift in between them. To reduce rotor inertia and make the operation more fast, double induction loop structure is used.Such a structure shown in bellow.

In all the induction relay widely used for productive relays involving A.C quantities.High,low and adjustable speeds are possible in these relays.Various shapes of time against operating quantity curves can be obtained.

4. Explain non-directional induction type over current relay (or) earth leakage induction type relay.(Dec 2007)(Dec 15)(Nov /Dec 2017)

The over current relay operates when the current in the circuits exceeds a certain preset value. The induction type non directional over current relay has a construction similar to a Watthour meter, with slight modification.



NON DIRECTIONAL INDUCTION OVER CURRENT RELAY

It consists of two electro magnet .the upper is E shaped while the lower is U shaped. The aluminum disc is free to rotate between the two magnets. The spindle of the disc carries moving contacts and when the disc rotates the moving conducts and when the disc rotates the moving contacts come in contacts which are the terminals of a trip circuit.

The upper magnet has two windings, primary and secondary. The primary connected to the secondary of C.T. on the line to be protected. This winding is tapped at intervals. The trappings are connected to plug setting bridge.

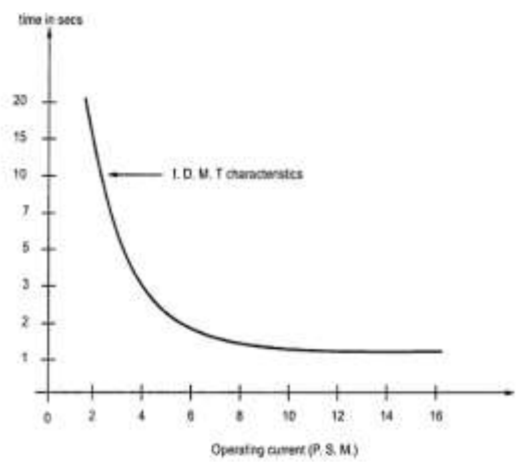
With the help of this bridge, number of turns of primary winding can be adjusted. Thus the desired current setting for the relay can be obtained. There are usually seven sections of tapping to have a over current rang from 50%to 200% in steps of 25%. These values are percentages of current rating of the relay. Thus a relay current rating may be 10A i.e. it can be connected to C.T. with secondary current rating of 10A but with 50% setting the relay will start operating at 5A. So adjustment of the current setting is made by inserting a pin between spring loaded jaw of the bridge socket, at the proper tap value required. When the pin is withdrawn for the purpose of changing the setting wile relay is in service then relay automatically adopts a higher current setting thus secondary of C.T. is not open circulated. So relay remains operative for the fault occurring the process of changing the setting.

The secondary winding on the central limb of upper magnet is connected in series with winding on thelower magnet. This winding is energized by the induction from primary. By this arrangement of secondary winding, leakage flux of upper and lower magnets are sufficiently displayed in space and time to provide a rotational torque on the alumimium disc. The control torque is provided by the spiral spring.

When the current exceeds its preset value, disc rotates and moving contacts on spindle make connection with trip circuit terminal. Angle through which the disc rotates is between 0˙to 360˙.the travel of moving contacts can be adjusted by adjusting angle of rotation of disc. This gives the relay any desired time setting which is indicated by pointer on a time a time scale dial. The dial is calibrated from 0 to 1.This does not give direct operating time but it gives multiplier which can be used along with the Time-Plug Setting multiplier curve to obtain actual operating time of the relay.

$$\mathbf{P.S.M} = \frac{\boldsymbol{faultcurrentinrelaycoli}}{\boldsymbol{RatedsecondaryC.Tcurrent} \times \boldsymbol{currentsetting}}$$

Fault current in relay coil=line fault current ×C.T. ratio



Time – current characteristics

OPERATION

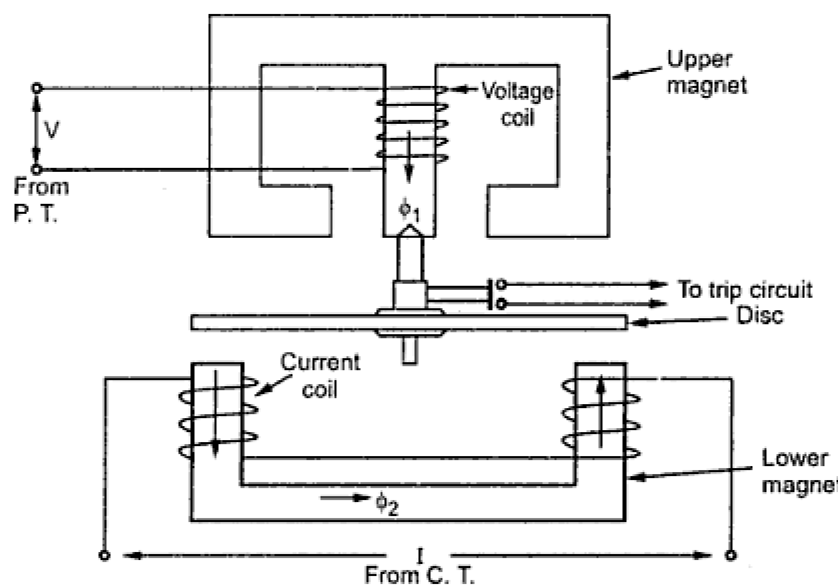
The torque is produced due to induction principle; this torque is opposed by restraining force produced by spiral springs. Under normal conditions the restraining force is more than driving force hence disc remains stationary. Under fault conditions when current becomes high,the disc rotates through the preset angle and makes contact with the fixed contacts of trip circuit. The trip circuit opens the circuit breaker, isolating the fault part from rest of the healthy system.

5. Explain with help of neat diagram the construction and working of induction type directional power relay.(May-2008,June-13) (may-16)

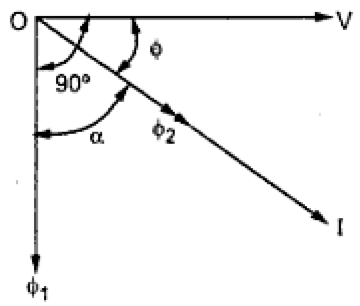
Direction Power Relay

The directional relay means the relay operates for the specific direction of the actuating quantity in the circuit. The directional power relay operates when the power in the circuit floes in the specific direction. The construction and principle of operation of this relay is similar to the induction type Watt-hour meter relay. The difference is that in watt-hour meter type relay the torque is produced by only the current derived from secondary of C.T.while in directional power relay the torque is produced due to interaction of the fluxes produced from both voltage and current in the circuit. The relay has two winding one act as voltage coil while other as current coil which is energized from C.T. in the line to protected.

The of trappings are provided to the current coil with which desired current setting can be achieved. The restraining torque is produced by the spiral spring. The spindle of disc carries the moving contacts which make contact with tripping circuit terminals when the disc rotates. The voltage coil provided on the upper magnet produces the flux φ_1. This lags the voltage by 90˚.the current I is sensed by the current coil on lower magnet which produces the flux φ_2.this is in phase with current I. The current I lags voltage V by an angle φ. the angle between $\varphi_1$and φ_2 is α .shown in phasor diagram.



DIRECTIONAL POWER RELAY



The interaction of fluxes $\varphi_1$and φ_2 produces the torque.

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

$$\phi_1 \propto V \qquad and\ \phi_2 = I$$

$$\alpha = 90° - \phi$$

$$T \propto VI \sin(90° - \phi)$$

$$\boldsymbol{T \propto VI\ \mathbf{Cos}\phi}$$

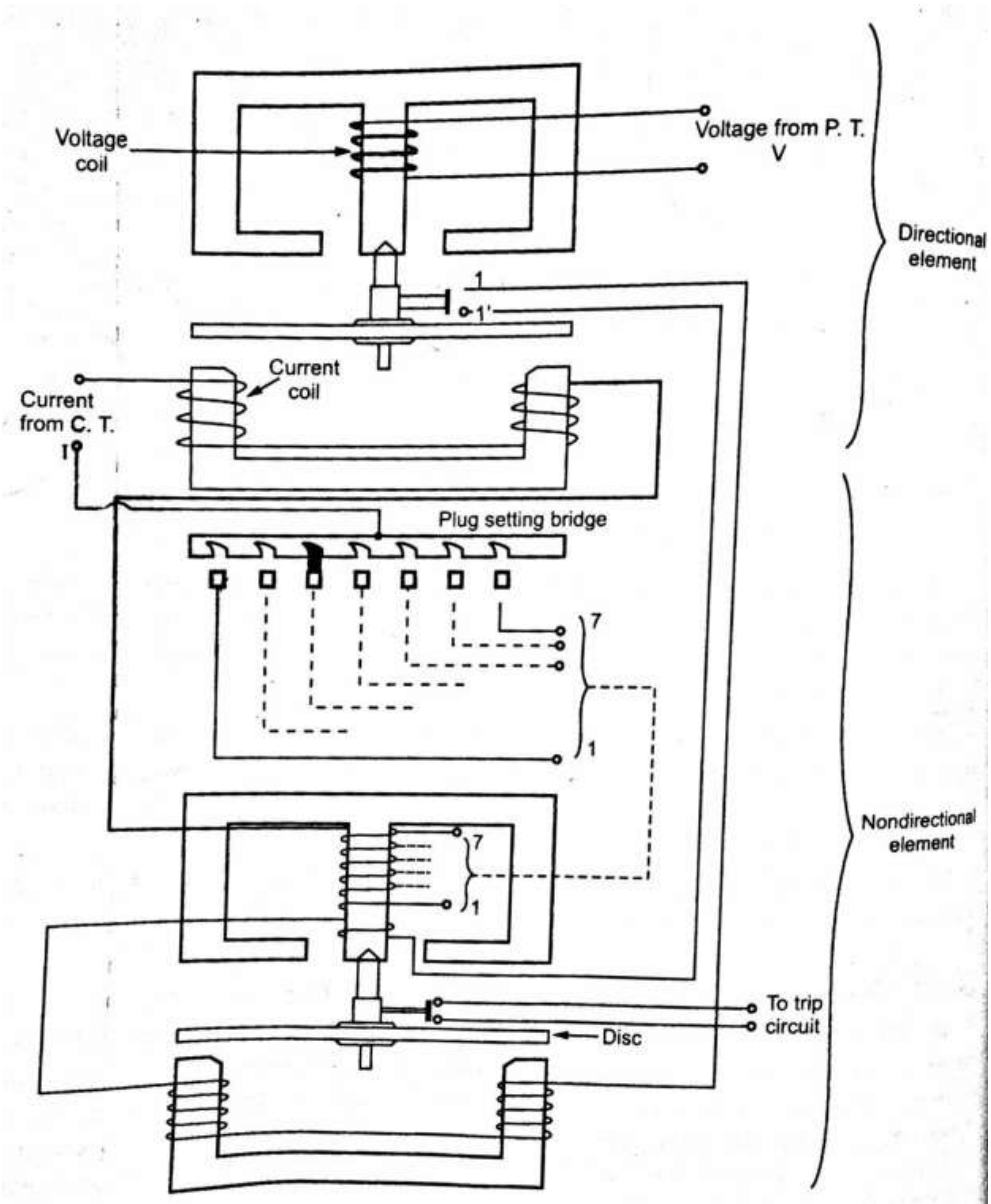
Under normal working conditions, the driving torque acts in the same direction as that of restraining torque. This moves the moving contacts away from the fixed tripping circuit conditions. Thus relay remains inoperative as power flow is in one particular direction.But when there is a current reversal and hence the power reversal then the driving torque acts in opposite direction to the restraining torque in such a manner that the moving contacts close the tripping circuit contacts. This opens the circuit breaker to isolate the faulty part.

This relay is used for providing reverse power protection to synchronous machines.The relay can be single phase or three phase.

6. Explain the construction and operating principle of over current relaywith Directional type (scheme). (Dec-2012, MAY-14)
With a neat diagram explain the working of a directional over current relay. Derive the torque equation and also explain about directional relay connection.(Dec 2016)

The directional power relay is not suitable under short circuit conditions because as short circuit occurs the system voltage falls to a low value resulting in insufficient torque to cause relay operations. This difficulty is overcome in the directional over current relay, which is independent of system voltage and power factor.

Constructional details: – Figure shows the constructional details of a typical induction type directional over current relay. It consists of two relay elements mounted on a common case viz. (i) directional element and (ii) non-directional element.



(i)Directional element: It is essentially a directional power relay, which operates when power flows in a specific direction. The potential of this element is connected through a potential transformer (PT.) to the system voltage. The current coil of the element is energized through a CT by the circuit current. This winding is carried over the upper magnet of the non-directional element. The trip contacts (1 and 2) of the directional element are connected in series with secondary circuit of the over current element. The latter element cannot start to operate until its secondary circuit is completed. In other words, the directional element must first operate (ie. contacts 1 and 2 should close) in order to operate the over current element.

(ii) Non-directional element: – It is an over current element similar in all respects to a non-directional over current relay. The spindle of the disc of this element carries a moving contact which closes the fixed contact after the operation of directional element. Plug setting bridge is rovided for current setting. The tappings are provided on the upper magnet of over current element and are connected to the bridge.

Operation:

During normal conditions, power flow in the proper direction and hence directional element of the relay is in-operation, thus the secondary winding of lower magnet of non-direction element is open and hence non-directional element is also in-operative.

Under faulty conditions, current flows through current coil of directional element which produces flux. The current in voltage coil produces another flux. The two fluxes interact to produce the torque due to which the disc rotates. As disc rotates the trip contact gets closed, the current coil is mainly responsible for disc rotation.

The design of directional element is so sensitive that it can operate even at 2% of power flow in reverse direction. From the current coil of directional element, the current flows to primary winding of upper magnet which is the non-directional element.

The energies to produce the flux. This flux induces the emf in the secondary winding of non-directional relay. As the contacts are closed(1-1'),the secondary winding has a closed path. Hence, Induced e.m.f drives current through it, producing another flux. These two fluxes interact to produce torque and rotates disc. This makes contacts with trip circuit and it opens C.B to isolate faulty sections. Directional element should operate first to operate non-directional element.

<u>The following condition must satisfy for relay operations:</u>

1.The direction of current in the circuit must reverse to operate directional element.

2.The current value in the reverse direction must be greater than the current setting.

3.The high value of current must persists for a long period which is greater than time setting of the relay.

Directional Characteristics

Torque equations and Pharos diagram:

Let

V=relay voltage through PT

I=Relay coil current through CT

θ =angle between V ant I

Due to this, correct operation or relay at all types of fault is,

So current I leads voltage V by angle θ.

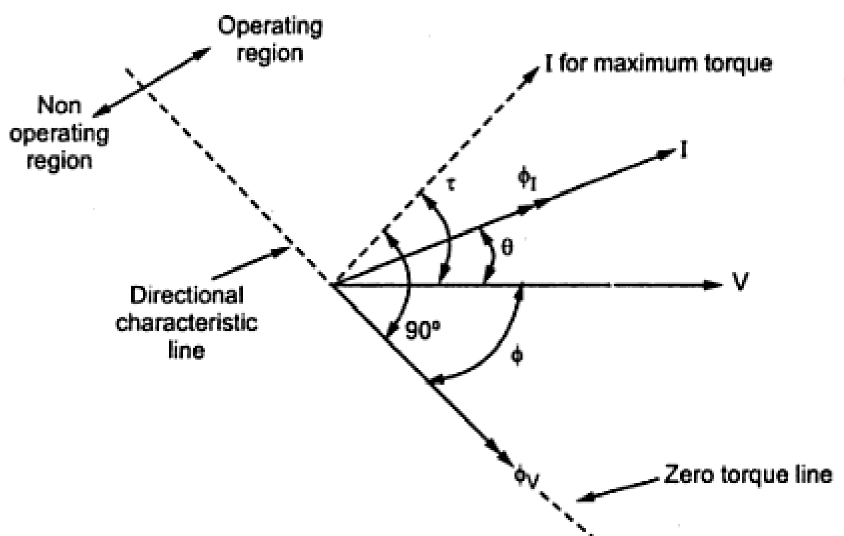
ϕ_v=Flux produced by voltage v.

Flux ϕ_v lags voltage v by an angle ϕ

$\emptyset_I$ =Flux produced by current I.

Flux $\emptyset_I$ is in-phase with the current I,

considering V as reference.



Torque is proportional to fluxes $\emptyset_V, \emptyset_I$& sine of angle between the two fluxes.

$$T \propto \emptyset_V \emptyset_I sin(\emptyset_V + \emptyset_I)$$

$$\propto \emptyset_V \emptyset_I sin(\theta + \phi)$$

Now $\emptyset_V \propto V$ and $\emptyset_I \propto I$

$$T = KVI\,Sin\,(\theta + \emptyset)$$

K=constant

Maximum torque occurs when $\sin(\theta + \emptyset)=1$

$$(\theta + \emptyset) = 90°$$

The condition for the maximum torque is shown in dotted

The torque is zero when $\sin(\theta + \emptyset)=0$ or 180

This line of 0 is called ***zero torque line*** it is right angles to maximum torque condition line.

Maximum torque angle

The angle by which the current supplied to the relay leads the voltage supplied to the relay so as to obtain the maximum torque is called ***maximum torque angle.***

It is denoted byτ

We can write,

$(\emptyset = 90^o - \tau)$

Substituting in the torque equation,

T=KVI Sin $(\emptyset + 90^o - \tau)$

T=KVI Cos $(\emptyset - \tau)$

The typical values of the maximum torque angle are 0^0,30^0,45^0 etc.

7. Derive the universal torque equation of relay. (June-13)

Most of the protection relays consist of some arrangement of electromagnets with armature or induction disc, which carry contacts. The relays also carry the closing or opening of contacts control devices like trip coils of circuit breaker. The electromagnets have voltage or both the types of windings. Currents through windings produce magnetic fluxes and torque is developed by the integration between the fluxes of same windings or between the fluxes of both the windings. In general the torque produced by current winding is proportional to square of the current the torque produced by voltage winding is proportional to square of the voltage, and the torque produced by the windings is proportional to product of voltage and the current.

Mathematically we can write,

Torque produced by current coil=$\mathbf{k_1 I^2}$

Torque produced by voltage coil=$\mathbf{K_2 V^2}$

Torque produced by both the coils=$\mathbf{K_3VIcos(\theta - \tau)}$

Where K_1,K_2 and K_3 = constant =angle between V and I

τ is maximum torque angle

Torque produced by control spring=$\mathbf{k_4}$

The control springs are used as restraining elements

If all the elements are present in a relay then total torque produced by all the causes can be expressed by a general equation as,

$\mathbf{T=K_1I^2+K_2V^2+K_3\,VI\cos(\theta - \tau) + K_4}$

This equation is called universal torque equation the term k4 can be restraing torque due to springs or gravity.

By assigning positive and negative signs to certain constants and lets other constants to be zero and sometimes by adding similar other terms, the operating characteristics equation of all the types of protective relays can be obtained from universal equation.

For example, for over current relay K_2=K_3=0 and the spring torque is negative so we get, $\mathbf{T=K_1I^2-K_4}$

For the directional relay K_1=K_2=0 and the spring torque is negative so we get, $\mathbf{T=K_3\,VI\cos(\theta - \tau) - K_4}$

8. Explain the types of differential relay 1.current differential relay (Apr/May 2018), 2.biased beam (or) percentage of differential relay, 3.voltage balance differential relay.

Differential Relays

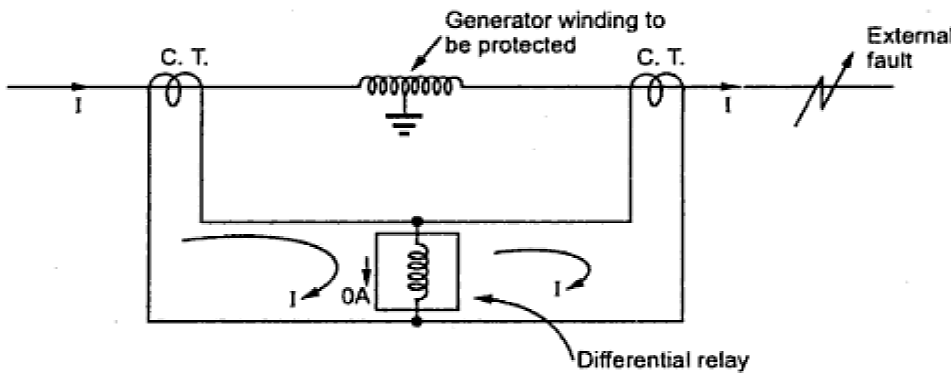
A differential relay is defined as the relay that operates when the phasor difference of two or more similar electrical quantities exceeds a predetermined value

The various types of differential relays are,

- Current differential relay
- Biased beam relay or percentage differential relay
- Voltage balance differential relay

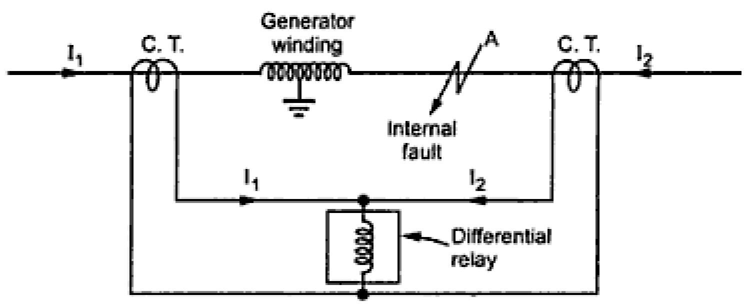
Current Differential Relay(Dec-2010)

Most of the differential relays are of current differential type. Consider an over current relay connected in the circuit so as to operate as the current differential relay.



Two current transformers are used having same ratio are connected on the either side of the section to be protected. The secondaries of current transformers are connected in series, so they carry induced currents in the same direction. Let current I is flowing through the primary of current transformers towards the external fault. As the current transformers are identical, the secondaries of current transformers will carry equal currents. Due to the connection of relay, no current will flow through the operating coil for the relay. Hence relay will remain inoperative. So relay cannot operate if there is an external fault.

Consider now that an internal fault occurs at point A, as shown in the diagram.



The current flows through the fault from both sides. The two secondary currents through C.T.s are not equal. The current flowing through the relay coil is now I_1+I_2. This high current causes the relay to operate.

It should be noted that the fault current need not always flow to the fault from both sides. A flow on one side only or even some current flowing out of one side while a large current entering the other side can cause differential relay to operate. Thus the amount of current flowing through a relay coil depends upon the way the fault is being fed.

This relay suffers from the following disadvantages,

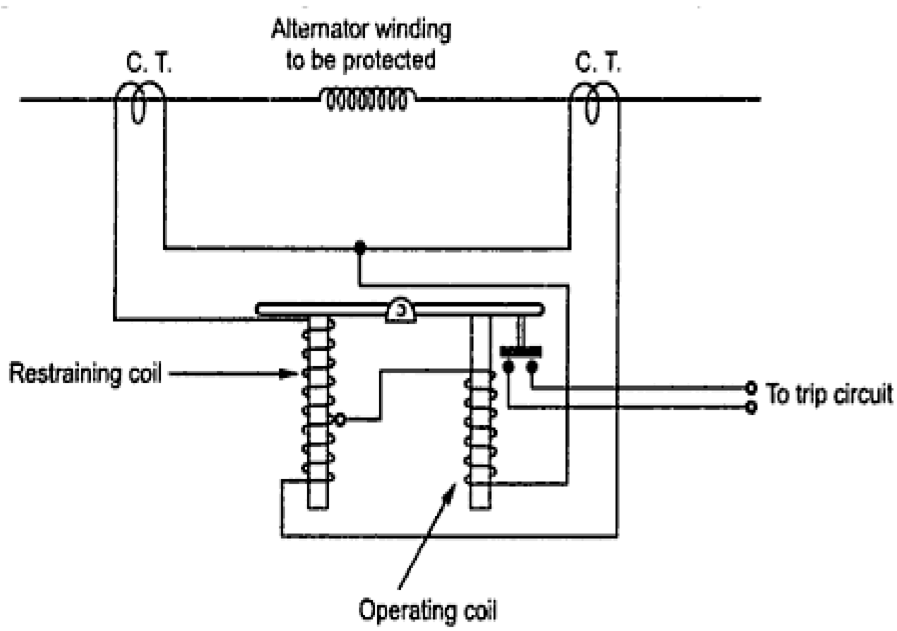
1. The current transformers are connected through cables called pilot cables. The impedance of such pilot cables generally causes a slight difference between the currents at the ends of the section to be protected. A sensitive relay can operate to a very small difference in the two currents, though there is no fault existing.

2. The relay is likely to operate inaccurately with heavy through current flows. This is because the assumed identical current transformers may not have identical secondary currents due to the constructional errors and pilot cable impedances.
3. Under severe through fault conditions, the current transformers may saturate and cause unequal secondary currents. The difference between the currents may approach the pick value to cause the inaccurate operation for the relay.
4. Under heavy current flows, pilot cable capacitances may cause inaccurate operation of the relay.

All these disadvantages are overcome in biased beam relay.

Biased Beam Relay or Percentage Differential Relay.

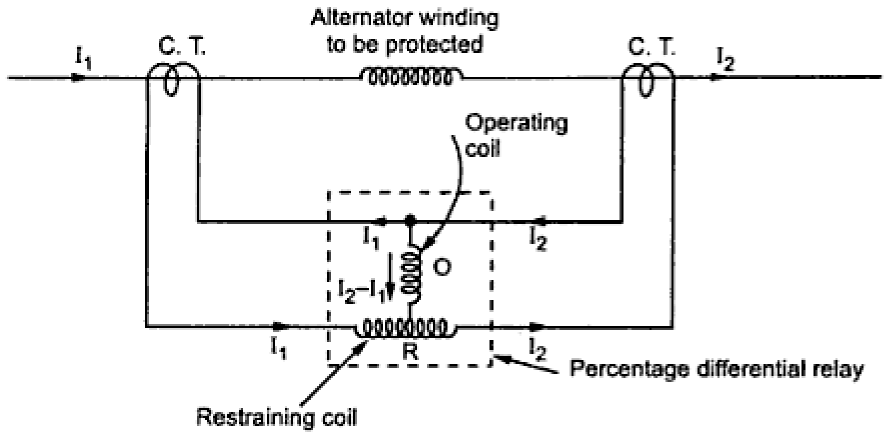
As the name suggests, this relay is designed to operate to the differential current in terms of its fractional relation with the actual current flowing through the protected circuit. The diagramshows the arrangement of a biased beam relay.



Biased Beam Relay

Biased Beam Relay

The simple circuit connection of this type of relay is shown in the **Fig**



Simple circuit biased beam relay

The operating coil **O** of the relay carries a differential current (I_1-I_2) while the restraining coil R carries the current proportional to **(** $\frac{I_1-I_2}{2}$ **)** as the operating coil is connected at the midpoint of the restraining coil. This can be explained as,

Let

N = Total number of turns of restraining coil.

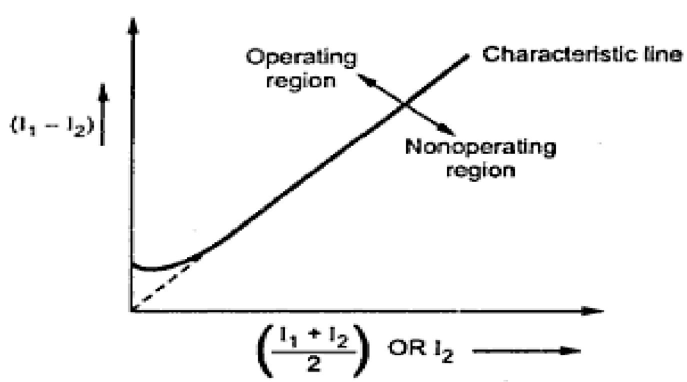
So current I_1 flows through $\frac{N}{2}$ turns of while current I_2 flows through $\frac{N}{2}$

Effective ampere turns = $I_1N/2 + I_2N/2 = N\left(\frac{I_1+I_2}{2}\right)$

Thus it can be assumed that the current $\frac{I_1-I_2}{2}$ flows through the entire N turns of the restraining coil.

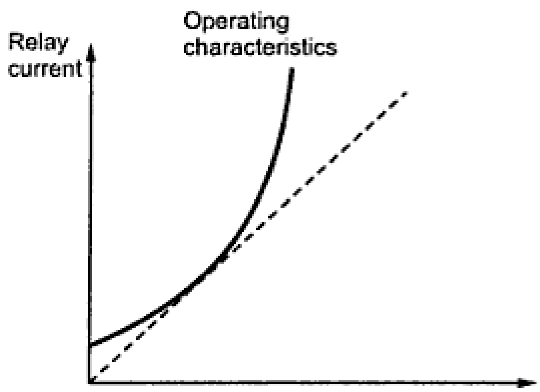
Under normal and through load conditions, the bias force produced due to the restraining coil is greater than the operating force produced by the operating coil hence relay is inoperative. When internal fault occurs, the operating force becomes more than the bias force. Due to this, beam moves and the trip contacts are closed to open then circuit breaker.

The operating characteristics of this type of relay are shown in the **Fig.**



It can be seen that except at low currents, the characteristics is a straight line.Thus the ratio of the differential operating current to the average restraining current is a fixed percentage. Hence the relay name is percentage differential relay.

The relays with constant slope characteristics are called constant slope percentage differential relays.In some relays, the slope of the characteristics increases as the short circuit current increases. Such characteristics are shown in the **Fig.**

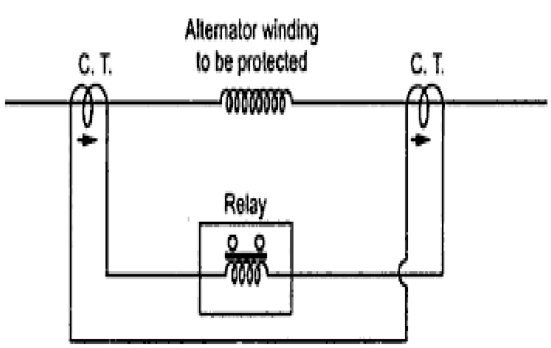


Such relays are called increasing slope percentage differential relays.

The important fact about increasing slope type relays is that their cost is more but requires less accuracy in the performance of their current transformers. Constant slope type relays require good accuracy in the performance of the current transformers.

Voltage Balance Differential Relay

This is also called opposed voltage method. In this type, the over current relay is connected in series with the secondaries of the current transformers. This is shown in the Fig.



- Under normal conditions, the current at the two ends of the section to be protected is same. Hence there is no voltage drop across the relay to cause the current to flow.

- Under fault conditions, the currents in the two secondaries of current transformers are different. This causes a large voltage drop across the relay. Thus the voltage balance of the circuit gets disturbed. Hence large current flows through the relay due to which the relay operates to open the circuit breaker.

9. Explain with neat diagram of following bus protection. (Dec-2010)

1. Frame leakage protection. 2. Circulating current protection.

3. High impedance differential protection.

Busbar Protection

The busbar plays an important role in the supply system. The busbar faults are rare but if occurs there can be interruption of supply, considerable damage and loss. Hence busbar protection is must and it must be fast, stable and reliable. The busbar protection needs to protect not only the busbar but the apparatus associated with it such as circuit breakers, isolating switches, instrument transformers etc.

Bus bar Faults

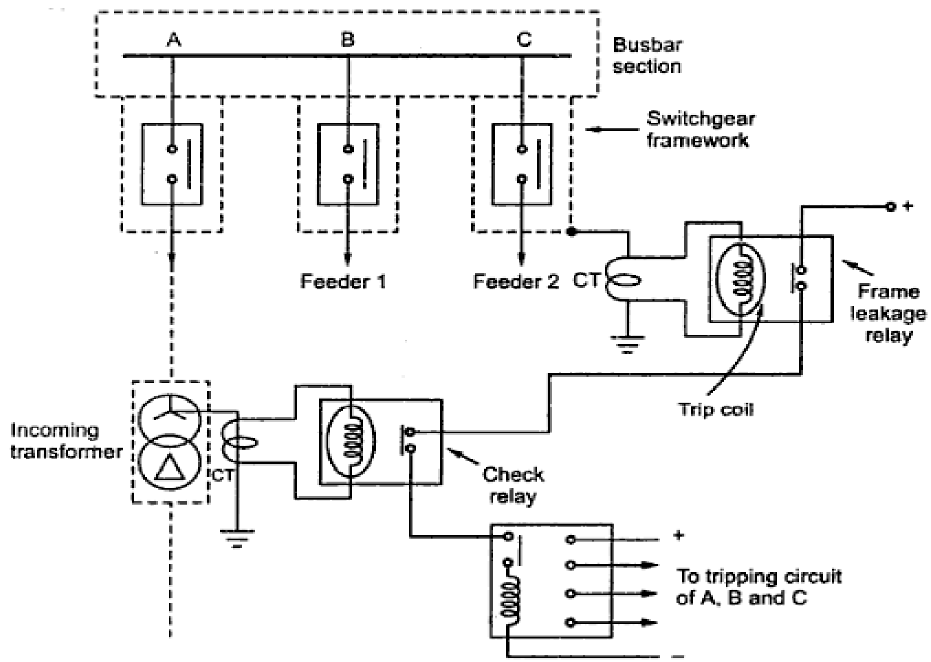
The various bus bar faults can be classified as,

1. Failure of insulation due to material deterioration.
2. Failure of circuit breaker.
3. Earth fault due to failure of support insulator.
4. Flashover due to sustained excessive over voltages.
5. Errors in the operation and maintenance of switchgear.
6. Earthquake and mechanical damage.
7. Accidents due to foreign bodies falling across the bus bars.
8. Flashover due to heavily polluted insulator.

Frame Leakage Protection of Bus bar

All bus bar protection schemes are mostly designed for earth faults. Each conductor is surrounded by the earthed metal barrier. All the metal frameworks are bonded together and insulated from earth. The switchgear framework is also insulated from lead cable sheaths.

The arrangement of frame leakage protection to a single bus bar substation with a switchgear unit is shown in the **fig.**



Frame Leakage Protection

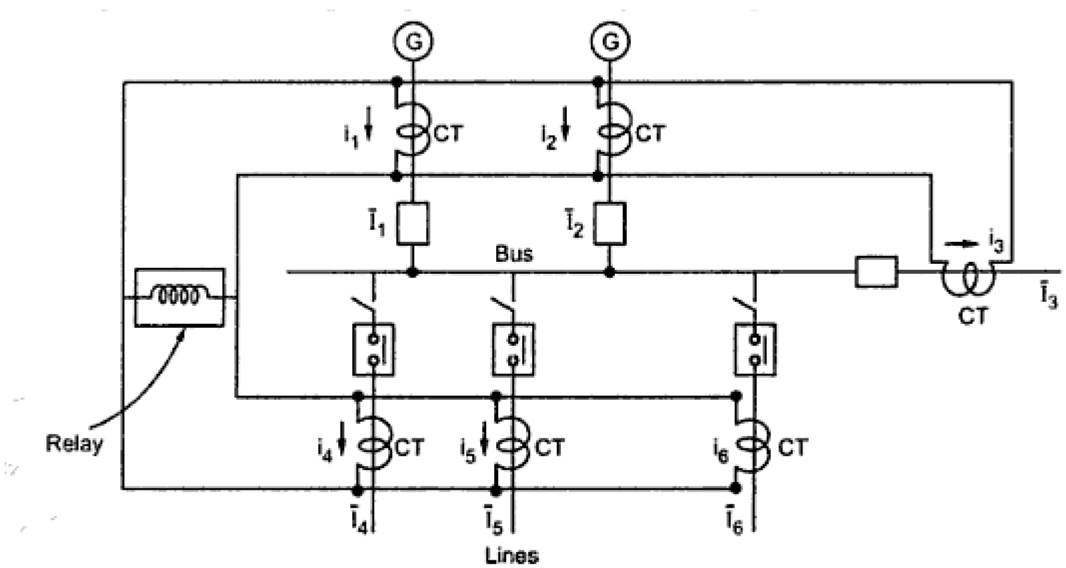
Metal supporting framework known as fault bus is earthed through a CT. When the fault is there, a contact between conductor and earth results. This drives current through this CT. This energizes the frame leakage relay.

The CT energizing the check relay is mounted in neutral earth of the transformer. The contacts of check relay and frame leakage relay are in series.

Thus before tripping circuit gets energized both the relays must operate. Once both the relays operate due to earth fault, all the breakers will trip connecting the equipment to the busbar, due to check relay; accidental operation of single relay to trip the circuit gets avoided.

Circulating Current Protection of Bus bar

This is nothing but the differential scheme of the protection of bus bar . The circulating current principle states that under normal working conditions or external fault condition, sum of the currents entering the bus equals sum of the currents leaving the bus. Under any abnormal conditions in the protected zone i.e. short circuit or phase to phase faults, the current condition gets distributed and sensing this relay can be operated.



$I_1, I_2 \ldots I_6$ are the current in the circuit connected to the bus bar.

Under normal condition, $\sum I=0$.

i.e.

$$\bar{I}_1+\bar{I}_2+\bar{I}_3+\bar{I}_4+\bar{I}_5+\bar{I}_6=0(vector\ sum)$$

No current flows through the relay and hence remains inoperative.

Under fault conductions,

$$\bar{I}_1+\bar{I}_2+\bar{I}_3+\bar{I}_4+\bar{I}_5+\bar{I}_6=\bar{I}_f$$

Where $\bar{I}_f = fault\ current = unbalanced\ current$

- Under normal conditions, currents in the secondary's of CT balance each other and no current flows through the relay. Thus relay is inoperative. Under any fault conditions, the fault current flows through relay coil to activate it.
- To obtain exact balance of currents, all current transformers must have same ratio. But in practice there exists a difference in the magnetic conditions of iron cored current transformers and false operation of the relay is possible, at the time of external faults. For large fault currents there is a possibility of saturation of the cores of current transformers. To overcome such difficulties, a special type of CT having no iron core is used. It is called linear coupler.

The linear coupler has a property that its secondary voltage is proportional to the primary current and the secondary winding of all the linear couplers are connected in series to the relay.

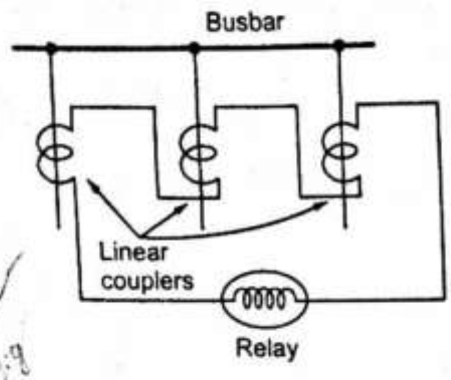


Fig. 3.10

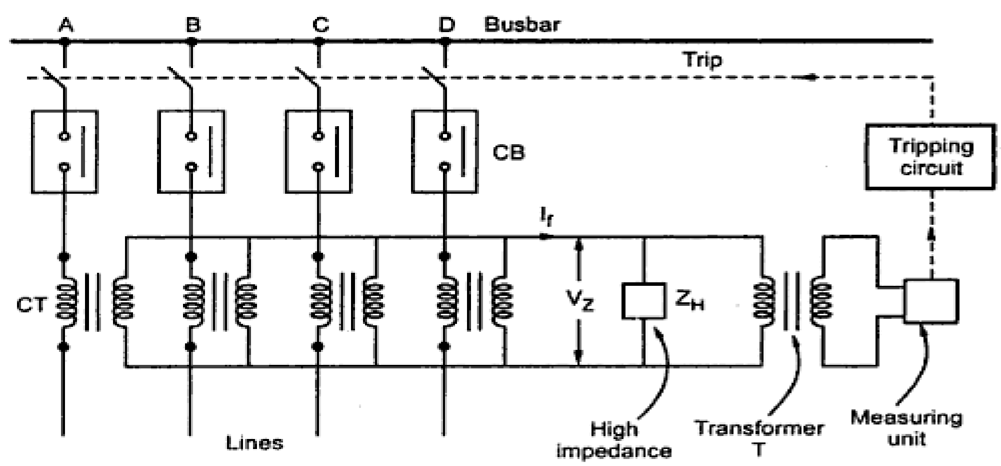
The sum of the voltage outputs of linear couplers is equal to the vector sum of the voltages in the circuits connected to the busbars. Hence under normal condition overall voltages in the secondary circuits are zero and relay is inoperative. Under fault conditions, there is resultant voltage in the secondary and relay operates.

A high impedance relay can differentiate properly the internal and external faults compared to normal low impedance relay. Hence in circulating current protection, high impedance relay are used. A high resistance is connected in series with the relay operating coil to get high impedance relay. This resistance is called stabilizing resistance.

10. Explain with need diagram High impedance differential protection. (Dec-2010)

This method of protection based on sensing a voltage drop across a high impedance, under fault conductions. Shown in FIG.

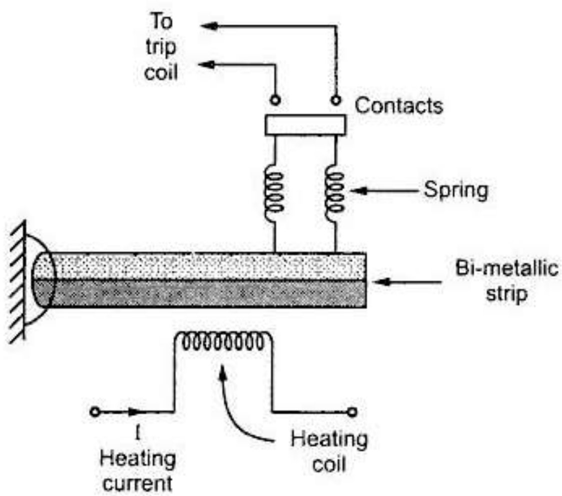
The basic principle remains same as differential scheme. Under normal conditions vector sum of the currents in the lines is zero. Hence I_f current flowing through high impedance Z_H is zero. And the relay is inoperative.



During the fault conditions, unbalanced currents exist. Such an out of balance current I_f flows through Z_H causing a high voltage drop V_Z across it. It is given to a transformer. A Measuring Unit Is connected to secondary of this transformer which measures this drop and trips the relay accordingly. Main advantage is that as voltage drop is sensed, saturation of core of one of the current transformer has no effect on the protection scheme.

11. Write short notes on Thermal relay?

It works on the principle of heating effect of an electric current in the relay coil. They sense the temperature rise produces by the current.



Under normal conditions, the heating due to current I increases beyond safe value producing very high I^2R losses and corresponding large heat. Thus the strip gets heated up & bends. Due to bending of strips, spring opens the contact and I is interrupted.

12. Explain with neat diagram Impedance Relay :(Dec-2010, Dec-2013)
Explain the construction and operating principle of impeadance type distance relay with R-X diagram.(May 2017) (Apr/May 2018)

Impedance Relay

The impedance relay works corresponding to the ratio of voltage V and current I of the circuit to be protected. There are two elements in this relay, the one produces a torque proportional to current while the other produces a torque proportional to voltage. The torque produced by the current element is balanced against torque produced by the voltage element. Thus the current element produces operating torque, Pickup torque which can be said to be positive torque. The voltage element produces restraining torque, reset torque which can be said to be negative torque. So this relay is ***voltage restrained overcurrent relay***.

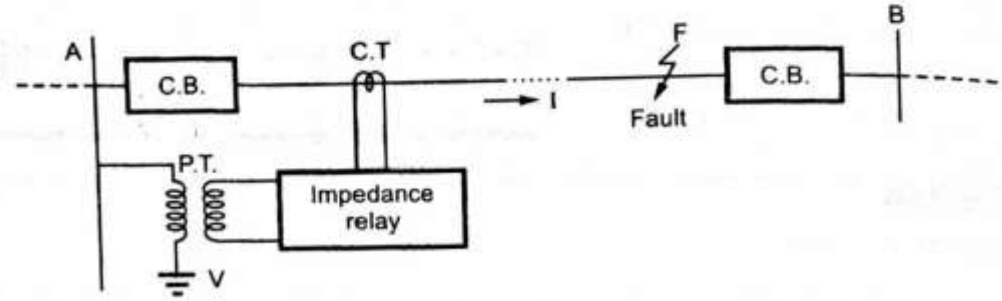


Fig. 4.1 Basic operation of impedance relay

- The current element is energized by current through C.T. while voltage element is energized by voltage through P.T. The section AB of the line is protected zone.
- Under normal conditions, the ratio of voltage V and current I is denoted As Z_L which is impedance of line. The relay is inoperative under this condition.
- When the fault occurs at point F in the protected zone then the voltage drops while current increases. Thus the ratio V/I i.e. the impedance reduces drastically. This is the impedance of line between the point at which relay is connected and the point F at which fault occurs. So when the impedance reduces than its predetermined value Z_L it trips and makes the circuit breaker open.

Torque Equations:

The torque element produced by current element is $\propto$ to I^2 and –ve torque produced by voltage element is $\propto$ to V^2

Let control spring effect produces a constant torque of $-K_3$

Hence the torque equation becomes,

$T=K_1I^2-K_2V^2-K_3$

Where K_1, K_2 are the constants, while V and I are r.m.s. values.

At the balance point, when the relay is on the verge of operating the net torque is zero hence we can write,

$$0 = K_1 I^2 - K_2 V^2 - K_3$$

$$K_2 V^2 = K_1 I^2 - K_3$$

Dividing both sides by K_2I^2

$$\frac{V^2}{I^2} = \frac{K_1}{K_2} - \frac{K_3}{K_2 I^2}$$

$$Z = \sqrt{\frac{K_1}{K_2} - \frac{K_3}{K_2 I^2}}$$

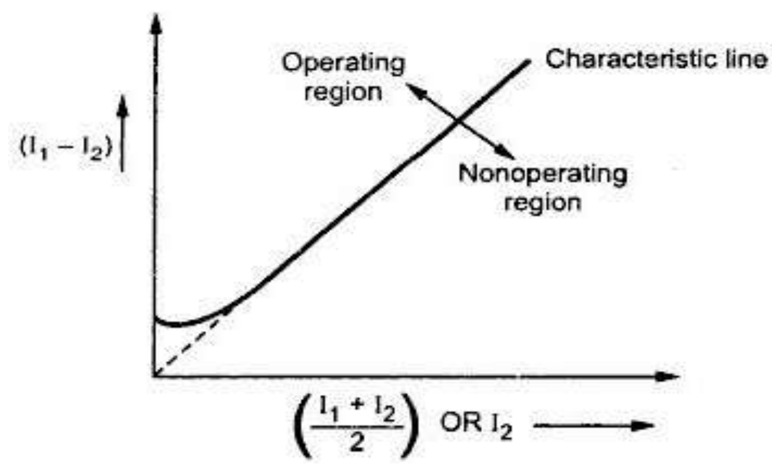
With negligible spring effects,(K_3=0)

$$Z = \sqrt{\frac{\mathrm{K}_1}{\mathrm{K}_2}}$$

$$\frac{\mathbf{V}}{\mathbf{I}} = \boldsymbol{Z} = \boldsymbol{constant}$$

Operating Characteristics:

For a particular fault position, V/I is constant, and it changes when fault position changes. If fault is nearer to relay this ratio will be low and as fault position moves away from the relay the ratio becomes higher and higher. So it can be installed to operate for the section to be protected and once installed and adjusted for a particular section, it is in-operative beyond that section.

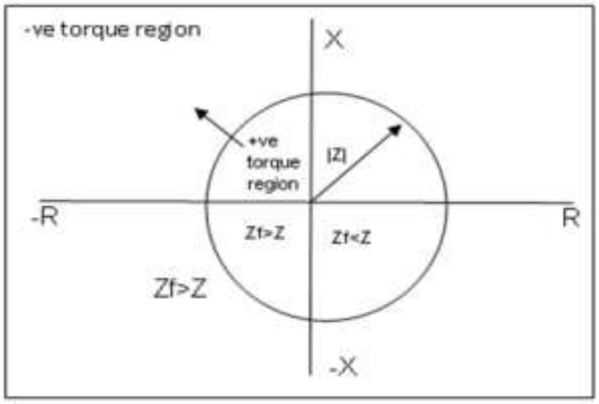


R-X Diagram:

Operating character of impedance relay is easily represented by a diagram called as R-X diagram. It's X-axis is rep. as "R" while y-axis as X-axis as

This plane is called R-X plan. The impedance "Z" can be

$$Z = R + jx$$



$$Z = \sqrt{R^2 + X^2}$$
$$Z^2 = R^2 + X^2$$

$X^2 + y^2 = Q^2$representing a circle's eqn.

$$tan\emptyset = \frac{X}{R} \therefore \emptyset = tan^{-1}\left(\frac{X}{R}\right)$$

"Z" can be determined by numerical value of V&I,
While "Φ" can be determined by angle b/w V&I.

case 1;

If 'I' is in-phase with "v",Z-vector lies along R-axis.

Case 2:

If "I" lags vector "V"then "X" is negative.

Case 3:

If "I" leads vector "V" then "X" is positive.

At any pt of value of "Z" less than the radius of the circle the relay operates. Hence the entire position inside the Ole is +ve torque region.

While the portion exterior to the circle is –ve torque region i.e –ve torque region.

Where,

Z_f=Impedance between relay and fault pt.

Z=Set value for impedance=Radius of the circle,

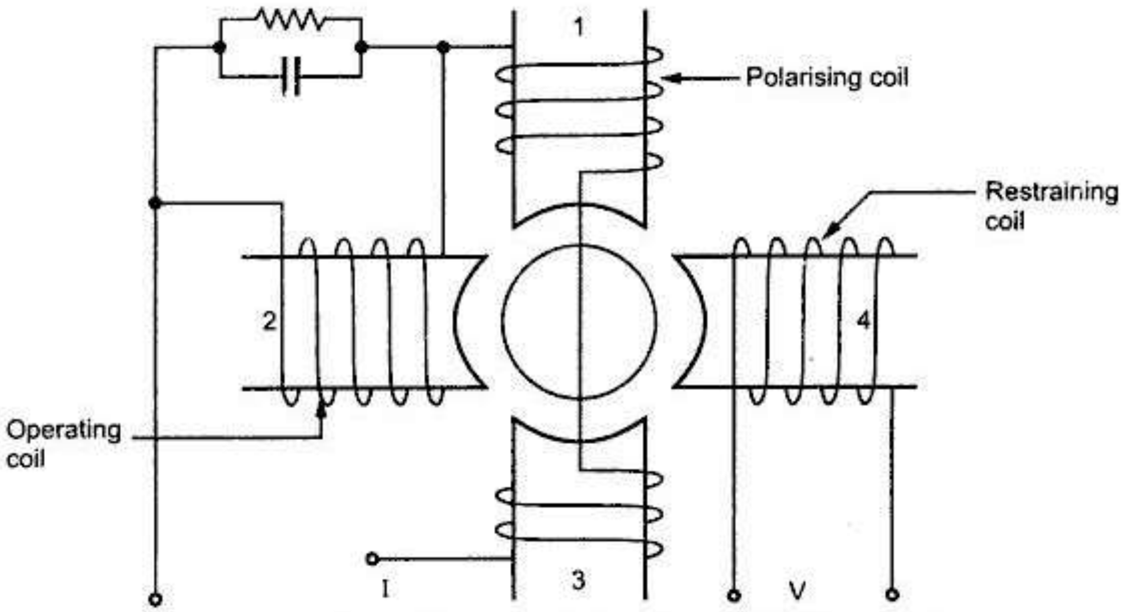
Z_f<Z→Relay operates.

Z_f>Z→Relay is in-operative.

13. Explain the construction working principle of reactance relay with need diagram.(Jun-2007)(dec-15)

In this relay the over current element develops a +ve torque and directional element produces –ve torque.

The directional element is designed that maximum torque angle is 90.



It has an operating coil, polarizing coil, and a restraining coil. The "I" flows from pole 1,through Iron Core stacks –ve to pole 3.The winding on pole 4 is fed from voltage v, The operating torque is produced by interacting fluxes, due to winding carrying current coils. While the restraining torque produced by coils (1, 2& 4).Hence operating torque is to square of the "I" & restraining torque is to product of "V &I".Desired max. Torque is obtained with the help of RC circuit.

Torque Equation:

The driving torque is proportional to the square of the current while the restraining torque is proportional to the product of V and I.

Hence the net torque neglecting the effect of spring is given by,

$$T = K_1 I^2 - K_2 VI \cos(\theta - \tau)$$

At the balance point net torque is zero,

$$\therefore 0 = K_1 I^2 - K_2 VI \cos(\theta - \tau)$$

$$\therefore K_1 I^2 = K_2 VI \cos(\theta - \tau)$$

$$\therefore K_1 = K_2 \frac{VI}{I^2} cos(\theta - \tau)$$

$$\therefore K_1 = K_2 Z\, cos(\theta - \tau)$$

Adding capacitor, the torque angle is adjusted as 90°,

$$\therefore K_1 = K_2 Z\, cos(\theta - 90°)$$

$$\therefore K_1 = K_2 Z\, sin\,\theta$$

$\therefore Z\, sin\,\theta = \frac{K_1}{K_2}$

Consider an impedance triangle shown in the Fig. 4.10.

$$Z\, sin\,\theta = X = reactance$$

$$Z\, cos\,\theta = R = resistance$$

$$\therefore X = \frac{K_1}{K_2} = constant$$

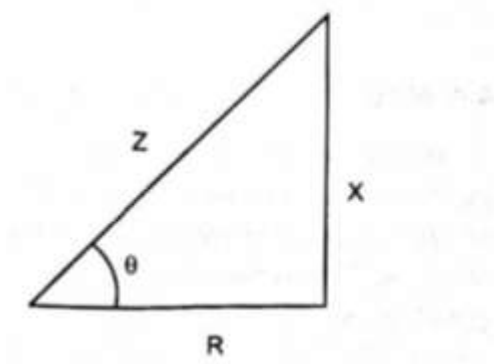


Fig. 4.10

Thus the relay operates on the reactance only. The constant X means a straight lineparallel to X-axis on R-X diagram. For the operation of the relay, the reactance seen by the relay should be smaller than the reactance for which the relay is designed

Operating Characteristics

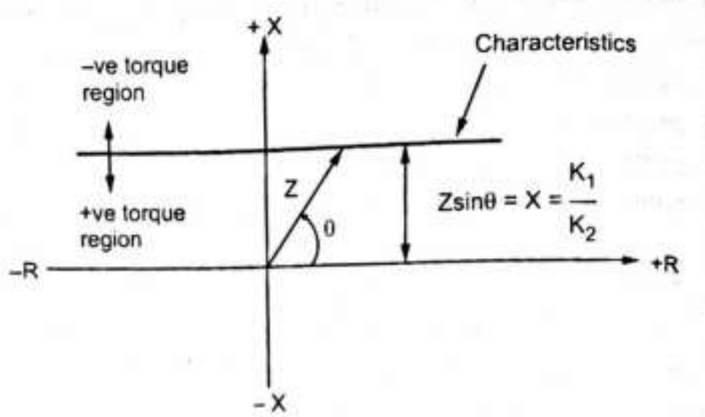


Fig. 4.11 Operating characteristics of reactance relay

The relay will operate for all the impedances whose heads lie below the operating characteristics, whether below or above the R-axis.

Disadvantages

- This relay as can be seen from the characteristics is a ***non-directionalrelay***
- This will not be able discriminate when used on transmission line, whether the fault has taken place in the section where relay is located or it has taken place in the adjoining section.
- The reactance relay with directional feature called ***mho relay*** or ***admittance relay***

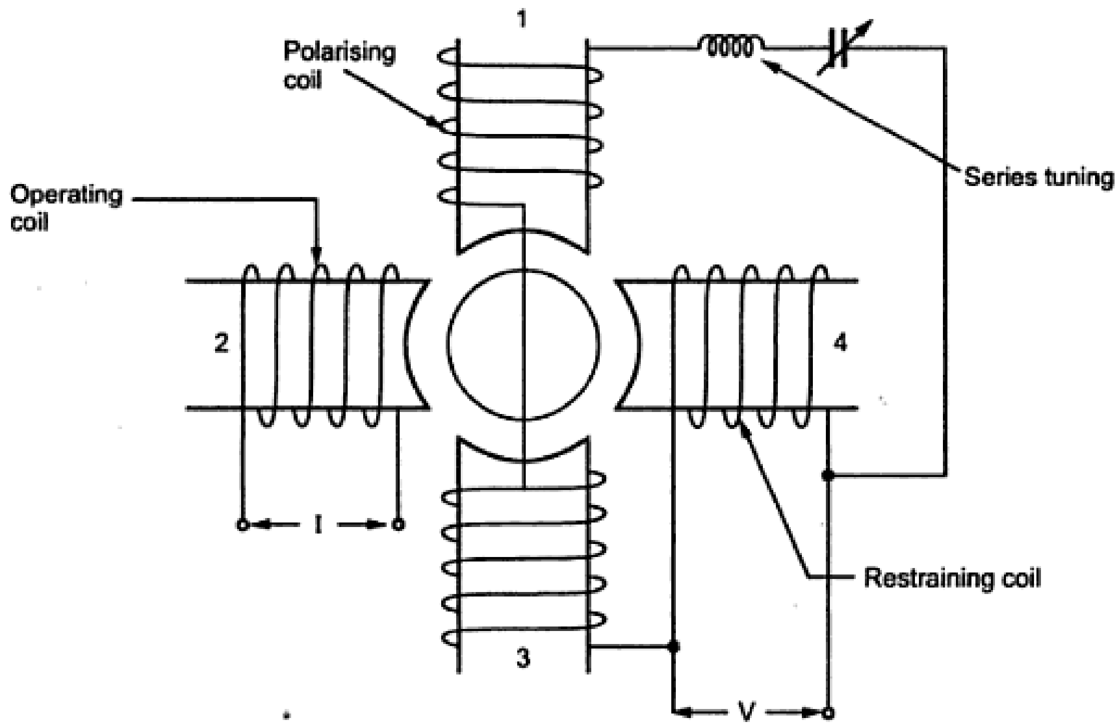
14. Explain MHO relay characteristics on the R-X diagram .discuss the range setting of various distance relay placed on a particular location.(Dec-2012,2013) (May 2016)

MHO Relay (or) ADMITANCE RELAY:

The reactance relay with directional feature is called a MHO relay. It is inherently a direction relay as it detects the fault only in forward direction. It works on the measurement of admittance Y. It is also called angle impedance relay.

CONSTRUCTION

This relay also uses an induction cup type structure. It also has an operating coil, polarizing coil and restraining coil. The schematic arrangement of all the coils is shown in the Fig. 4.12.



- In this relay the operating torque is obtained by V and I element while the restraining torque is obtained by a voltage element. Thus an admittance relay is a voltage restrained directional relay.
- The operating torque is produced by the interaction of the fluxes due to the windings carried by the poles 1, 2 and 3. While the restraining torque is produced by the interaction of the fluxes due to the windings carried by the poles 1, 3 and 4.
- Thus the restraining torque is proportional to the square of the voltage (V^2) while the operating torque is proportional to the product of voltage and current (VI). The torque angle is adjusted using series tuning circuit.

Torque Equation:

The operating torque is proportional to VI while restraining torque is proportional to V^2. Hence net torque is given by,

$$T = K_1\, V\, I \cos(\theta - \tau) - K_2 V^2 - K_3$$

Where K_3 = control spring effect

Generally control spring effect is neglected ($K_3 = 0$).

And at balance net torque is also zero.

$$0 = K_1\, V\, I \cos(\theta - \tau) - K_2 V^2 - 0$$

$$K_1\, V\, I \cos(\theta - \tau) = K_2 V^2$$

$$K_1 \cos(\theta - \tau) = \frac{K_2 V^2}{V\, I}$$

$$K_1 \cos(\theta - \tau) = \frac{K_2 V}{I}$$

$$Z = \frac{K_1}{K_2} \cos(\theta - \tau)$$

This is the equation of a circle having diameter $\frac{K_1}{K_2}$ passing through origin. And this constant $\frac{K_1}{K_2}$ *is* the ohmic setting of this relay.

Operating Characteristics

As seen from the torque equation, the characteristics of *this* relay is a circle passing through origin with diameter as K_1/K_2.

$$\text{Let } \frac{K_1}{K_2} = Z_r = ohmic\ setting\ of\ relay = diameter$$

The *circle is* shown in the Fig. 4.13.

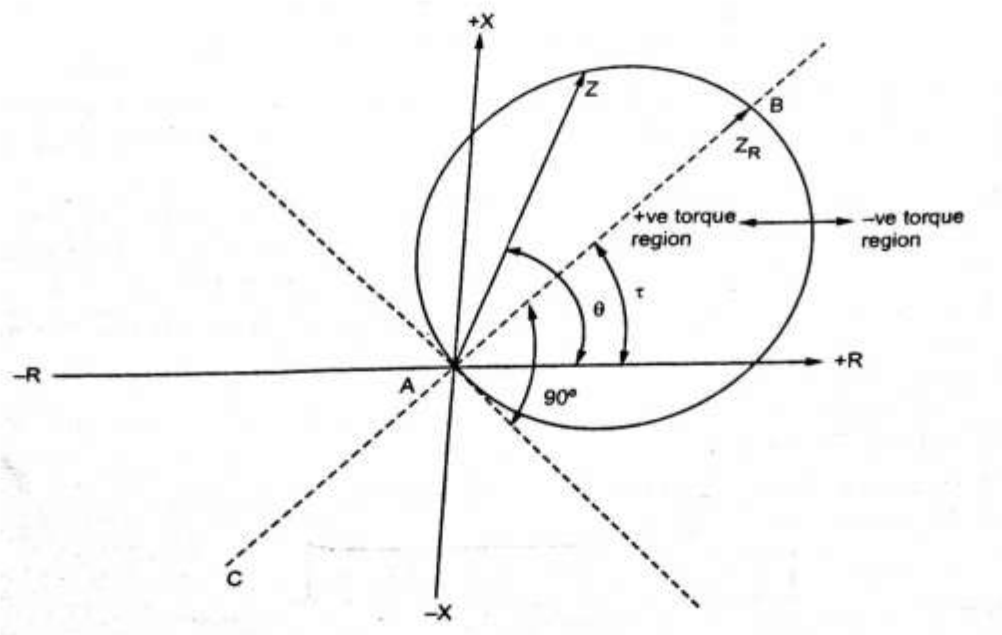


Fig. 4.13 Operating characteristics of mho relay

The relay operates when the impedance seen by the relay falls within this circle Consider two lines AB and AC with mho relay located at the point A. The relay will operate for the faults occurring in the section AB only and not for the faults occurring in the section AC. This shows that this relay is inherently directional without any additional directional unit required.

The angle τ can be adjusted to be 45°, 60°, 75° and so on. This angle is maximum torque angle. The setting of 45° is used for high voltage (33 or 11 kV) distribution lines, the setting of 60° is used for 66 or 132 kV lines while the setting of 75° is used for 275 and 400 kV lines.

15. Explain in detail the different types of distance relays?

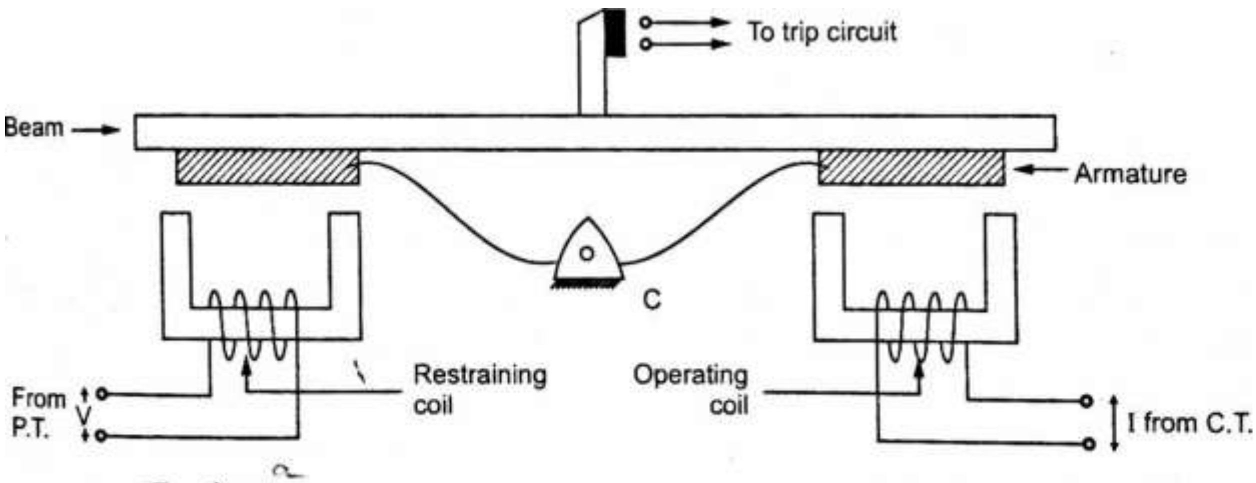
Classification of Distance Relays

we have seen that the distance relay basically measures ohmic values and operates hen the impedance is below the preset, value The distance relays are classified as,

1. **Definite distance relays:** These can be of impedance type, reactance type or mho type. This operates instantaneously for the faults up to certain predetermined distance from the relay.
2. **Distance time relays:** These can be also of impedance type, reactance type or mho type, in these relays the time of operation, is proportional to the distance of the fault from the point where relay is installed. The fault nearer to the relay operates it faster than for the faults further away from the relay.

1. Definite Distance Type Impedance Relay

The construction of this relay can be balanced beam type or induction disc type. The balanced beam type construction of definite distance impedance relay is shown in the Fig. 4.15.



$T \propto V^2$

Fig. 4.15 Definite distance type impedance relay

It consists of a balanced beam pivoted at the central point G. The beam carries the armatures of the two electromagnets. The two electromagnets are energized by a current from C.T, and voltage from P.T., which are located in the circuit to be protected. The voltage coil acts as restraining coil while the current coil acts as operating coil. The beam also carries the moving contacts which can bridge the two fixed contacts of a trip circuit when the relay operates.

The torque produced by voltage coil is proportional to square of the voltage (K_1V^2) while the torque produced by current coil is proportional to the square of the current ($K_2 I^2$). Under normal operating conditions, the torque produced by voltage coil is more than the torque produced by the current coil. Thus restraining torque is more than the operating torque and hence the relay is inoperative. On the occurrence of any fault, the voltage of system decreases and current increases. Thusthe ratio V/I which is impedance also decreases. It falls below its preset value. The torque produced by current coil becomes greater than the torque produced by the voltage coil. Hence beam experiences a pull on the current coil side. As the beam tilts, the moving contacts of beam bridges the fixed contacts of the trip circuit. This operates the trip circuit and opens the circuit breaker.

Torque Equation:

The torque by voltage coil is proportional to V^2 while that by current coil is I^2. The relay will operate when torque produced by voltage coil is less than that produced by current coil. So we can write,

$$K_1V^2 < K_2I^2 \quad \ldots..relay\ operates$$

Where K_1, K_2 are constants

$$\therefore \frac{V^2}{I^2} < \frac{K_2}{K_1}$$

$$\therefore \frac{V}{I} < \sqrt{\frac{K_2}{K_1}}$$

$$\therefore Z < \sqrt{\frac{K_2}{K_1}}$$

So for impedance value less than $\sqrt{\frac{K_2}{K_1}}$, the relay operate.

The constants K_1 and K_2 are dependent on the ampere turns of the two electromagnets. By providing tappings on the coils K_1 and K_2 can be changed and hence any preset value for the impedance can be adjusted as per the requirement.

Characteristics

The Fig. 4.16 shows the characteristics of the definite distance type impedance relay. The Y-axis represents time for *operation* while the X-axis represents distance which is measured intermsof *impedance between* fault position and the *point* where relay installed.

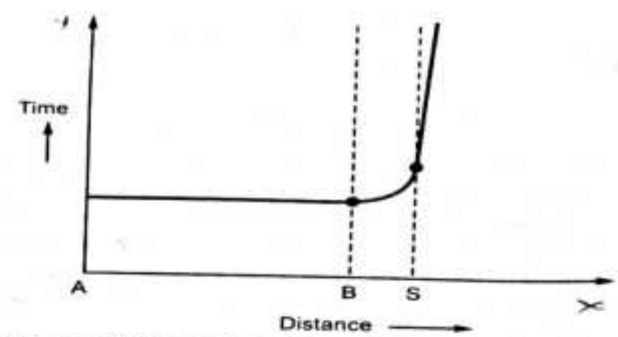


Fig. 4.16 Characteristics of definite distance impedance relay

For the entire length of the line, the time of operation remains constant, irrespective of distance. But if fault occurs in the section of line which is not protected, the operating time becomes suddenly infinite as shown in the figure. Towards end of the protected zone, the curve rises gradually

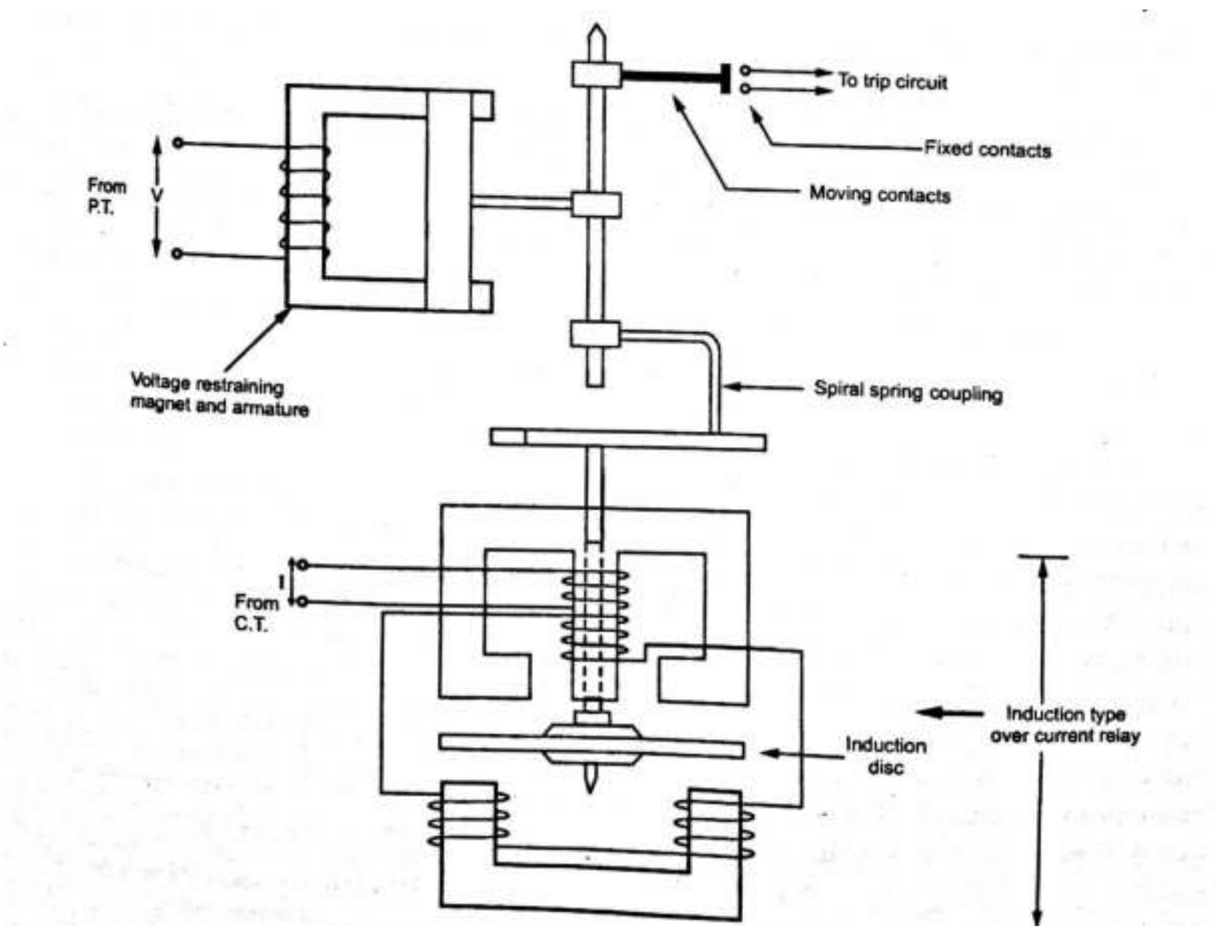
Its advantages are,

- Superior to the time graded over current relay
- Number of feeders in series which can be protected is unlimited as the relay time is constant

2. Distance Time Impedance Relay

This relay adjusts automatically, its time of operation corresponding to the distance of the fault from the relay

Operating time ∝ Z∝ distance



It consists of an induction type over current relay unit which is a current driven element The spindle which is carrying the disc of the element is connected to a second spindle with the help of spiral spring coupling) this second spindle carries moving contacts which is nothing but a bridging piece which can bridge the trip contacts when relay operates

Operation:

- Under normal conditions, the force exerted by voltage restraining magnet is more than that produced by an overcurrent induction element. Thus the trip contacts remain open and the relay is inoperative
- When the fault occurs, the induction disc starts rotating. The speed of the disc is proportional to the operating current
- *As* the disc rotates, spiral spring is wound. This exerts a force on armature so as to pull it away from the voltage restrained magnet. The disc continues to rotate till the tension of the spring is sufficient to overcome the restraining force produced by voltage restraining magnet on the armature. Immediately the moving contacts bridge the fixed contacts of tripping circuit. This opens the circuit breaker to isolate the faulty section.

Time of operation of relay $\propto \frac{V}{I} \propto Z \propto distance$

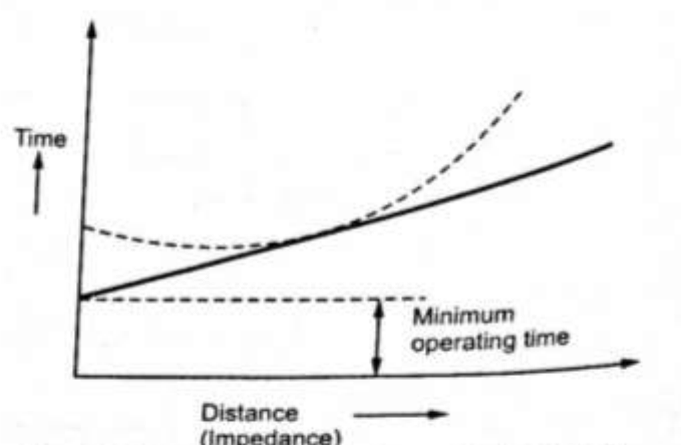


Fig. 4.18 Time-distance characteristics of distance time impedance relay

Applications and Advantages of Distance Relays

The various advantages of the distance relays are.

- Gives faster operation
- Simpler to co-ordinate
- Less effect of fault levels and fault current magnitudes
- Permits high line loading.

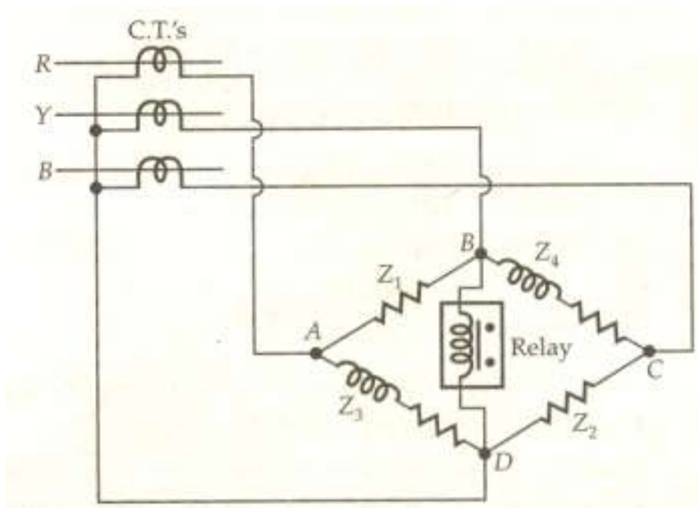
- With the need at readjustments, permanent settings can be done.

Thus the distance relays are used for providing the primary i.e. main protection and backup protection for a.c. transmission and distribution lines against the following faults,

- Three phase faults
- Phase to phase faults
- Phase to earth faults.

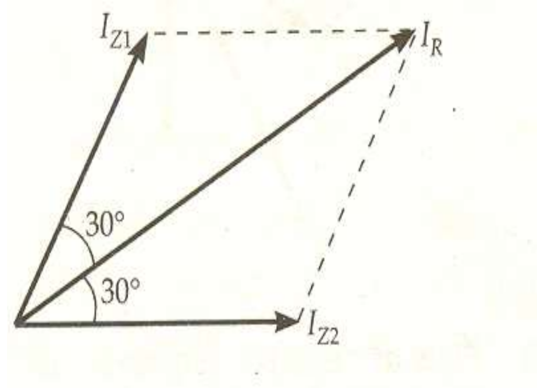
16. Explain the operation of Negative sequence relay.(Apr/May 2018)

A negative sequence relay provides protection to generators and motors against unbalanced loading that may result from phase to phase fault. **Fig** shows the phase imbalance protective equipment. The equipment consist of network energized from three current transformer and a single pole relay having an inverse time characteristic connected across the network. The network consist of four impedances Z_1,Z_2,Z_3,Z_4 of equal magnitude connected in a bridge formation. Z_1 and Z_2 are non inductive resistances while Z_3 and Z_4 are composed of both resistance and reactance.The values of Z_2 and Z_4 are also adjusted that the current flowing in these lag behind those in the impedances Z_1 and Z_2 by 60°.the relay is assumed to have a negligible impedance.



Current from R phase divide in to two equal components I_{z1} and I_{z3} at A,I_{z1} being ahead of I_{z3} by 60°from **vector diagram**.

$I_{z1}=I_{z3}=\frac{IR}{\sqrt{3}}$



Similarly,the current from phase B divide in two equal components I_{z2} and I_{z4} each equal to $\frac{IB}{\sqrt{3}}$ and I_{z2} leadings I_{z4} by 60°.

$\therefore$The current entering the relay at point B=$I_{z1}+I_{z4}+I_y$

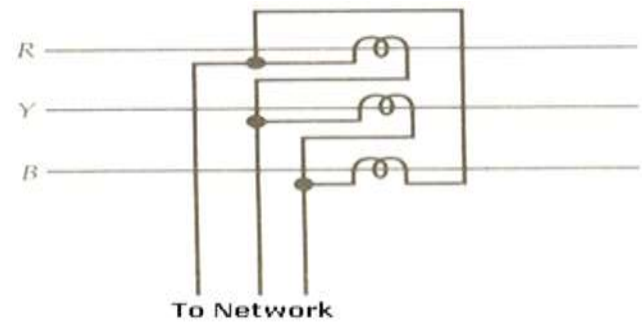
Let us now study the operation during the flow of +ve and –ve zero sequence currents.

Flow of +ve sequence currents.
Figshows –ve sequence current I_R,I_Y,I_B.since the current through the relay is$I_{z1}+I_{z4}+I_y=0$
$I_{z1}+I_{z4}=-I_y$
$\therefore$the relay remains inoperative.

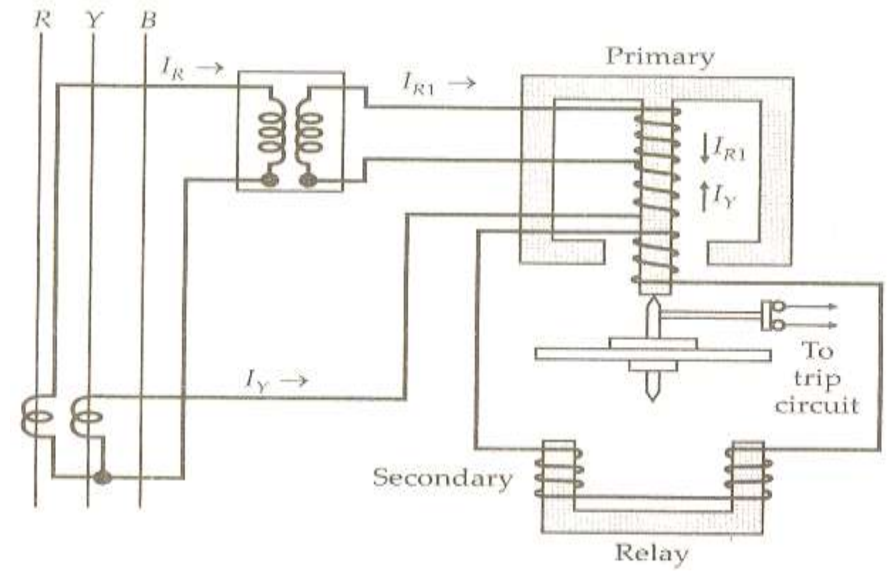
Flow of -ve sequence currents.
The –ve sequence currents in the 3 phases. resolving I_R and I_B in to their components I_{z1},I_{z3} and I_{z2},I_{z4},we find that the act current flowing in the relay=I_y since I_{z4} cancels out I_{z4}.the relay is operate under the influence of I_y. A low setting value well below the normal full-load rating of the machine is provided since comparatively small values of unbalance current produce a great danger.

Flow of zero sequence currents.

It is observed that $I_{z1}+I_{z2}=I_y$, so that a total current of twice the zero sequence current would flow through the relay and would therefore cause its operation. To make the relay inoperative under the influence of zero sequence current can flow in the network circuit. The delta connection of CTs shown fig.

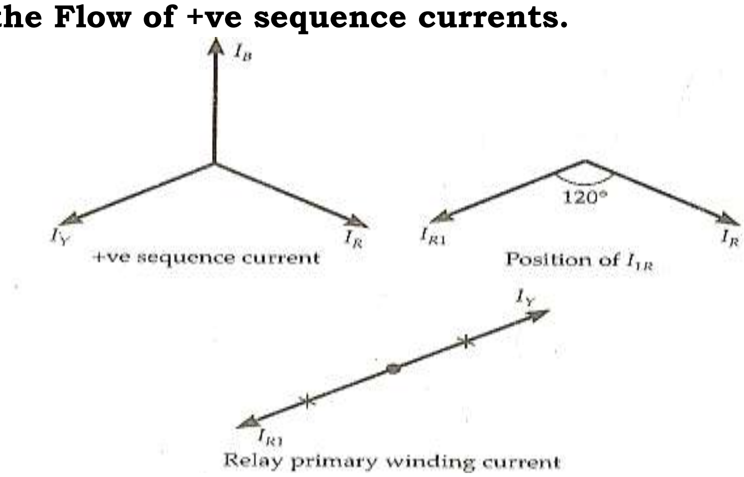


Another form of negative sequence relay associated with equipment by metropolitan Vickers fig



The primary winding is provided with a centre tap, one half of the winding is energized direct from the Y phase while the other half is energized from R phase through an auxiliary transformer. The auxiliary transformer is provided with an air gap in its magnetic circuits and its possible to adjust the phase displacement between $I_R$and I_{R1} to any angle (phase shift of 180°) the adjustment is made that I_{R1} lag behind I_R by 120° the relay primary current is, the phaser difference to $I_{R1}$and I_Y

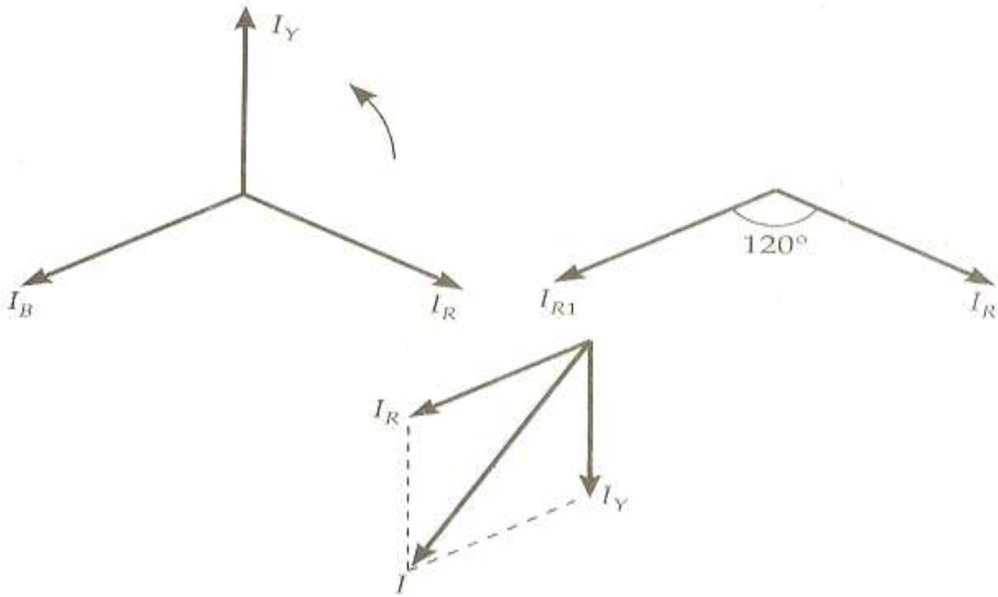
Operation under the Flow of +ve sequence currents.



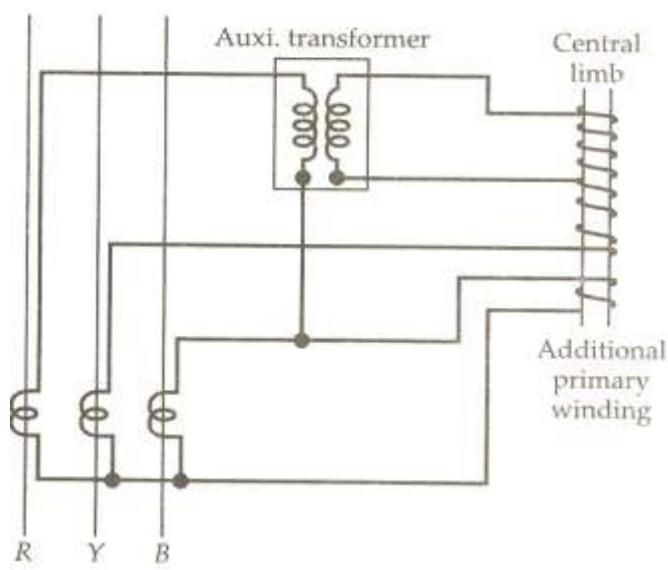
Itis clear from the vector diagram, the relay primary winding current is zero. thus the relay does not respond to the flow of +ve sequence current.

Operation under the Flow of -ve sequence currents.

Thevector diagram theflow of current Iin the primary winding and thus the relay will operate.



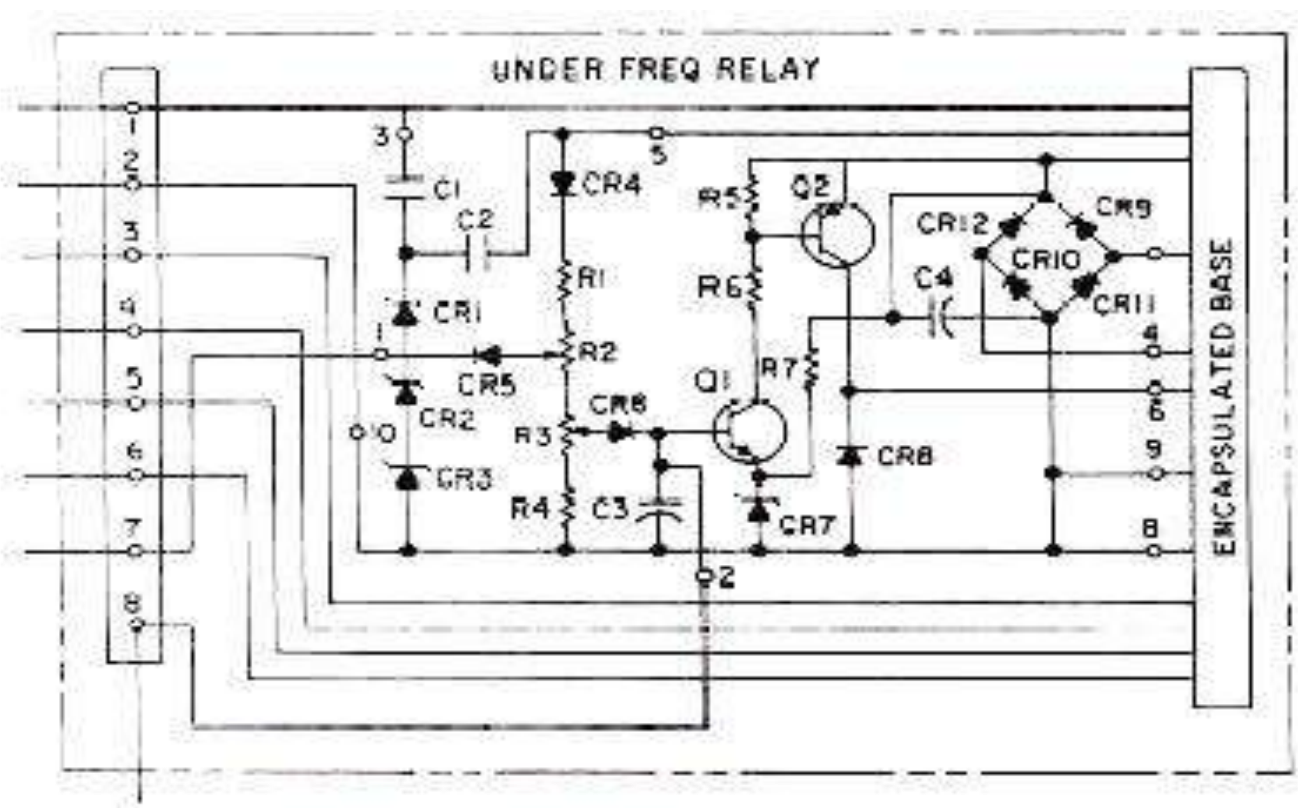
This relay can made response to the flow of zero sequence currents as well by providing another winding on the central limb of the upper electromagnet, connected in the residual circuit of three line CTs shown fig below**.**



17. Describe the Principle Of Under Frequency Relay (May-2014,Nov-14)

The under frequency relay below is a solidstate device that functions to protect the load in the event generator frequency decreases below preset limits. It actuates when the frequency decreases to 55 hertz for 60-hertz operation and 46 hertz for 50-hertz operation. Upon actuation, contacts within the relay close to signal the annunciator and open to de-energize the generator breaker (contactor), resulting in a display of the fault condition and removal of the load from the generator.

Frequency sensing is accomplished by a tuned circuit consisting of capacitors C1 and C2 and components in the encapsulated base. Zener diodes CR1, CR2, and CR3 limit the peak voltage to the tuned circuit. The ac output of the tuned circuit is rectified by diode CR4 and applied to a voltage divider consisting of resistors R1, R2, R3, and R4. Transistor Q1 compares the voltage at the wiper of potentiometer R3 with the reference voltage established by zener diode CR7. When transistor Q1 conducts, transistor 42 operates as a switch to control the coil voltage on a relay contained in the encapsulated base. Both transistors Q1 and Q2 and the relay in the encapsulated base are energized when the frequency of the input voltage to terminals 1 and 2 is normal frequency (50 to 60 hertz). When an underfrequency condition occurs, the voltage at the base of transistor Q1 is not sufficient for conduction. This causes the relay to be de-energized and its contacts to switch. The underfrequency trip point is adjusted by potentiometer R3.



18. From the universal torque equation determine the condition of operation for impeadance relay, reactance relay and admittance relay. (Dec-2016)

impeadancerelayTorque Equations:

The torque element produced by current element is $\propto$ to I^2 and –ve torque produced by voltage element is $\propto$ to V^2

Let control spring effect produces a constant torque of $-K_3$

Hence the torque equation becomes,

$T=K_1I^2-K_2V^2-K_3$

Where K_1,K_2 are the constants, while V and I are r.m.s. values.

At the balance point, when the relay is on the verge of operating the net torque is zero hence we can write,

$$0 = K_1I^2 - K_2V^2 - K_3$$

$$K_2V^2 = K_1I^2 - K_3$$

Dividing both sides by K_2I^2

$$\frac{V^2}{I^2} = \frac{K_1}{K_2} - \frac{K_3}{K_2I^2}$$

$$Z = \sqrt{\frac{K_1}{K_2} - \frac{K_3}{K_2I^2}}$$

With negligible spring effects, (K_3=0)

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

$$\frac{\mathbf{V}}{\mathbf{I}} = \boldsymbol{Z = constant}$$

reactance relay Torque Equation:

The driving torque is proportional to the square of the current while the restraining torque is proportional to the product of V and I.

Hence the net torque neglecting the effect of spring is given by,

$$\boldsymbol{T = K_1I^2 - K_2VI\,cos(\theta - \tau)}$$

At the balance point net torque is zero,

$$\therefore \boldsymbol{0 = K_1I^2 - K_2VI\,cos(\theta - \tau)}$$

$$\therefore \boldsymbol{K_1 I^2 = K_2 VI\, cos(\theta - \tau)}$$

$$\therefore \boldsymbol{K_1 = K_2 \frac{VI}{I^2}\, cos(\theta - \tau)}$$

$$\therefore \boldsymbol{K_1 = K_2 Z\, cos(\theta - \tau)}$$

Adding capacitor, the torque angle is adjusted as 90°,

$$\therefore \boldsymbol{K_1 = K_2 Z\, cos(\theta - 90°)}$$

$$\therefore \boldsymbol{K_1 = K_2 Z\, sin\, \theta}$$

$$\therefore \boldsymbol{Z\, sin\, \theta = \frac{K_1}{K_2}}$$

admittance relay Torque Equation:

The operating torque is proportional to VI while restraining torque is proportional to V^2. Hence net torque is given by,

$$T = K_1\, V\, I \cos(\theta - \tau) - K_2 V^2 - K_3$$

Where K_3 = control spring effect

Generally control spring effect is neglected ($K_3 = 0$).

And at balance net torque is also zero.

$$0 = K_1\, V\, I \cos(\theta - \tau) - K_2 V^2 - 0$$

$$K_1\, V\, I \cos(\theta - \tau) = K_2 V^2$$

$$K_1 \cos(\theta - \tau) = \frac{K_2 V^2}{V\, I}$$

$$K_1 \cos(\theta - \tau) = \frac{K_2 V}{I}$$

$$Z = \frac{K_1}{K_2} \cos(\theta - \tau)$$

This is the equation of a circle having diameter $\frac{K_1}{K_2}$ passing through origin. And this constant $\frac{K_1}{K_2}$ is the ohmic setting of this relay.

UNIT III
APPARATUS PROTECTION

Current transformers and Potential transformers and their applications in protection schemes - Protection of transformer, generator, motor, busbars and transmission line.

PART A

1. **What is the meaning of burden on C.T.? (N/D-2006)**
   It is defined as the load connected across its secondary.The unit of burden is expressed as (VA).

2. **What is the importance of bus bar protection? (M/J-2007)**
   1. Fault level at bus bar is high.
   2. The stability of the system is affected by the faults in the bus zone.
   3. A fault in the bus bar causes interruption of supply to a large portion of the system network.

3. **What are the application of CTs and PTs in power system? (N/D-2007,May-14)**
   What is the need for instrument transformer? (May-2017)
   Current transformer is used for measuring high level current and for protection. It steps down the current
   Potential transformer is used for measuring high level voltage. It steps down the voltage

4. **Give the limitations of Merz protection? (Dec-12)**
   If an earth-fault occurs near the neutral point, the voltage may be insufficient to operate the relay.
   In this method there is an inherent phase difference between the primary and the secondary quantities and possibility of current through the relay even when there is no fault.
   It is extremely difficult to find two identical CT's

5. **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. 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.

6. **What are the short comings of differential protection scheme are as applied to power transformer? (Dec 2015)**

   - Difference in CT ratio error
   - Difference in lengths of pilot wires
   - Tap changing alters the ratio of voltage and currents between HV and LV sides

7. Can current transformer secondary winding be open circuited? Justify the answer? (Dec-14,May-15,16)(Nov/ Dec 2017)

If secondary are open-circuited two things will happen

(i) Due to absence of secondary current flux in core of CT rises to saturation level which can damage it permanently.

(ii) Since number of turns in secondary is very high (1: 1000) for, a very high voltage may be induced in secondary that can harm the persons working on the instruments panel.

8. 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 added between them

9. What is field suppression in alternator?

It is a method of discharging stored energy in the field winding through a resistor

10. What is the general connection rule for CT in differential protection?

If the winding of the power transformer are delta connected then the current transformer are star connected and vice versa

11. Explain the basic difference between the measurement and protection CT's?

CT used in measurement	**CT used in protection**
used in conjunction with ammeter, Wattmeter etc	Used in association with relays, trip coils, pilot wires etc.

12. What are the two types of protection given for bus-bars? (N/D-06,Nov/Dec 2017)

Two types of protection given for bus-bars

i) Differential protection

ii) Fault bus protection.

13. What are the common methods used for line protection?(M/J-2007)(Apr/May 2018)

The common methods of line protection are,

- Time graded over current protection
- Differential protection
- Distance protection

14. What are the different protection schemes used in bus-bars?(N/D-2007)(Dec-2016)

1. Differential scheme of protection.
2. Frame leakage protection.

15. Why current transformers are required in protection schemes?(A/M-2008)

- It is measured very high current using standard 5A.
- Current transformer used for protection is used in conjunction with measuring instruments, protective relays and control circuits.
- In conjunction with ammeters, over current relay
- The current ratio is substantially constant for a given range of primary current and phase angle error is within prescribed limits.

16. Bus bar protection needs special attention why?(A/M-2008)

- The main drawback is there may be false operation in the case of external fault.
- This is due to the saturation of one of the C.T of the faulted feeder. When the C.T saturates, the output is reduced and sum of all the C.T secondary currents will not be zero. So bus bar protection needs special attention.

17. Why bus bar protection is needed?(Dec-12) (May-13)

1. Fault level at busbar is high.
2. The stability of the system is affected by the faults in the bus zone.
3. A fault in the busbar causes interruption of supply to a large portion of the system network.

18. What are the various possible transformer faults? (A/M-2008)

- Insulation failure
- thermal ride breakdown the insulation
- spark to lead the damage the winding
- short circuit current

19. Why the protection of generators is complex? (A/M-2008)

- **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. The above fault occurs in the generator so the protection is complex.

20. What is the requirement of protection of lines? (M/J-2009)

Direct lightning strokes on transmission lines.

21. What is Buchholz relay? Why it is used?(M/J-2009)

Buchholz relay is a gas actuated relay installed in oil immersed transformer for protections to against all kind of faults to supplement biased differential protection of the power transformer.

Bucholz relay is used to give an alarm in case of incipient(slow-developing)faults in the transformer and to dis 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.

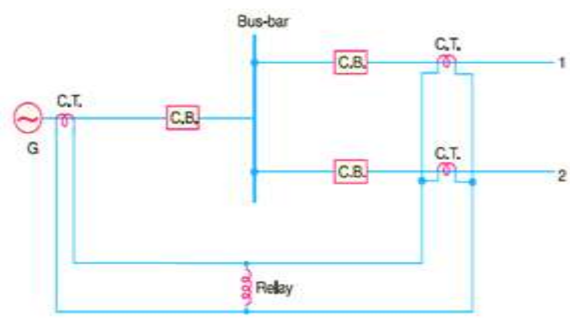
22. Whatare the limitations of buchholz relay?(MAY-2017)

(i) It can only be used with oil immersed transformers with conservator tanks.
(ii) The device can detect only faults below oil level in the transformer.

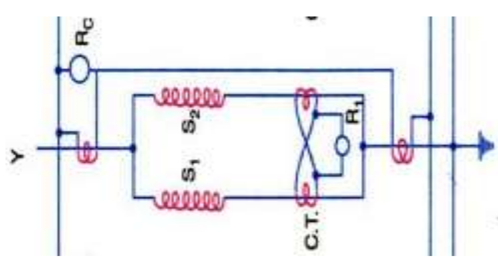
23. Explain the basic difference between the measurement and protection CT's?(A/M-2010)

1. Measuring current transformer-used in conjunction with ammeter,Wattmeter etc.
2. Protection current transformers-used in association with relays, trip coils, pilot wires etc.

24. Draw the protection scheme for bus bar protection?(A/M-2010)



25. Draw a protection scheme to detect a turn –turn fault in winding of an alternator?(N/D-2010)



26. Why are current transformersrequired in protection schemes? (N/D-2010)

- Current transformers are used to reduce the heavy current flowinginanelement of a power system to low values.
- Besides reducing the current level, the C.T. also isolates the relay circuit from the primary circuit which is a high voltage power circuit and allows the use of standardized current rating for relays.

27. What are the various faults that would affect an alternator?(M-13,M-15)

A. stator faults

- Insulation failure of stator winding, either between phase to phase or Phase to earth fault.
- Unbalance loading and subsequent heating of alternator.
- Stator inter turn fault in any of turns.
- Over loading.
- Over voltage at the terminal of alternator.
- Bearing oil failure and Ventilation failure
- Current leakage in body of alternator.

B. Rotor fault

- Field over loading and excitation failure.
- Field winding grounding
- Heating of rotor
- Rotor earth fault.

C. Abnormal running condition

- over loading
- over speeding
- Unbalanced loading
- Failure of prime mover
- Loss of excitation (or)Field failure
- Cooling system failure

28. What are the causes of over speed and how alternators are protected from it? (Apr/May 2018)

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.

29. What are the different types of protection schemes for transmission lines?

The common methods of line protection are :

1. **Time-graded overcurrent protection**
2. **Differential protection**
3. **Distance protection**

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

- Definite time relay
- Inverse-definite time relay.

31. What are the main safety devices available with transformer?

- Oil level guage,
- sudden pressure delay,
- oil temperature indicator,
- Winding Temperature indicator.

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

1. Difference in lengths of pilot wires on either sides of the relay.
   - This isovercome by connecting adjustable resistors to pilot wires to get equipotentialpoints on the pilot wires.
2. Difference in CT ratio error difference at high values of short circuit currentsthat makes the relay to operate even for external or through faults.
   - This is overcome by introducing bias coil.
3. 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.

33. What is REF relay?

It is restricted earth fault relay. When the fault occurs very near to the neutralpoint 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.

34. What is over fluxing. How it affects transformer? (Dec-2016)

If the turns ratio of the transformer is more than 1:1, there will be higher core loss. This phenomenon is called over fluxing.

35. What are the merits of carrier current protection?

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

36. What are the different types of zones of protection (Dec-2013)

1. Generator protection,
2.Bus-bar protection,
3.Transmission line protection,
4. Transformer protection

37. Enumerate the concept of ring feeder. (May -14)

The ring main feeder which covers the whole area of supply finally returning to generating station.
Feeder is closed on it self. Advantage of this greater reliability of supply.in the event of fault on any section of the feeder, supply to all consumer to be available by isolating the faulty section.

38. Give the examples for unit and non-unit systems of protection. (Dec 2015) & (May 2016)

Unit systems of protection protect a specific area of the system, i.e., a transformer, transmission line, generator or bus bar.

Non-Unit systems of protection are intended to protect specific areas which have no fixed boundaries.

- Time graded over current protection
- Current graded over current protection
- Distance or Impedance Protection

PART B

Protection of generator

1. Explain in detail the classification of fault in the generator or alternator? (NOV-06,Dec-12)
Explain the circulating current protection on alternator?
Explain Merz price circulation current protection in alternator
Explain the differential protection of alternator?
Explain with neat diagram generator protection from stator fault?
Briefly explain types of stator fault protection of Alternators.(May-14,May-15)

Various faults which can occur associated with a generator can be classified as,

A. stator faults

- Insulation failure of stator winding, either between phase to phase or Phase to earth fault.
- Unbalance loading and subsequent heating of alternator.
- Stator inter turn fault in any of turns.
- Over loading.
- Over voltage at the terminal of alternator.
- Bearing oil failure and Ventilation failure
- Current leakage in body of alternator.

B. Rotor fault

- Field over loading and excitation failure.
- Field winding grounding
- Heating of rotor
- Rotor earth fault.

C. Abnormal running condition

- over loading
- over speeding

- Unbalanced loading
- Failure of prime mover
- Loss of excitation (or)Field failure
- Cooling system failure

A. Stator fault(Phase to phase or Phase to ground)

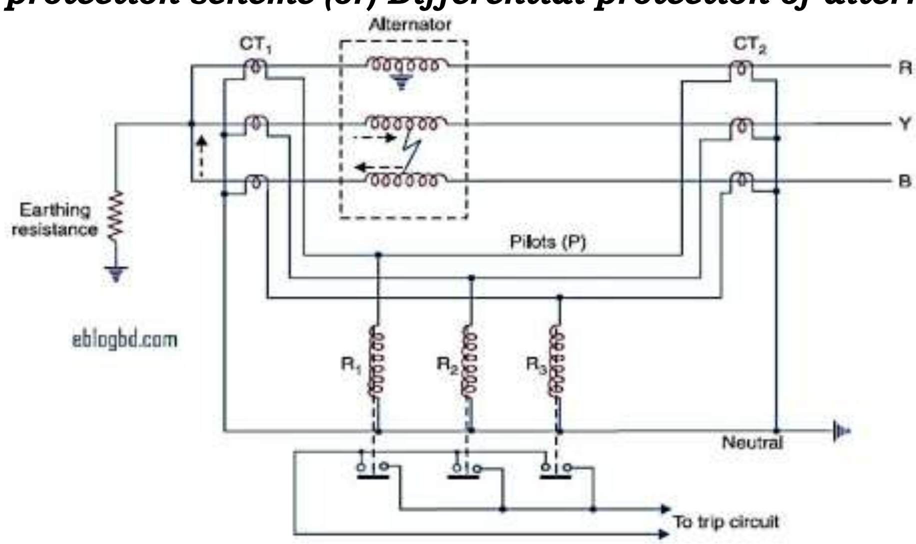
The stator faults means faults associated with the three phase armature windings of the generator. These faults are mainly due to the insulation failure of the armature windings.

The main types of stator faults are,

- ♦ Phase to earth faults
- ♦ Phase to phase faults
- ♦ Inter-turn faults involving turns of same phase winding.

The most important and common fault is phase to earth fault. The other two are not very common while inter-turn fault is very difficult to detect.

Circulating Current Protection in alternator (or) Merz price circulating current protection scheme (or) Differential protection of alternator (Nov/Dec 2017)



Differential protection

- ✓ The above scheme is differential protection scheme for 3 phase alternator. CT1 are mounted in the neutral connection. CT2 are connected in the switchgear equipment.
- ✓ Consider an earth fault in phase R,
- ✓ The current in CT1 will increase and the fault current in secondary of CT1 will spill through the Corresponding relay coil returning via neutral pilot. This results in operating of tripping circuit.

- ✓ If a short circuit occurs between Y phase and B phase , the short circuit current will be reflected in the both the secondary winding of CT1. This results in operating of tripping circuit
- ✓ If an earth fault occurs near the Neutral end of the winding, only a small fault current will flow and thus not operating the relay to trip the circuit. Thus the above protection scheme protects only 85%. The remaining 15 % is unprotected.

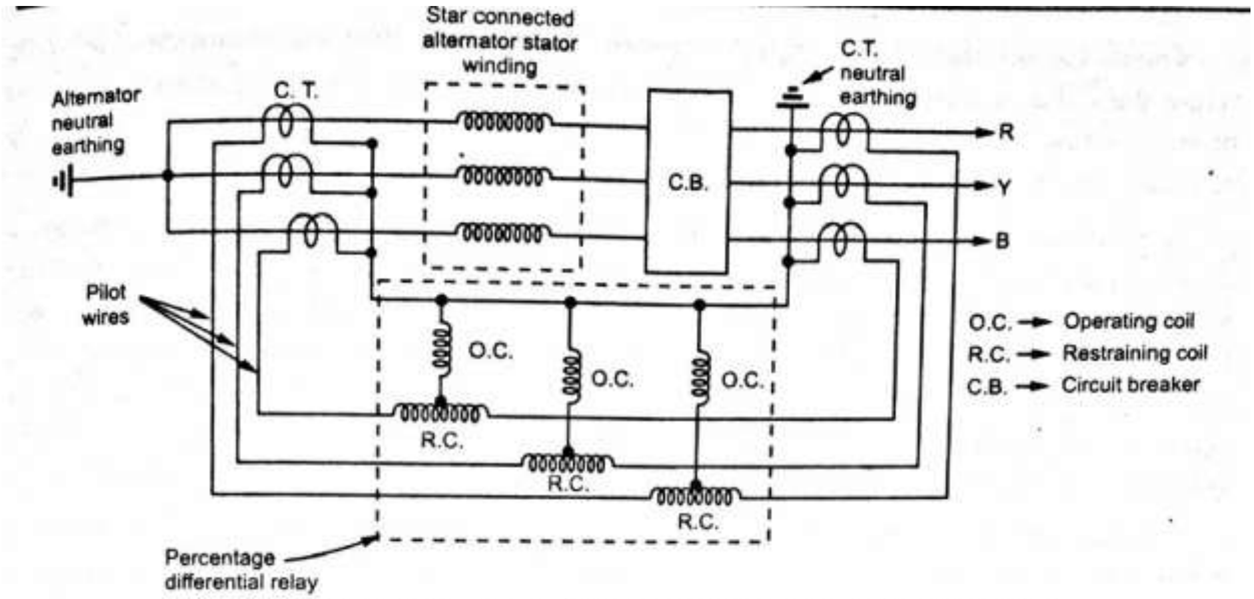


Fig. 5.5 Merz-Price protection for star connected alternator

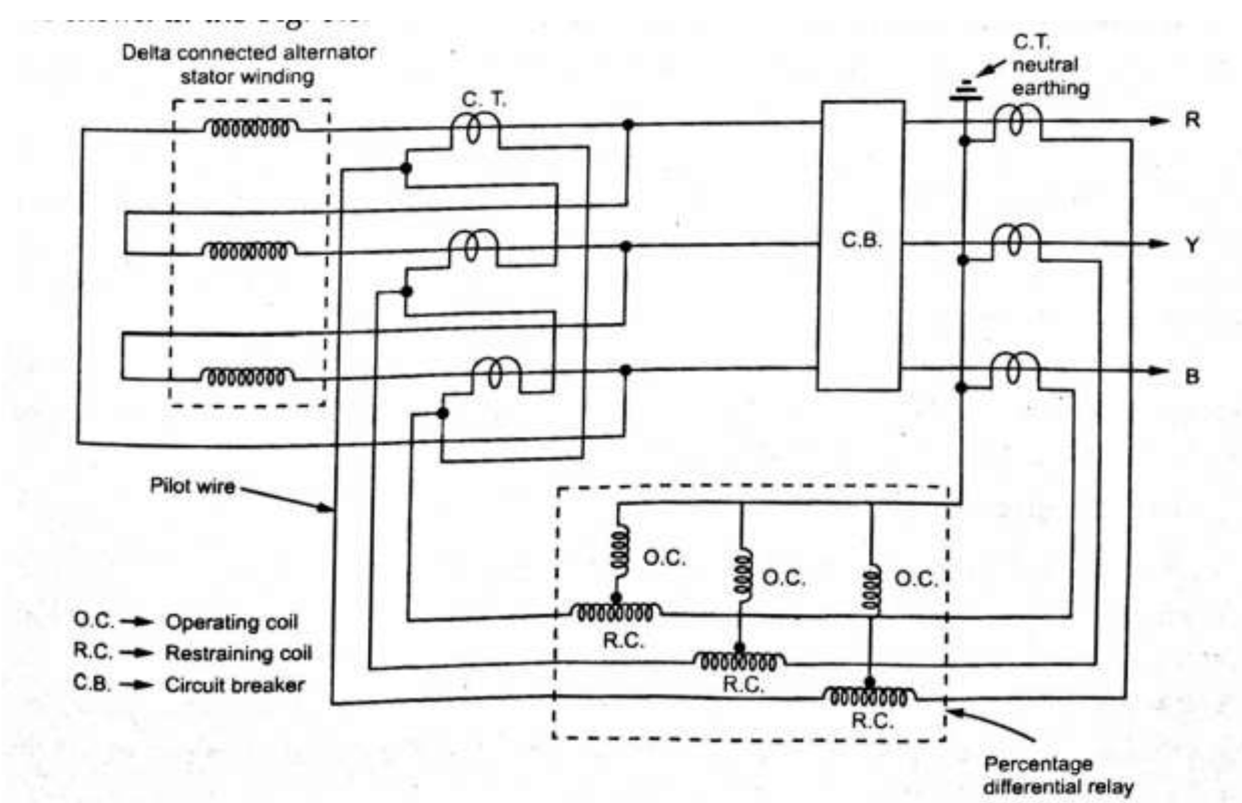
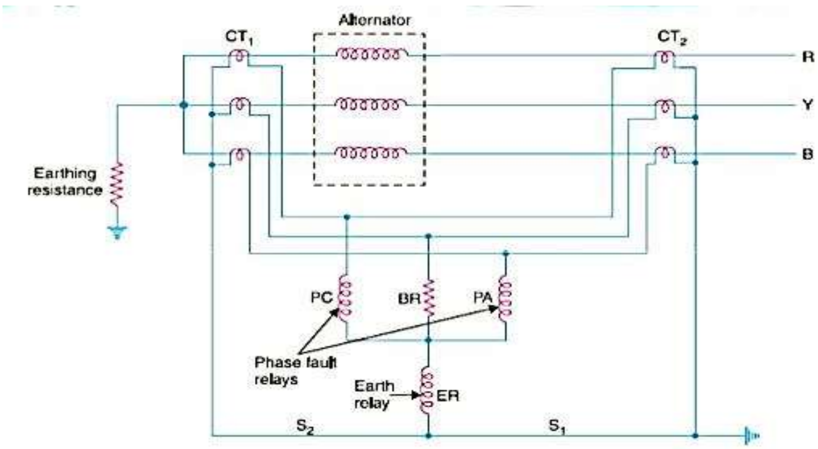


Fig. 5.6 Merz-Price protection for delta connected alternator

- ✓ To overcome this 15% un-protection, a modified scheme is shown below.

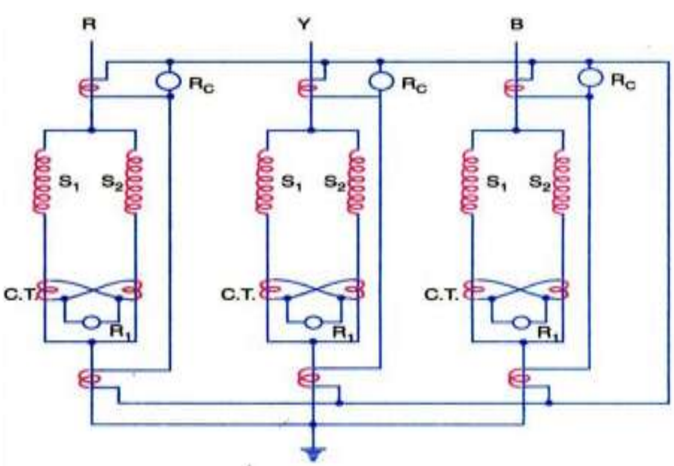


Modified differential protection

- ✓ There are 2 elements for phase fault detection(PC and PA) these elements are connected in star along with balancing resistor BR.
- ✓ A high sensitive earth fault relay ER is used to detect the small fault current occurred near the neutral end. This enables low setting for the elements which provides protection to a great percentage of winding.

Stator Inter-turn fault protection

- Merz-price circulating-current system protects against phase-to-ground and phase-to-phase faults.
- It does not protect against turn-to-turn fault on the same phase winding of the stator.
- In single turn generator (e.g. large steam-turbine generators), there is no necessity of protection against inter-turn faults.
- However, inter-turn protection is provided for multi-turn generators such as hydro-electric generators. These generators have double-winding armatures (i.n. each phase winding is divided into two halves).

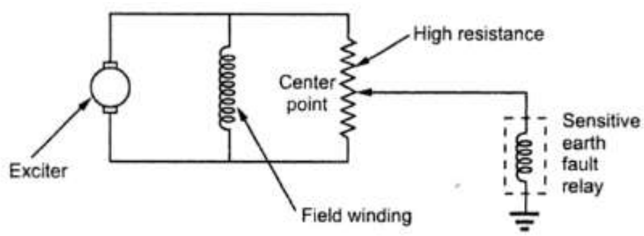


- The relays RC provide protec tion against phase-to-ground and phase-to-phase faults whereas relays Rl pro vide protection against inter-tum faults.

2. Explain with neat diagram generator protection from rotor fault fault and loss of excitation?

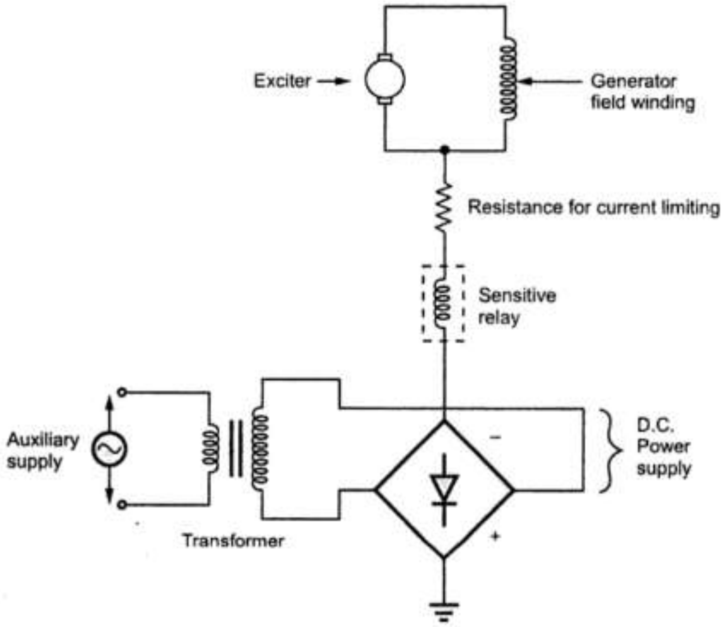
Rotor earth fault Protection

- ✓ The rotor circuit of the alternator is not earthed and DC voltage is fed to it for excitation purpose.
- ✓ Single ground fault in rotor does not cause any circulating current and hence no damage done.
- ✓ But the single ground over time causes another second ground fault and may continue, This causes unbalance in the rotor crcuit and hence mechanical and thermal stress occur on the rotor and gets damaged.
- ✓ To protect rotor against these ground or earth faults the following method is used



Rotor earth fault protection

- ✓ In this method a high resistance is connected across the rotor circuit. It is provided with centre tap and the centre tap is connected to the ground through a senitive earth fault relay
- ✓ The modern method of providing earth fault protection includes d.c injection or a.c injection

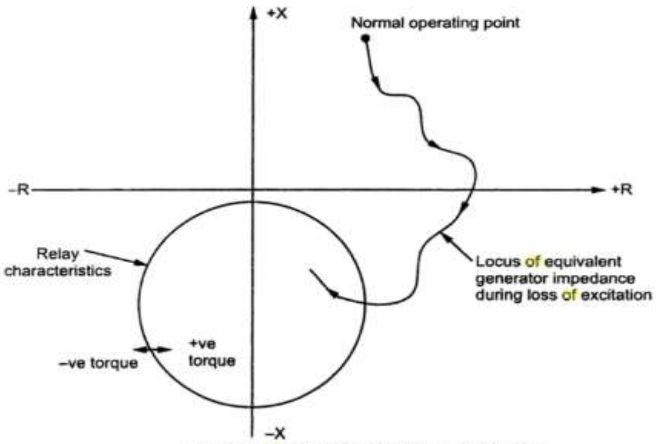


Rotor earth fault protection

- ✓ In this method small dc power supply is connected to the field current. The high resistance limits the current through the circuit
- ✓ A fault at any point of the field circuit will operate the sensitive relay.
- ✓ In case of a.c injection the high resistance is replaced by a capacitor.
- ✓ The earth fault relay are instantaneous in operation and are connected to alarm circuit and does not shut down the generator

Protection against loss of excitation

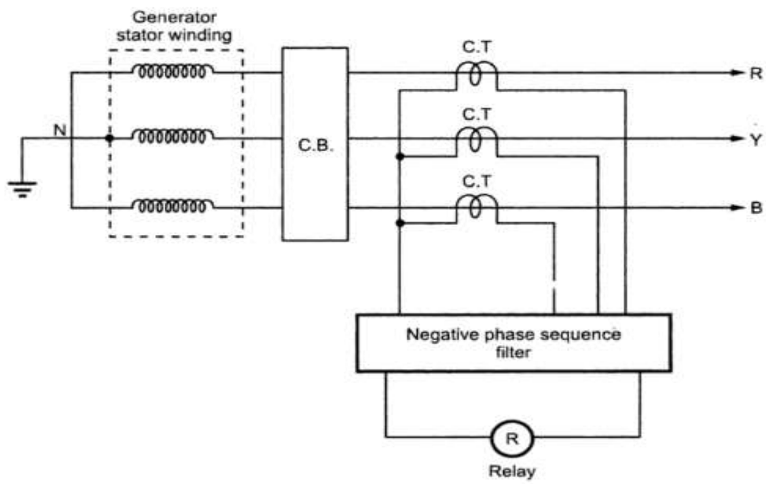
- ✓ The loss of excitation of generator may result in loss of synchronism and slightly increases the generator speed as a result it draws reactive power from the system instead of generating, which is not desiarable.
- ✓ The loss of excitation may lead to pole slipping condition
- ✓ To protect against loss of excitation directional distance type impeadance relay is used



Loss of excitation characteristics

- ✓ The relay operates when the impeadance takes value in the region covered by the relay characteresitcs.

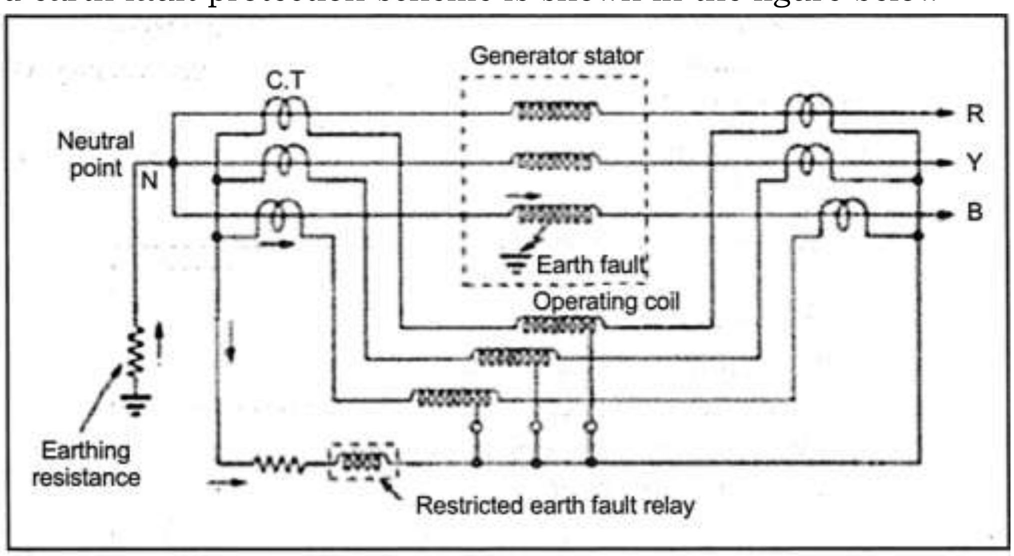
Protection against unbalanced Loading



- ✓ When the load in the generator becomes unbalanced , negative phase sequence current flows.
- ✓ The negative sequence component produces rotating magnetic field opposing the direction of rotor field and hence creating a opposite current in the rotor.
- ✓ There fore the rotor is carried with heavy current and gets over heated causing the damage of rotor.
- ✓ Hence a negative sequence current protection is employed as shown in the figure

3. Explain in detail about Restricted Earth Fault Protection of Generator?

- Generally Merz-Price protection based on circulating current principle provides the protection against internal earth faults. But for large generators, as there are costly, an additional protection scheme called restricted earth fault protection is provided.
- When the neutral is solidly grounded then the generator gets completely protected against earth faults. But when neutral is grounded through earth resistance, then the stator windings gets partly protected against earth faults. The percentage of windings protected depends on the value of earthing resistance and the relay setting.
- In this scheme, the value of earth resistance, relay setting, current rating of earth resistance must be carefully selected. The earth faults are rare near the neutral point as the voltage of neutral point with respect to earth is very less. But when earth fault occurs near the neutral point then the insufficient voltage across the fault drivers very low fault current than the pickup current of relay coil.
- Hence the relay coil remains unprotected in this scheme. Hence it is called restricted earth fault protection. It is usual practice to protect 85% of the winding.
- The restricted earth fault protection scheme is shown in the figure below



- Consider that earth fault occurs on phase B due to breakdown of its insulation to earth, as shown in the figure 3.6. The fault current if will flow through the core, frame of machine to earth and complete the path through the earthing resistance.
- The C.T. secondary current Is flows through the operating coil and the restricted earth fault relay coil of the differential protection, the setting of restricted earth fault relay and setting of over current relay are independent of each other.

- Under this secondary current Is, the relay operates to trip the circuit breaker. The voltage Vbx is sufficient to drive the enough faults current If when the fault point x is away from the neutral point.
- If the fault point x is nearer to the neutral point then the voltage Vbx is small and not sufficient to drive enough fault current If And for this If, relay cannot operate.
- Thus part of the winding from the neutral point remains unprotected. To overcome this, if relay setting is chosen very low to make it sensitive to low fault currents, then wrong operation of relay may result.
- The relay can operate under the conditions of heavy through faults, inaccurate C.T.s, saturation of C.T.s etc. Hence practically 15% of winding from the neutral point is kept unprotected, protecting the remaining 85% of the winding against phase to earth faults.

Transformer Protection

4. Explain the Protection scheme for large transformer & explain Bucholz relay? (June-13, Dec-14)

Explain a protection scheme for protection of transformer against incipient fault? (Dec-2016) (Apr/May 2018)

Why is the harmonic restrained differential relay required to be used for protecting a large size transformer? Describe the construction and working of such a relay. (Dec 2015)

Explain briefly Merz- price protection for star-star power transformer. (Dec-2013, May-14)

Describe the differential protective scheme of transformer. (May 2016)

Give a detailed explanation for protection of transformer using differential protection which includes associated faults? (MAY-2017) (Nov/Dec 2017)

The principal relays and systems used for transformer protection are :

- **Buchholz devices** providing protection against all kinds of faults i.e. slow-developing faults such as insulation failure of windings, core heating, fall of oil level due to leaky joints etc.
- **Earth-fault relays** providing protection against earth-faults only.
- **Overcurrent relays** providing protection mainly against phase-to-phase faults and overloading.
- **Differential system** (or circulating-current system) providing protection against both earth and phase faults.
- The complete protection of transformer usually requires the combination of these systems.

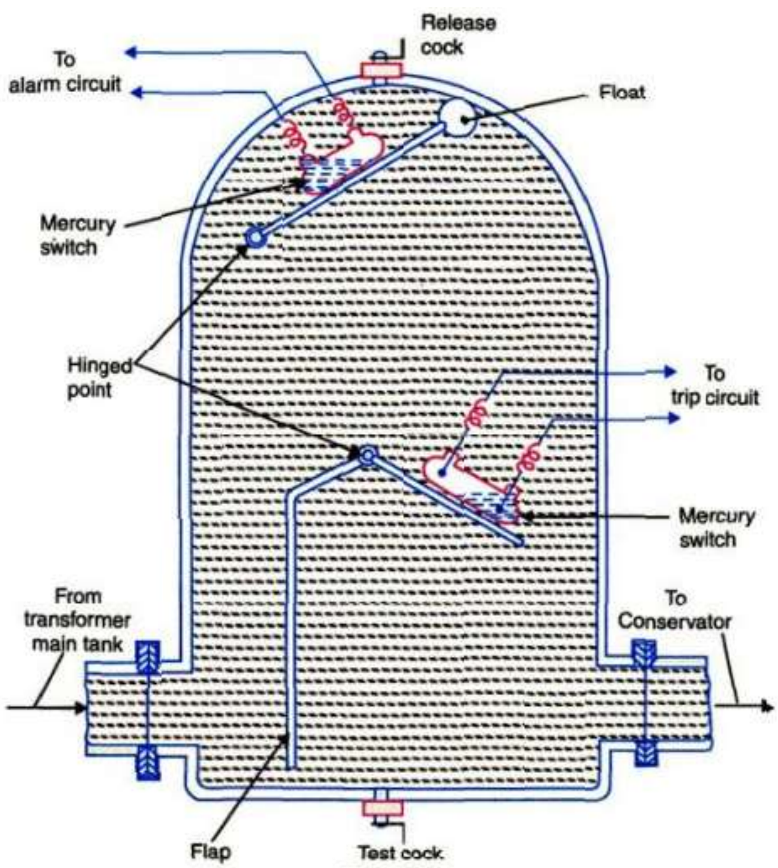
Buchholz Relay

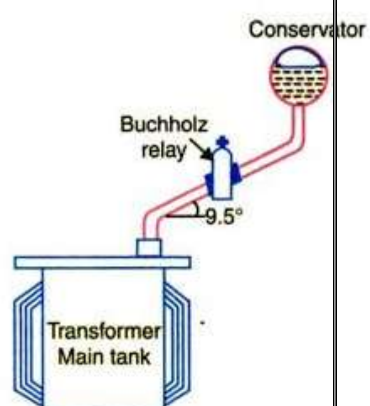
- ✓ Buchholz relay is a gas-actuated relay installed in oil immersed transformers for protection against all kinds of faults. Named after its inventor, Buchholz.
- ✓ It is used to give an alarm in case of incipient (i.e.slow-developing) faults in the transformer and to disconnect the transformer from the supply in the event of severe internal faults.
- ✓ It is usually installed in the pipe connecting the conservator to the main tank as shown in the belo figure. It is a universal practice to use Buchholz relays on all such oil immersed transformers having ratings in excess of 750KVA

Operation

The operation of Buchholz relay is as follows :

(i) In case of **incipient**(slow developing) faults within the transformer, the heat due to fault causes the decomposition of some transformer oil in the main tank. Which produces more than 70% of hydrogen gas. The hydrogen gas being light tries to go into the conservator and in the process gets entrapped in the upper part of relay chamber. When a pre determined amount of gas gets accumulated, it exerts sufficient pressure on the float to cause it to tilt and close the contacts of mercury switch attached to it. This completes the alarm circuit to sound an alarm.





(ii)If a serious fault occurs in the transformer, an enormous amount of gas is generated in the main tank. The oil in the main tank rushes towards the conservator via the Buchholz relay and in doing so tilts the flap to close the contacts of mercury switch. This completes the trip circuit to open the circuit breaker controlling the transformer.

Advantages

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

Disadvantages

(iii) It can only be used with oil immersed transformers with conservator tanks.
(iv) The device can detect only faults below oil level in the transformer.

Earth-Fault or Leakage Protection

- ✓ An earth-fault usually involves a partial breakdown of winding insulation to earth. The resulting leakage current is considerably less than the short-circuit current.
- ✓ The earth-fault may continue for a long time and cause considerable damage before it ultimately develops into a short-circuit and removed from the system
- ✓ Under these circumstances, it is profitable to employ earth-fault relays in order to ensure the disconnection of earth-fault or leak in the early stage.
- ✓ An ***earth-fault relay is essentially an overcurrent relay of low setting*** and operates as soon as an earth-fault or leak develops. One method of protection against earth-faults in a transformer is the core-balance leakage protection shown below

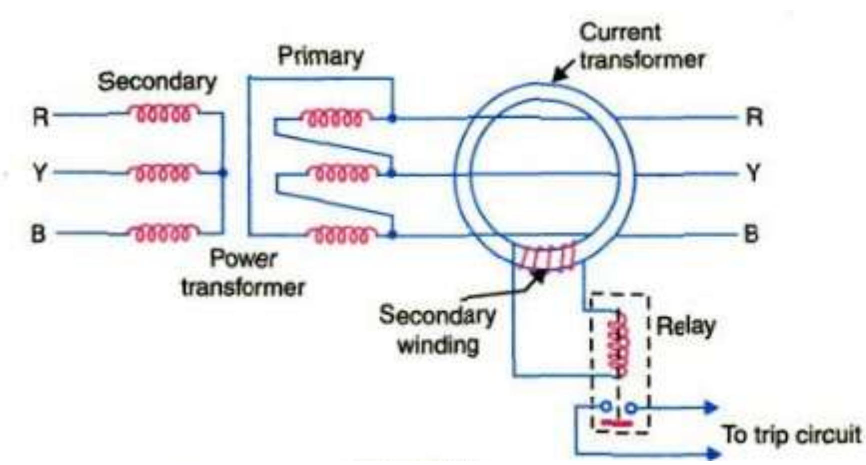
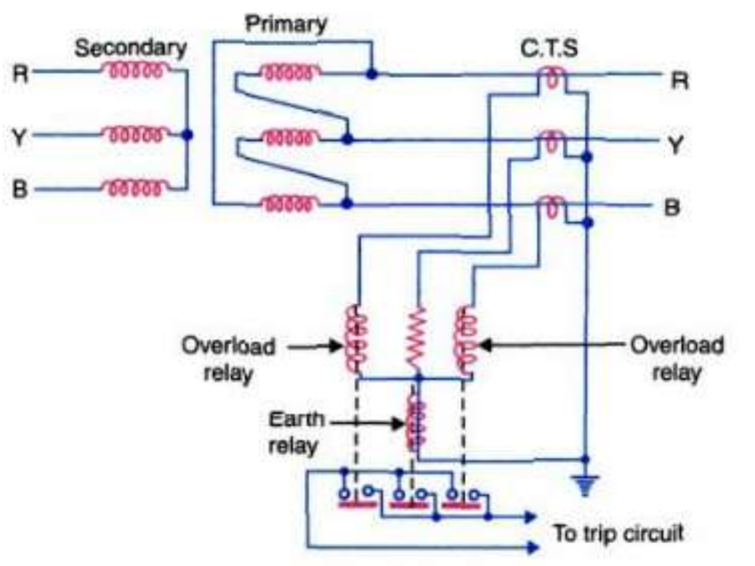


Fig:Core Balance Leakage Protection

Combined Leakage and Overload Protection

- ✓ The core-balance protection described above suffers from the drawback that it ***cannot provide protection against overloads***
- ✓ If a fault or leakage occurs between phases, the core-balance relay will not operate.
- ✓ It is a usual practice to provide combined leakage and overload protection for transformers.
- ✓ The earth relay has low current setting and operates under earth or leakage faults only“ The overload relays have high current setting and are arranged to operate against faults between the phases.
- ✓ The schematic arrangement of combined leakage and over load protectioin is shown.

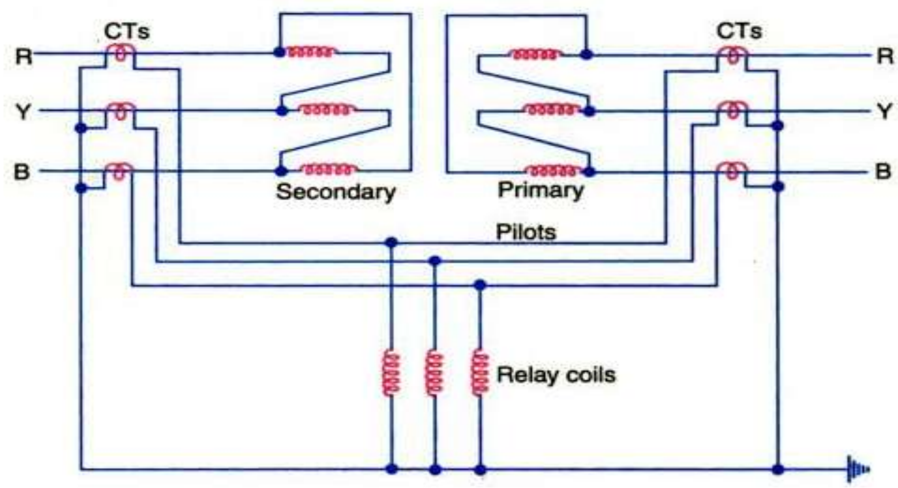


- ✓ In this system of protection, two overload relays and one leakage or earth relay are connected as shown.
- ✓ The two overload relays are sufficient to protect against phase-to-phase faults.
- ✓ The trip contacts of overload relays and earth fault relay are connected in parallel. Therefore, with the energising of either overload relay or earth relay, the circuit breaker will be tripped.

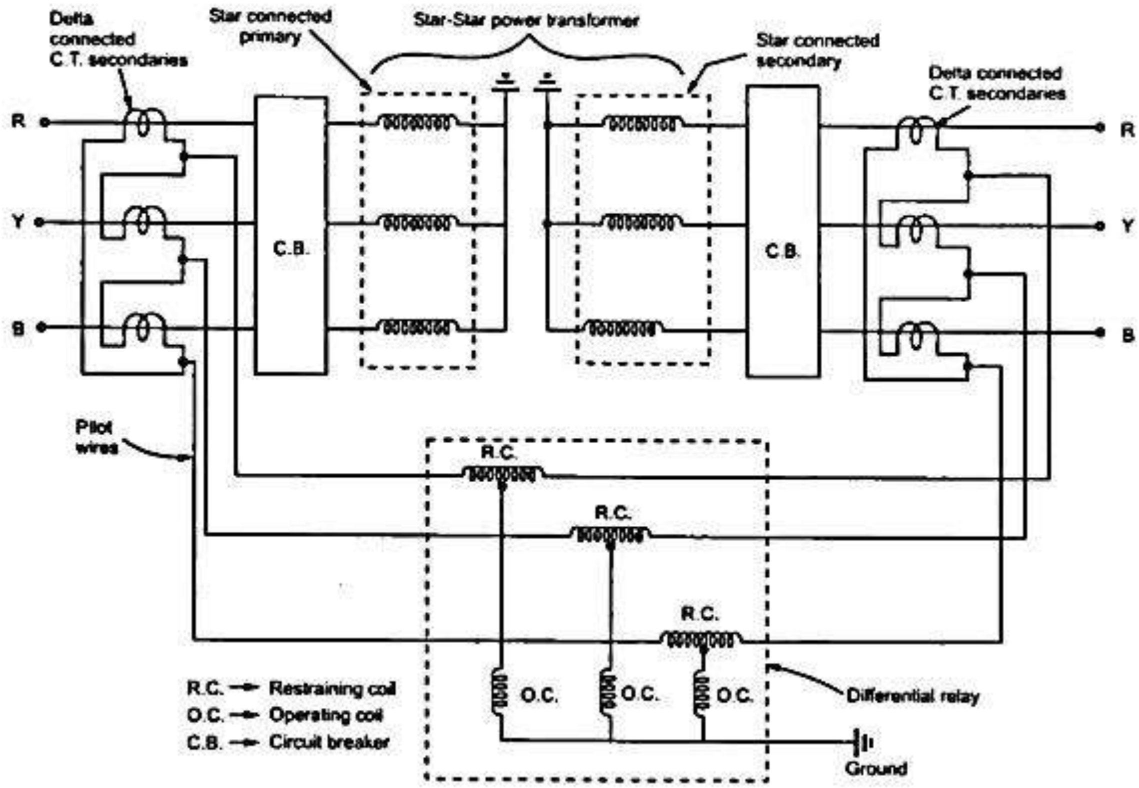
Describe the differential protective scheme of transformer. (May 2016)

Circulating-Current Scheme for Transformer Protection

The below figure shows Merz-Price circulating-current scheme for the protection of a 3- phase delta/delta power Y- transformer against phase-to- ground and phase-to-phase faults.



- ✓ Note that CTs on the two sides of the transformer are connected in star.
- ✓ The CTs on the two sides are connected by pilot wires and one relay is used for each pair of CTs.
- ✓ During normal operating conditions, the secondaries of CTs carry identical currents. Therefore, the currents entering and leaving the pilot wires at both ends are the same and no current flows through the relays.
- ✓ If a ground or phase-to-phase fault occurs, the currents in the secondaries of CTs will not be same and hence the there exist a differntial current operating the relay.
- ✓ The-protected zone is limited to the region between CTs on the high-voltage side and the CTs on the low-voltage side of the power transformer.
- ✓ It also provides protection for short-circuits between turns on the same phase winding. When a short-circuit occurs between the turns, the turn-ratio of the power transformer is altered and causes unbalance between current transformer pairs. If turn-ratio ofpower transformer is altered sufficiently, enough differential current may flow through the relay to cause its operation. However, such short-circuits are better taken care of by Buchholz relays.



The above figure shows the percentage differential protection for Stat-Star Transformer

BUS BAR PROTECTION

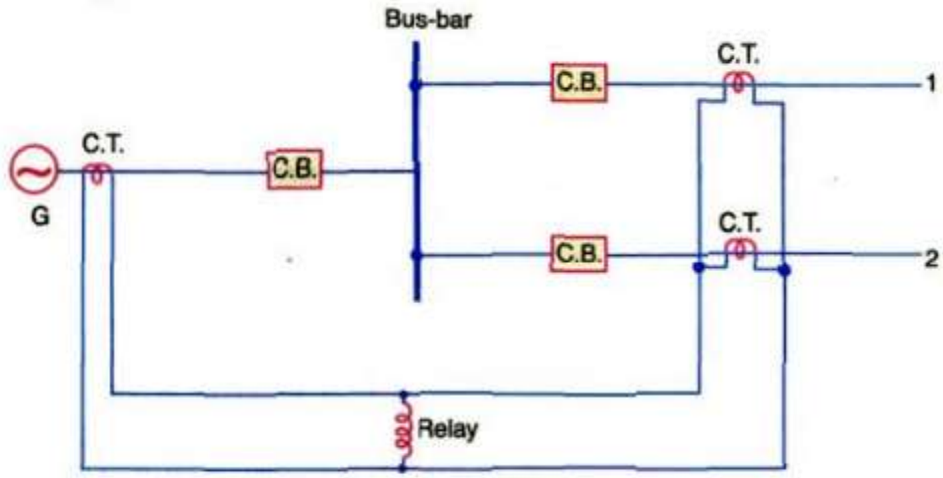
5. Enumerate the protective scheme employed for the bus bar. (May 2016) (Apr/May 2018)

The two most com monly used schemes for busbar protection are :

(i) Differential protection

(ii) Fault bus protection

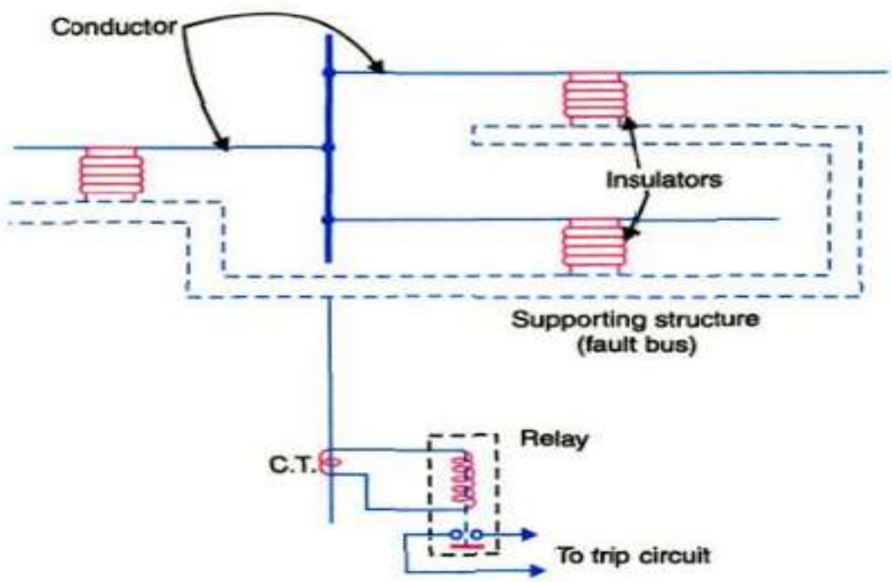
(i) Differential protection.



- ✓ The busbar is fed by a generator and supplies load to two lines.
- ✓ The secondaries of current transformers in the generator lead, in line 1 and in line 2 are all connected in parallel.
- ✓ The protective relay is connected across this parallel connection.
- ✓ All CTs must be of the same ratio.
- ✓ Under normal load conditions or external fault conditions, the sum of the currents entering the bus is equal to those leaving it and no current flows through the relay.
- ✓ If a fault occurs within the protected zone, the currents entering the bus will no longer be equal to those leaving it. The difference of these currents will flow through the relay and cause the opening of the generator, circuit breaker and each of the line circuit breakers.

(ii) Fault Bus protection or frame leakage Protection

- ✓ It is possible to design a station so that the faults that develop are mostly earth-faults.



- ✓ With this arrangement, 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.

- ✓ The metal supporting struc ture or fault bus is earthed through a current transformer.
- ✓ A relay is connected across the secondary of this CT.
- ✓ Under normal operating conditions, there is no current flow from fault bus to ground and the relay remains inoperative.
- ✓ A fault involving a connection between a conductor and earthed supporting structure will result in current flow to ground through the fault bus, causing the relay to operate. The operation of relay will trip all breakers connecting equipment to the bus.

<u>Protection of Lines</u>

6. Explain in detail the various Protection schemes for transmission lines?
With neat sketches, explain the different types of protective schemes for transmission lines. (May 2016)

The common methods of line protection are :

1. **Time-graded overcurrent protection**
2. **Differential protection**
3. **Distance protection**

shows the symbols indicating the various types of relays.

A. Time-Graded Overcurrent Protection

In this scheme of overcurrent protection, time discrimination is incorporated.

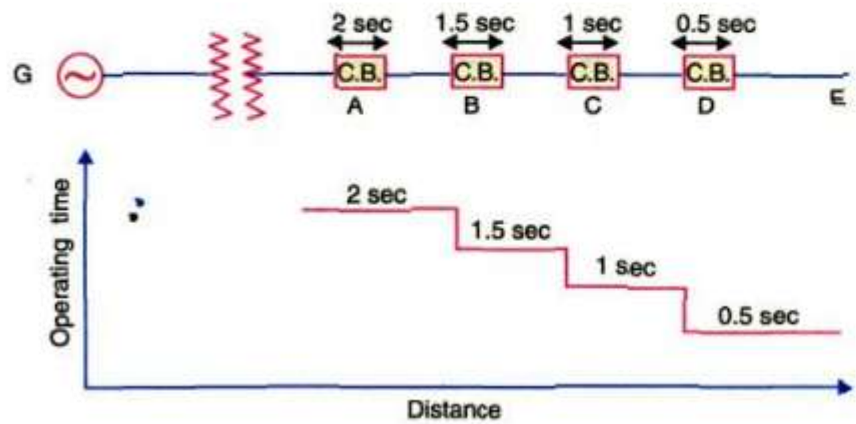
1 . Radial feeder.

The main characteristic of a radial system is that power can flow only in one direction, from generator or supply end to the load.

Time-graded protection of a radial feeder can be achieved by using

(i) definite time relays and
(ii) inverse time relays.

(i) Using definite time relays

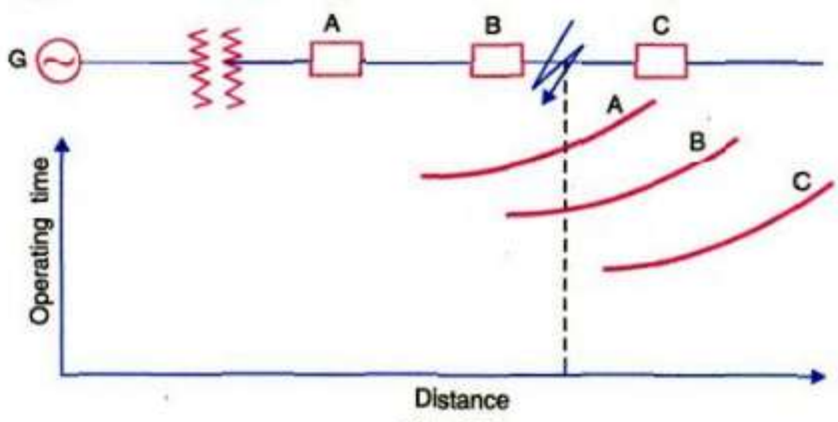


- ✓ The figure above shows the overcurrent protection of a radial feeder by definite time relays.
- ✓ The time of operation of each relay is fixed and is independent of the operating current.
- ✓ Thus relay D has an operating time of 0.5 second while for other relays, time delay is successively increased by 0.5 second.
- ✓ If a fault occurs in the section DE, it will be cleared in 0.5 second by the relay and circuit breaker at D because all other relays have higher operating time. In this way only section DE of the system will be isolated.
- ✓ If the relay at D fails to trip, the relay at C will operate after a time delay of 0.5 second i.e. after 1 second from the occurrence of fault.

- ✓ The disadvantage of this system is that if there are a number of feeders in series, the tripping time for faults near the supply end becomes high (2 seconds in this case).
- ✓ This disadvantage can be overcome to a reasonable extent by using inverse-time relays.

(ii) Using inverse time relays.

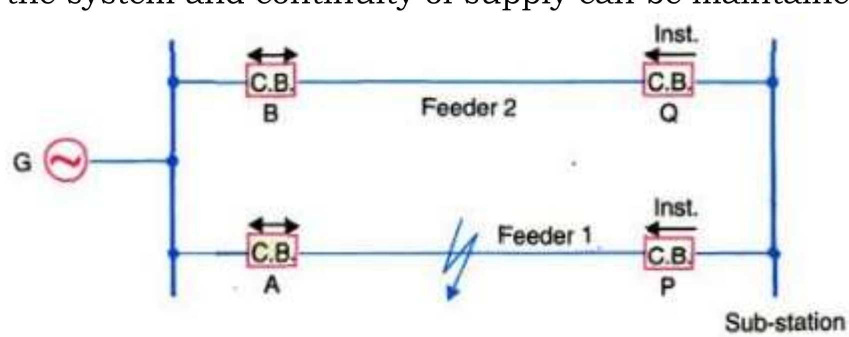
The below figure shows overcurrent protection of a radial feeder using inverse time relays in which operating time is inversely proportional to the operating current.



With this arrangement, the farther the circuit breaker from the generating station, the shorter is its relay operating time. The three relays at A, B and C are assumed to have inverse-time characteristics. A fault in section BC will give relay times which will allow breaker at B to trip out before the breaker at A.

2. Parallel feeders.

- ✓ Where continuity of supply is particularly necessary, two parallel feeders may be installed. If a fault occurs on one feeder, it can be disconnected from the system and continuity of supply can be maintained from the other feeder



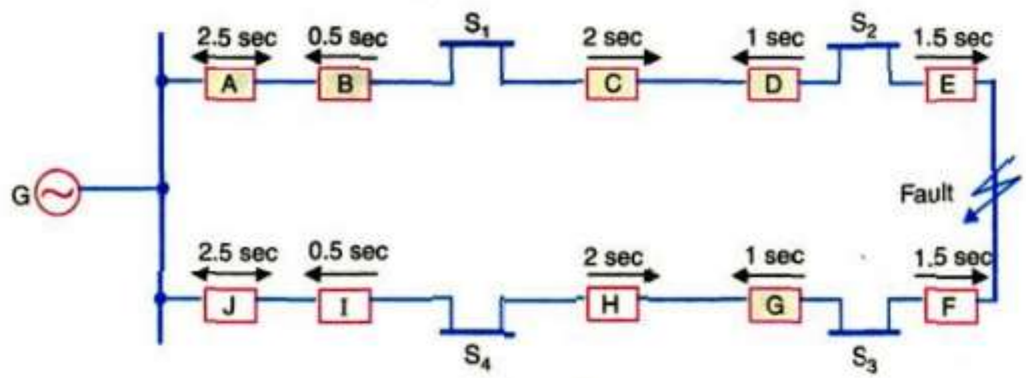
- ✓ The above figure shows the system where two feeders are connected in parallel between the generating station and the sub-station.
- ✓ The protection of this system requires that

- each feeder has a non-directional overcurrent relay at the generator end. These relays should have inverse-time characteristic.
- each feeder has a directional relay at the sub-station end. These relays should be instantaneous type and operate only when power flows in the reverse direction i.e. in the direction of arrow at P and Q.

✓ Suppose an earth fault occurs on feeder 1.
✓ It is desired that only circuit breakers at A and P should open to clear the fault whereas feeder 2 should remain intact to maintain the continuity of supply

3. Ring main system.

✓ In this system, various power stations or sub-stations are intercon nected by alternate routes, thus forming a closed ring.
✓ In case of damage to any section of the ring, that section may be disconnected for repairs, and power will be supplied from both ends of the ring, thereby maintaining continuity of supply.



Explain in detail the carrier current protection scheme. Describe carrier phase comparison relay with neat sketches. (Dec 2015)

Explain Transmission line protection by means of carrier current protection.(May-15)

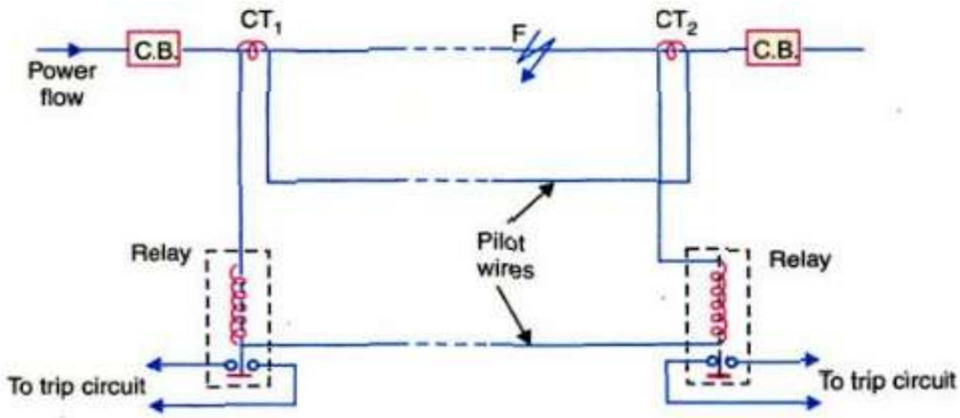
B. Differential Pilot wire Protection

There are several differential protection schemes in use for the lines. However, only the following two schemes will be discussed :

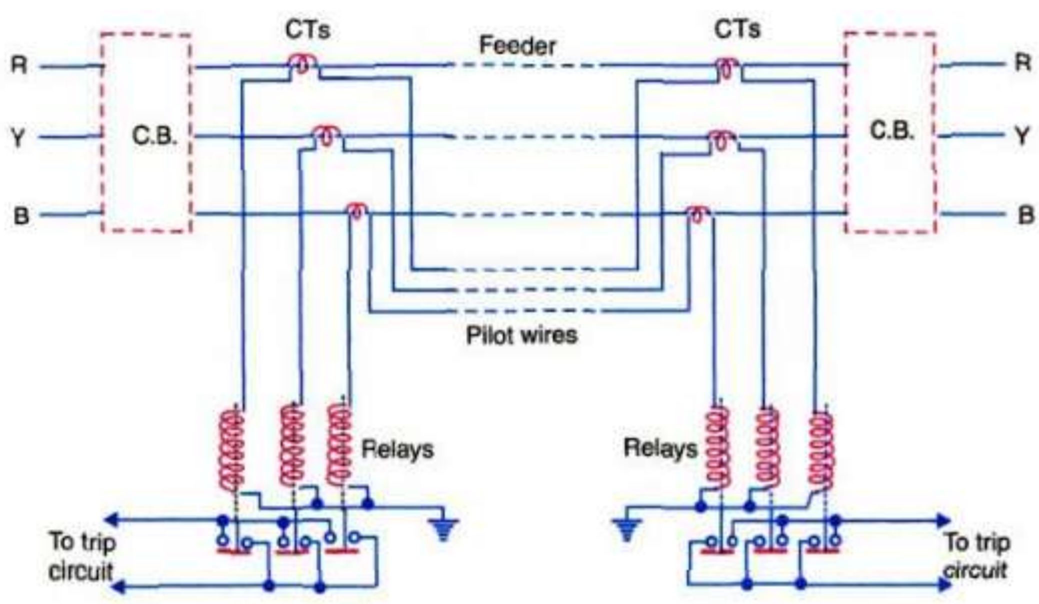
1 . Merz-Price voltage balance system
2. Translay scheme

1. Merz-Price voltage balance system.

- ✓ The below figure shows the single line diagram of Merz- Price voltage balance system for the protection of a 3-phase line.
- ✓ Identical current transformers are placed in each phase at both ends of the line. The pair of CTs in each line is connected in series with a relay in such a way that under normal conditions, their secondary voltages are equal and in opposi tion i.e. they balance each other.



- ✓ Under healthy conditions, current entering the line at one-end is equal to that leaving it at the other end. Therefore, equal and opposite voltages are induced in the secondaries of the CTs at the two ends of the line. The result is that no current flows through the relays.
- ✓ Suppose a fault occurs at point F. This will cause a greater current to flow through CTl than through CT2. Consequently, their secondary voltages become unequal and circulating current flows through the pilot wires and relays. The circuit breakers at both ends of the line will trip out and the faulty line will be isolated..



Advantages

(i) This system can be used for ring mains as well as parallel feeders.

(ii) This system provides instantaneous protection for ground faults. This decreases the possi bility of these faults involving other phases.

(iii) This system provides instantaneous relaying which reduces the amount of damage to over head conductors resulting from arcing faults.

Disadvantages

(i) Accurate matching of current transformers is very essential.

(ii) If there is a break in the pilot-wire circuit, the system will not operate.

(iii) This system is very expensive owing to the greater length of pilot wires required.

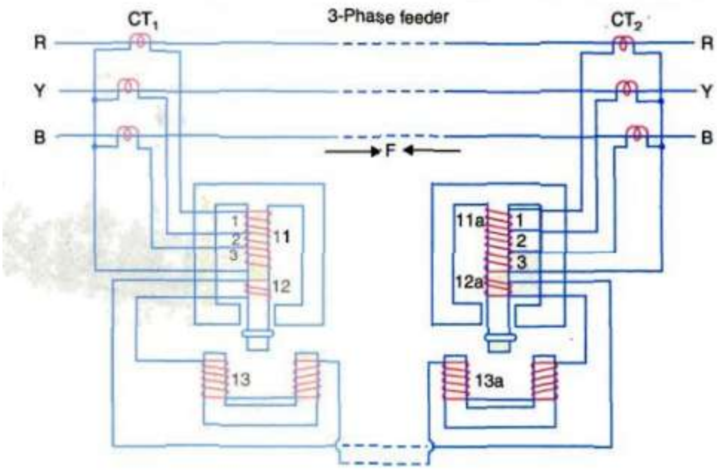
(iv) In case of long lines, charging current due to pilot-wire capacitance effects may be sufficient to cause relay operation even under normal conditions.

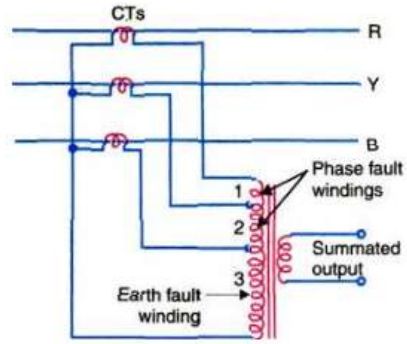
(v) This system cannot be used for line voltages beyond 33 kV because of constructional diffi culties in matching the current transformers.

Explain Transmission line protection by means of pilot wire or translay relay or longitudinal differential protection of feeders? (June-13,Dec-2013)

2. Translay scheme

- ✓ This system is similar to voltage balance system except that here 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.
- ✓ It is possible to make further simplification in voltage balance system by combining currents derived from all phases in a single relay at each end. using the principle of summation transformer .
- ✓ A ***summation transformer*** is a device that reproduces the polyphase line currents as a single-phase quantity. The three lines CTs are connected to the tapped primary of summation transformer. Each line CT energises a different number of turns (from line to neutral) with a resulting single phase output.
- ✓ The use of summation transformer permits two advan tages viz (i) primary windings 1 and 2 can be used for phase faults whereas winding 3 can be used for earth fault





Operation.

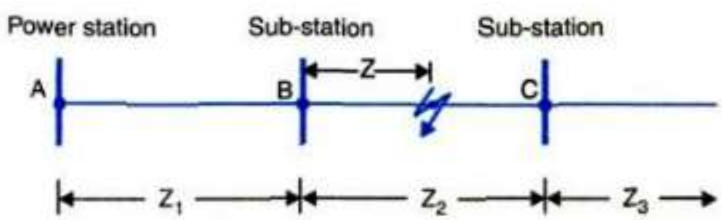
- ✓ When the feeder is healthy, the currents at its two ends are equal so that the secondary currents in both sets of CTs are equal. Consequently, the currents flowing in the relay primary wind ing "11" and "11a" will be equal and they will induce equal voltages in the secondary windings 12 and 12a.
- ✓ In the event of a fault on the protected line, the line current at one end must carry a greater current than that at the other end. The result is that voltages induced in the secondary windings 12 and 12 a will be different and the current will flow through the operating coils 13, 13a and the pilot circuit.
- ✓ Under these conditions, both upper and lower elements of each relay are energised and a forward torque acts on the each relay disc. The operation of the relays will open the circuit breakers at both ends of the line.

Advantages

(i) The system is economical as only two pilot wires are required for the protection of a 3-phase line.
(ii) Current transformers of normal design can be used.
(iii) The pilot wire capacitance currents do not affect the operation of relays.

C. DISTANCE PROTECTION

- ✓ Both time-graded and pilot-wire system are not suitable for the protection of very long high voltage transmission lines.
- ✓ The below figure shows a simple system consisting of lines in series such that power can flow only from left to right.

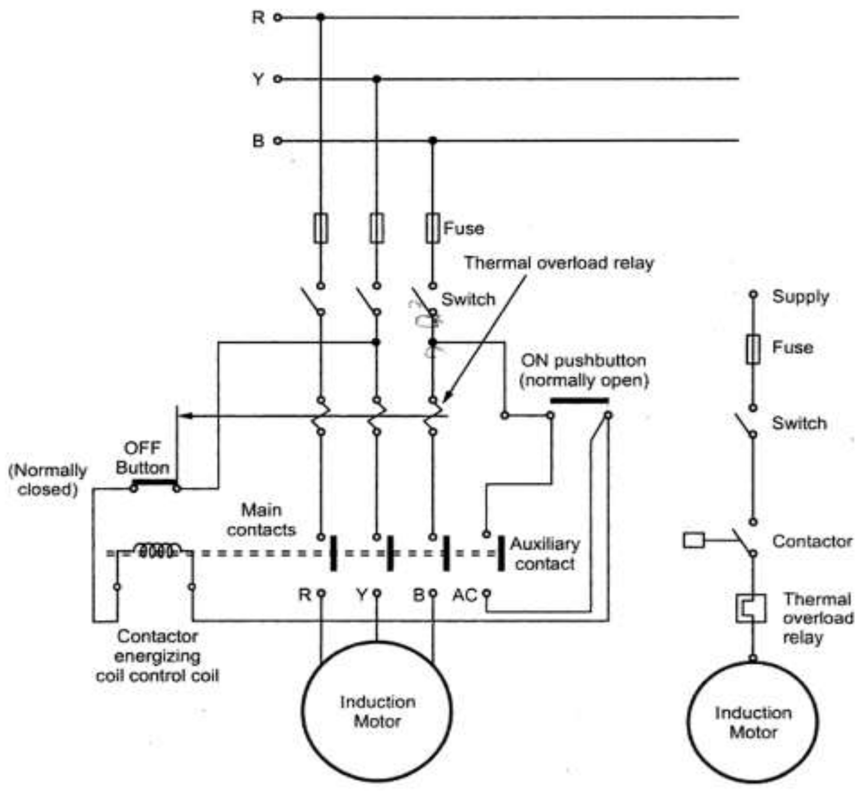


- ✓ The relays at A, B and C are set to operate for impedance less than Z1, Z2 and Z3 respectively.
- ✓ Suppose a fault occurs between sub-stations B and C, the fault impedance at power station and Sub-station A and B will beZ1+Zand Z respectively.
- ✓ only relay at B will operate. Similarly, if a fault occurs within section AB, then only relay at A will operate.

PROTECTION OF MOTOR

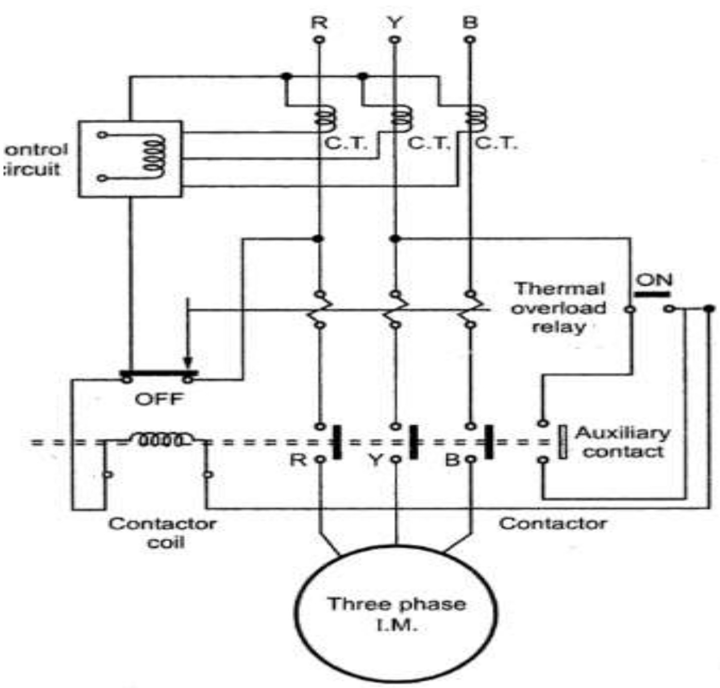
7. Draw and explain protection scheme of A.Cinduction Motor (3 phase) protection?(DEC-06) (Dec-2016)
Explain short circuit protection by (a) the (HRC)fuses (b)motor protection schemes?
Explain briefly about protection of induction motor. (Apr/May 2018)

- ✓ The three phase supply is given to the motor through fuse, switch, contactor and thermal overload relay
- ✓ The control circuit of contactor consist of energising coil, start and stop buttons
- ✓ When the start button is pressed then the contactor coil is energised
- ✓ Once the coil is energised it moves the main contact and auxillary contact to close
- ✓ The off push button which is normally closed as shown in the figure , when pushed the contact gets open, thus switching off the motor.
- ✓ During overload condition the overload relay operates(due to over courrent resulting in heating). Thermal overload relay consist of bimetalic strips. These strips bends (as a result of heating due to overcurrent) during overload operates the trip circuit to de-energize the coil.
- ✓ The Overload relay(OLR) is set to appropriate current value to operate.



(a) (b) Single line diagram

Single phasing preventer

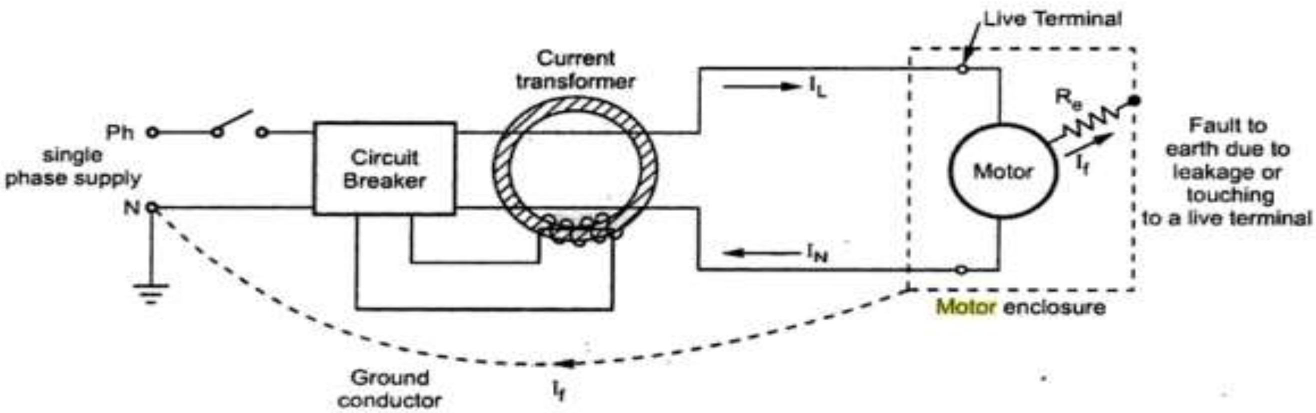


- ✓ In case of large induction motor separate single phasing preventor circuit is essential because even a small unbalance will cause damage of winding of motor
- ✓ It consist of CTs connected in each phase

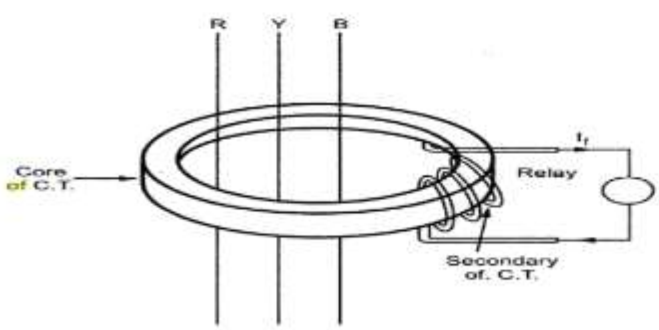
- ✓ The output of control circuit is fed to the level detector which sense the magnitude of unbalance.
- ✓ Depending upon the unbalance the tripping command is given to the circuit breaker

Ground fault Protection

- ✓ The ground fault protection is achied by using ELCB(Earth leakage circuit breaker). These faults are frequent and common in real time , so ELCB should be provided to protect motor.



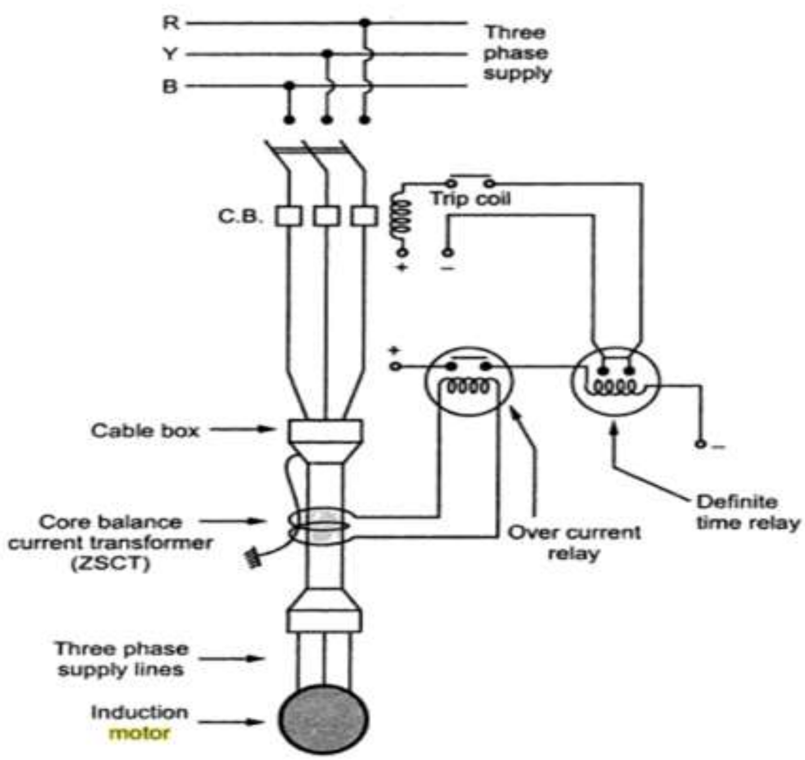
- ✓ ELCB consist of small current transformer surrounding live wire and netral wire. The secondary winding of current transformer is connected to relay circuit which helps trp the circuit breaker.
- ✓ Under normal condition there will be no current (I_L-I_N=0)passing through the CT secondary, therefore not operating the relay
- ✓ Under fault condition the current flowing in the CT will not be zero (I_L-I_N=I_F)



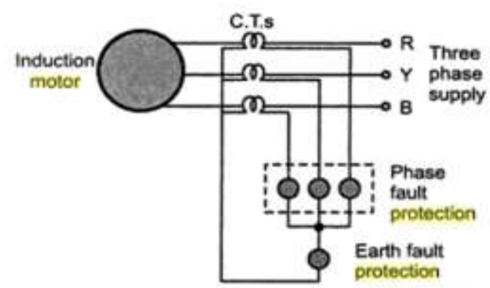
- ✓ The above figure represents the Core balance type protection or Zero sequence Current Transformer protection(ZSCT) for 3 phase motor.

Phase fault Protection

- ✓ This protection is also called as short circuit protection. At time of short circuit or phase fault the current increases by 8 to 10 times the full load current of the motor
- ✓ Attracted armature relay type unit is connected in each phase with a current setting of 4-5 times the full load current. This is because the starting current can be 4-5 times that of full load current.
- ✓ Hence to operate the relay only under fault condition such a setting is necessary
- ✓ The 3phase motor along with earth protection and phase protection is shown below



Earth fault protection by ZSCT



Phase and earth fault protection

8. Compare Current transformer and Potential Transformer

Sr. No.	Current Transformer	Potential Transformer
1.	It can be treated as series transformer under virtual short circuit conditions.	It can be treated as parallel transformer under open circuit secondary.
2.	Secondary must be always shorted.	Secondary is nearly under open circuit conditions.
3.	A small voltage exists across its terminals as connected in series.	Full line voltage appears across its terminals.
4.	The winding carries full line current.	The winding is impressed with full line voltage.
5.	The primary current and excitation varies over a wide range.	The line voltage is almost constant hence exciting current and flux density varies over a limited range.
6.	The primary current is independent of the secondary circuit conditions.	The primary current depends on the secondary circuit conditions.
7.	Needs only one bushing as the two ends of primary winding are brought out through the same insulator. Hence there is saving in cost.	Two bushings are required when neither side of the line is at ground potential.

9. Difference between Fuse and Circuit breaker

S. No.	Particular	Fuse	Circuit breaker
1.	*Function*	It performs both detection and interruption functions.	It performs interruption function only. The detection of fault is made by relay system.
2.	*Operation*	Inherently completely automatic.	Requires elaborate equipment (*i.e.* relays) for automatic action.
3.	*Breaking capacity*	Small	Very large
4.	*Operating time*	Very small (0·002 sec or so)	Comparatively large (0·1 to 0·2 sec)
5.	*Replacement*	Requires replacement after every operation.	No replacement after operation.

10. Write short notes on CT and PT?
Give a detailed explanation about CT's and PT's and its application to power system? (MAY-2017)

i) Current transformer (C.T):-

The large alternating currents which cannot be sensed or passed through normal ammeter and current coils of wattmeter's, energy meters, can easily be measured by use of current transformers along with normal low range instruments.

A transformer is device which consists of two windings called primary and secondary. It transfers energy from the side to another with suitable change in level of current or voltage. A current transformer basically has a primary coil of one or more turns of heavy cross sectional area. In some, the bar carrying high current in may act as primary. This is connected in series with the line carrying high current. The bar type primary is shown in fig. The secondary of the transformer is made up of a large number of turns of the fine wire ie, having small cross sectional area. This is usually rated for 5a current. The is connected to the coil of normal low range meter.

These transformer are basically step up transformers ie., stepping up a voltage from primary to secondary. Hence obviously current considerably gets stepped down from primary to secondary. For example CT is of 500:5 range, ie., if primary current is 500A. It will reduce it to %A on secondary. But it steps up the primary voltage 100 times.

$$\frac{I_1}{I_2} = \frac{N_2}{N_1}$$

This is the current and number of turn's relationship for the current transformer. Hence if current ratio of C.T. is known and meter reading is known, the actual high current value can be determined

It is very important that the secondary of CT should not be kept open. Either it should be shorted or must be connected in series with a low resistance coil such as current coils of wattmeter coils of ammeter, etc. If it is left open, then current through secondary becomes zero, hence the ampere turns produced by secondary which generally oppose primary ampere turns becomes zero.

As there is no current emf produce high flux in the core. This produce excessive core losses, heating the core beyond limits, similarly heavy emf's will be induced on the primary and induced on the primary and secondary side. Thus may damaged the insulation of the winding. This is danger from the operator point of view, as well. It is usual to ground the C.t. on the secondary side to avoid danger of shock to the operator.

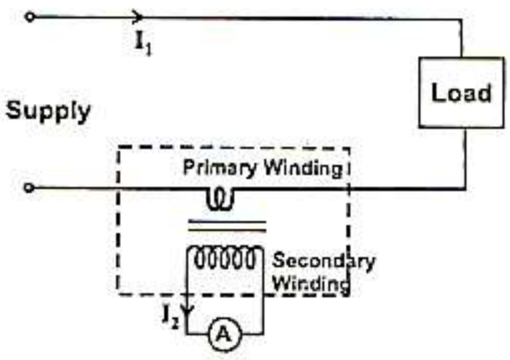


Fig. 2.55: Current transformer

In case of a C.T, $turns\ a\ ratio, n = \frac{N_2}{N_1}$

Where N1is the No. of turns of primary winding

N2 is the No. of turns of secondary winding

$$for\ a\ CT, \qquad \frac{I_1}{I_2} = \frac{N_2}{N_1} = \frac{V_2}{V_1} --- (1)$$

I1=primary current in A

I2=secondary current in A

V1=primary voltage in V

V2=secondary voltage in V

From the above equation,

if the range of C.T is 500:5

$$I1 = 500A$$
$$I2 = 5A$$
$$N = 500/5 = 100$$
$$V2/V1 = 100$$
$$V2 = 100V1 ----------- (2)$$

From the eq(2) it is clear that in order to decrease the secondary current by 100 times, the secondary voltage should be increased by 100 times.

If the turn's ratio of C.T is known and the meter reading is known, the actual high line current value can be determined.

ii) Potential transformer (P.T)):-

The basic principle of P.T. is same as that of C.T.

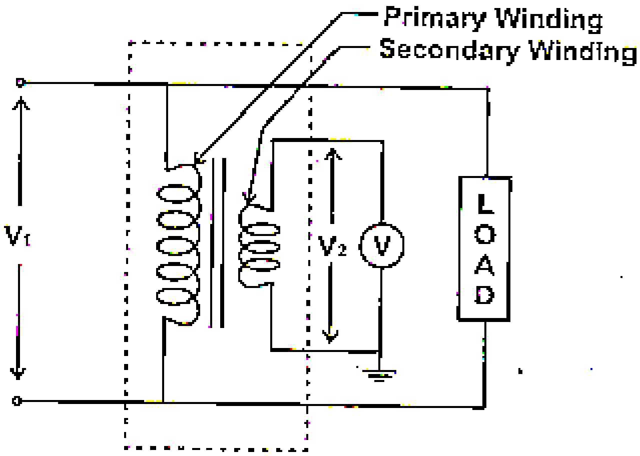


Fig. 2.56: Potential Transformer:

The main difference between P.T and C.T.

a. C.T acts as a step up transformer, while P.T acts as a step down transformer.
b. Secondary voltage of P.T is lesser than the primary voltage whereas secondary voltage of C.T is higher than the voltage.
c. Secondary current of P.T. is more than the primary in C.T secondary current is less than the primary current.
d. In P.T-more no. of turns in primary winding
e. In C.T-more no. of turns in secondary winding
f. In P.T –primary winding connected across the load
g. In C.T-primary winding connected in series with the load.
h. Turns ratio of P.T:$\frac{N_1}{N_2} = \frac{V_1}{V_2}$

   Turns ratio of C.T:-$\frac{I_1}{I_2} = \frac{N_2}{N_1}$

Errors

Two types of errors that affect the characteristics of instrument transformer are: i)Ratio error and ii)Phase angle error

i) Ratio error

$for\ a\ CT, \quad n = \frac{N_2}{N_1}$

$Current\ transformation\ ratio\ = \frac{I_1}{I_2}$

$$Voltage\ ratio = \frac{V_2}{V_1}$$

$Hence\ n = \frac{I_1}{I_2} = \frac{N_2}{N_1} = \frac{V_2}{V_1}\ \ for\ C.T ----------------- 1$

$$For\ \ P.T.,.n = \frac{N_1}{N_2}$$

$$Voltage\ ratio = \frac{V_1}{V_2}$$

$$Current\ ratio\ = \frac{I_2}{I_1}$$

$$Hence\ n = \frac{N_1}{N_2} = \frac{V_1}{V_2} = \frac{I_2}{I_1}\ for\ P.T ----------------- 2$$

Generally in case of CT
Current transformation ratio = turns ratio

$$\%\ Ratio\ error = \frac{nominal\ ratio - actual\ ratio \times 100}{Actual\ ratio} ------\ -3$$

$$\%Ratio\ error = \frac{K_n - R}{R} \times 100 ----\ ------------\ 4$$

$$Where\ Kn = \frac{rated\ primary\ current}{rated\ secodary\ current} for\ C.T.$$

$$And\ Kn = \frac{rated\ primary\ voltage}{rated\ secondary\ voltage} for\ P.T$$

$$R = \frac{actual\ primary\ current\ voltage}{actual\ secondary\ current} forC.T$$

$$And \quad R = \frac{autual\ primary\ voltage}{actual\ secondary\ voltage} for\ P.T$$

Precise formula to calculate

$$R = n + \frac{I_m sin\delta + I_C cos\delta}{I_2} ------------------------5$$

Where

N- Turns ratio

I_m-magnetizing component of exiting current

Ic-core loss component of exciting current

I_2-secondary current

δ-angle between secondary voltage and current in deg.

ii) Phase angle error:-

Secondary current is displaced by exactly 180° from that of primary current for C.T. while the phase of secondary voltage is displayed by 180° from that of primary voltage for P.T. the phase difference is different from 180° by an angle θ. The error which occurs due to this fact is called phase angle error.

$$\theta = \frac{180}{\pi}\left[\frac{Im\cos\delta - Ic\sin\delta}{nI2}\right] \text{in degrees}$$

Sub $\delta = 0$, $\sin\delta = o and \cos\delta = 1$ in above eqn

$$\theta = \frac{180}{\pi} \times \frac{Im}{nI2}$$

Since n=$\frac{I1}{I2}$

$$\theta = \frac{180}{\pi} \times \frac{Im}{I1} indegrees$$

Where I_1 is the primary current in A.

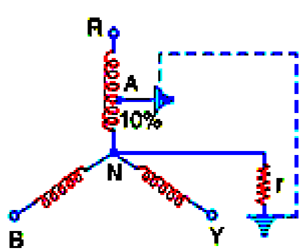
IMPORTANT QUESTIONS

1. Explain in detail the protection of generator?
2. Explain in detail the protection of Transmission line?
3. Explain in detail the protection of transformer using buchholz relay and differential method?
4. Explain in detail the protection of busbar using differential protection?

Problems

Problem 1

A star connected 3 phase,10MVA,6.6Kv alternator has a per phase reactance of 10%.it is protected by merz-price circulating current principle which is set to operate for fault current not less than 175A.calculate the value of earthing resistance to be provided in order to ensure that only 10% alternator winding remains unprotected.(Apr/May 2018)



Solution :

$$Voltage\ /phase \qquad Vph = \frac{6.6\ \times 10^3}{\sqrt{3}} = 3810V$$

$$Full\ load\ current, I = \frac{10^6}{\sqrt{3}\ \times X \times 6.6X10^3} = 875A$$

Let resistance /phase be X Ω

$$10 = \frac{\sqrt{3} \times X \times 875}{6600} \times 100$$
$$X = 0.436\Omega$$

Reactance of 10% winding=0436×0.1=0.0436Ω
E.M.F induced in 10% winding=Vph×0.1=3810×0.1=381V
Impedance offered to fault by 10% of winding is

$$Z_f = \sqrt{(0.0436)^2 + (r)^2}$$

Earth fault current due to 10% winding

$$= \frac{381}{Z_f} = \frac{381}{\sqrt{(0.0436)^2 + (r)^2}}$$

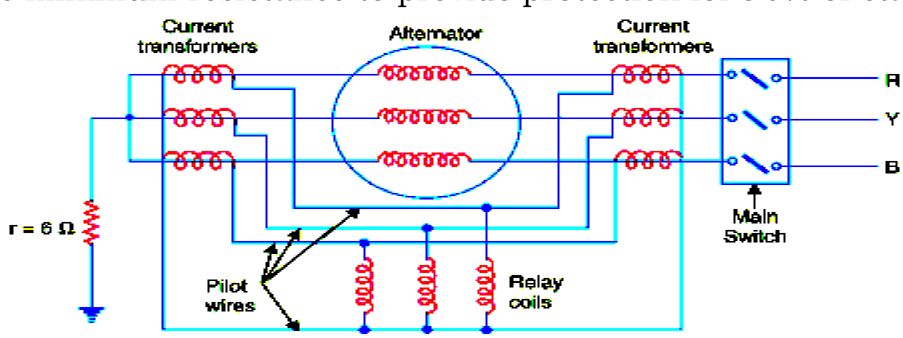
When this fault current becomes 175A.the relay will be trip

$$175 = \frac{381}{\sqrt{(0.0436)^2 + (r)^2}}$$
$$(0.0436)^2 + (r)^2 = \left(\frac{381}{175}\right)^2$$
$$R=2.171\Omega$$

Problem 2

A 10MVA,6.6KV,3-phase star-connected alternator is protected by merz-price circulating current system. If the ratio of the current transformers is 1000/5.the maximum operating current for the relay is 0.75A and the neutral point earthing resistance is 6Ω calculate.

(i) The percentage of each of the stator windings which is unprotected against earth faults when the machine is operating at normal voltage.
(ii) The minimum resistance to provide protection for 90% of stator winding.



Solution:

(i) Let x% of the winding be unprotected.
Earthing resistance r=6Ω
Voltage per phase,$V_{ph}=\frac{6.6X10^3}{\sqrt{3}}$= 3810 volts
Minimum fault current which will operate the relay =$\frac{1000}{5}$×0.75=150A

E.M.F induced in x% of stator winding=$V_{ph}\times(\frac{X}{100})$

$$=3810\times(\frac{X}{100})=38.1x \text{ volts}$$

Earth fault current which x% winding will cause

$$=\frac{38.1x}{r}=\frac{38.1x}{6}\text{Ampers}$$

This must be equal to 150A.

$$150 = \frac{38.1x}{6}$$

$$X=23.6\%$$

(ii) Let r ohms be minimum earthing resistance required to provide protection for 90% of stator winding.then 10% winding would be unprotected i.e.x=10%

$$150=\frac{38.1x}{r} : \quad r = \frac{38.1x}{150}= \frac{38.1\times10}{150}=2.54\Omega$$

Problem 3

A star connected ,3 phase,10MVA.6.6KV alternator is protected by circulating current protection, the star point being earthed via a resistance r.Estimate the value of earthing resistor if 85% of the stator winding is protected against earth faults. Assume the value of earth fault setting of 20%. Neglect the impeadance of the alternator winding?

Solution. Since 85% winding is to be protected, 15% would be unprotected. Let r ohms be the earthing resistance required to leave 15% of the winding unprotected.

$$\text{Full-load current} = \frac{10 \times 10^6}{\sqrt{3} \times 6{\cdot}6 \times 10^3} = 876 \text{ A}$$

Minimum fault current which will operate the relay

$$= 20\% \text{ of full-load current}$$

$$= \frac{20}{100} \times 876 = 175 \text{ A}$$

Voltage induced in 15% of winding

$$= \frac{15}{100} \times \frac{6{\cdot}6 \times 10^3}{\sqrt{3}} = 330\sqrt{3} \text{ volts}$$

Earth fault current which 15% winding will cause

$$= \frac{330\sqrt{3}}{r}$$

This current must be equal to 175 A.

$$\therefore \quad 175 = \frac{330\sqrt{3}}{r}$$

$$\text{or} \quad r = \frac{330\sqrt{3}}{175} = \mathbf{3{\cdot}27\ \Omega}$$

Problem 4

A 6600 volt 3phase turbo – alternator has a maximum continuous rating of 2000 $kW\ at\ 0.8 p.f.$ and its reactance is 12.5%. it is equipped with Mertz Price circulating current protection which is set to operate at fault currents not less than 200 amperes. Find what value of the neutral earthing resistance leaves 10% of the windings unprotected?

Solution:

Let the earth resistance be r ohms

Full load current of the alternator

$$= \frac{2000 \times 1000}{0.8 \times \sqrt{3} \times 6600} = 219\ amps.$$

Let the reactance per phase of the alternator be $x\ ohms$.

$$\therefore 12.5 = \frac{\sqrt{3} \times x \times 219}{6600} \times 100$$

$$or \qquad x = 2.19\ ohm$$

$$\therefore Reactance\ of\ 10\%\ of\ the\ winding = 0.219\ ohm$$

$$Voltage\ induced\ in\ winding\ NA = \frac{6600}{\sqrt{3} \times 10} = 381\ volts$$

$$The\ protection\ operates\ at\ a\ current = 200\ amps.$$

$$\therefore 200 = \frac{381}{\sqrt{r^2 + 0.219^2}} \qquad whence\ r = 1.89\ ohms.$$

Problem 5

A 3 phase, 20 MVA, 11kV, $star$ –connected generator is protected by the current balancing system of protection. If the ratio of the current transformer is 1200/5, the minimum operating current of the relay is 0.75ampere and the neutral point earthing resistance is 6 ohms, calculate the percentage of each phase of the stator winding which is unprotected against earh faults when the machine is operating at normal voltage. Show quantitatively, the effect of varying the neutral earthing resistance.

Solution:

$$Maximum\ fault\ current\ to\ operate\ the\ relay$$

$$= \frac{1200 \times 0.75}{5} = 180\ amps$$

$$let\ the\ unprotected\ portion\ be\ x\%.$$

$$voltage\ induced\ in\ this\ section = \frac{11000}{\sqrt{3}} \times \frac{x}{100}\ volts$$

$$Fault\ current\ 180 = \frac{\left(\frac{11000}{\sqrt{3}} \times \frac{x}{100}\right)}{6}$$

$$whence\ x = \frac{180 \times \sqrt{3} \times 100 \times 6}{11000} = 17\%$$

Let us see the effect of increasing earthing resistance keeping the relay operating current the same.

$(i)\quad R = 3\ ohms$

$$The\ unprotected\ portion = 8.5\%$$

$$\therefore Protected\ portion = 91.5\%$$

$(ii)\quad R = 6\ ohms$

$$The\ unprotected\ portion = 17\%$$

$$\therefore Protected\ portion = 85\%$$

$[this\ calculation\ has\ been\ shown\ only\ in\ the\ first\ part\ of\ this\ example]$

$(iii)\ R = 12\ ohms$

$The\ unprotected\ portion = 34\%$

$\therefore Protected\ portion = 66\%$

Thus we see that increasing R would result in operating current for the same value of earthing resistance.

$(i)\quad Relay\ operating\ current = 0.75A$

$\%age\ winding\ protected = 83\%$

$(ii)\quad Relay\ operating\ current = 0.5A$

$\%age\ winding\ protected = 89\%$

$(iii)\quad Relay\ operating\ current = 1A$

$\%age\ winding\ protected = 74.5\%$

Problem 6

A $5000\ kVA, 6600\ volts\ star -$ connected alternator has a synchronous reactance of 2 ohms per phase and 0.5 ohms resistance. It is protected by a Mertz Price balanced current system which operates when the out of balance current exceeds 30% of the load current.

Determine what proportion of the alternator winding is unprotected if the star – point is earthed through a resistor of 6.5 ohms.

Solution:

$$Full\ load\ current = \frac{5000 \times 1000}{\sqrt{3} \times 6600} = 437.5\ A = 438A$$

$$out\ of\ balance\ current = 438 \times \frac{30}{100} = 131.4\ A$$

$Let\ the\ winding\ unprotected\ be\ x\%$

$$Impedance\ of\ x\%\ winding = \frac{x}{100}(0.5 + j2)$$

$value\ of\ earthing\ resistance = 6.5\ ohms$

$Total\ impedance\ at\ fault\ of\ the\ fault\ circuit$

$$= \left[\left(6.5 + \frac{0.5x}{100}\right) + \frac{j2x}{100}\right]$$

$Voltage\ induced\ in\ x\%\ of\ the\ winding$

$$= \frac{6600}{\sqrt{3}} \times \frac{x}{100} = \frac{66x}{\sqrt{3}}$$

$$\therefore \quad 131.4 = \frac{\frac{66x}{\sqrt{3}}}{\left(6.5 + \frac{0.5x}{100}\right) + j\frac{2x}{100}}$$

One method of solving for x is the trial and error method. The alternate method is to neglect the reactance.

∴ Neglecting the reactance of the winding, current feed into fault

$$= \frac{\frac{66x}{\sqrt{3}}}{\left(6.5 + \frac{0.5x}{100}\right)} 131.4\ A$$

$Solving\ x = 22.8\%$

Problem 7

A generator is protected by restricted earth fault protection. The generator ratings are 13.2 KV, 10MVA. The percentage of winding protected against phase to ground fault is 85%. The relay setting is such that it trips for 20% out of balance. Calculate the resistance to be added in the neutral to ground connection. **(Dec-2016)**

Solution : The given values,

V_L = 13.2 kV   Rating = 10 MVA

From rating, calculate the full load current,

$$I = \frac{\text{Rating in VA}}{\sqrt{3}V_L} = \frac{10 \times 10^6}{\sqrt{3} \times 13.2 \times 10^3}$$

=437.386 A

Relay setting is 20% out of balance i.e. 20% of the rated current activates the relay.

$$I_0 = 437.386 \times \frac{20}{100} = 87.477\ A$$

$$= minimum\ operating\ current$$

$$V = Line\ to\ neutral\ voltage = \frac{V_L}{\sqrt{3}}$$

$$V = \frac{13.2 \times 10^3}{\sqrt{3}} = 7621.02\ \text{V}$$

% of winding unprotected = 15% as 85% is protected

$$15 = \frac{RI_0}{V} \times 100$$

$$15 = \frac{R \times 87.477}{7621.02} \times 100$$

$$R = 13.068\Omega$$

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

1. **Define static relay.(Nov/Dec 2017)**
A static relay is defined as one in which there is no armature or other moving parts . The desired output is produced by electronic solid state, magnetic components without mechanical movement.

2. **Define principles of static relay.**
The working principle of the Solid Static relays is similar to that of the Electromechanical Relay which means the Solid Static relays can perform tasks that the Electromechanical Relay can perform.

3. **Merits of static relay**
Reliability, sensitivity, speed, selectivity, versatility

4. **What are the types of comparator employed in static relay.**
   a) Amplitude comparator
   b) Phase comparator
   c) Hybrid comparator

5. **What is principle of duality**
Any circular or straight line characteristics synthesized by a comparator can also be synthesized by phase comparator, if the input of the amplitude comparator are modified to the sum and difference and fed to a phase comparator. The converse is also true

6. **List out the Advantages of Solid State Relay.**
   - Static Relay burden is less than Electromagnetic type. Hence Error is less.
     - Low Weight
     - Required Less Space which results in panel space saving.
     - Arc less switching
     - No acoustical noise.
   - Multi-function integration.
   - Fast response.

7. List out the Limitations of static relays.

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.

8. List the Characteristics ofof static relay?

a) High level of functionality integration
b) Self checking and self adaptability
c) More accurate
d) Signal storage is possible
e) Economical

9. Write two applications of static relay?(Dec-2016)

1. Overcurrent protection
2. Differential protection.

10. What are the different components of the digital relay

a) Isolation transformer and surge protection circuits
b) Multiplexor and S/H circuits
c) Anti aliasing filter
d) Digital input and output system
e) Central processing unit
f) Event storage system
g) Signal conditioning circuit
h) Communication peripheral
i) Power supply block
j) Sampling clock

11. Define Principles Numerical relays.

The input analogue signals are converted into a digital representation and processed according to the appropriate mathematical algorithm. Processing is carried out using a specialized microprocessor that is optimized for signal processing applications, known as a digital signal processor or DSP for short. Digital processing of signals in real time requires a very high power microprocessor.

12. List the Characteristics of Numerical relay.

a) Reliability
b) Self diagnosis
c) Event and disturbance record
d) Integration of digital systems

e) Adaptive protection

13. List out the general characteristics of Numerical protection.(Apr/May 2018)

Numerical relays are technically superior to the conventional type relays. Their general characteristics are:

- ♦ Reliability
- ♦ Event and disturbance records
- ♦ Self diagnosis
- ♦ Adaptive Protection

14. List out the Advantages of Numerical relays.

Flexibility: A variety of protection functions can be accomplished with **suitable** modifications in the software only either with the same hardware or with slight modifications in the hardware.

Reliability: A significant improvement in the relay reliability is obtained because the use of fewer components results in less interconnections and reduced component failures.

Multi Function Capability: Traditional electromechanical and static protection relays offers single-function and single characteristics. Range of operation of electromechanical relays is narrow as compared to numerical relay.

Different types of relay characteristics: It is possible to provide better matching of protection characteristics since these characteristics are stored in the memory of the microprocessor.

15. State the difference between conventional and numerical relay?(Nov/Dec 2016)

CONVENTIONAL RELAY	NUMERICAL RELAY
It uses mechanical comparison	It uses digital comparison
It is bulky in size	It is compact and smaller
It has lower reliability	It has higher reliability
It is slower compared to numerical relays	It is faster in working operation

16. Define sampling theorem?(APRIL/MAY-2017)

A continuous time signal can be represented in its samples and can be recovered back when sampling frequency fs is greater than or equal to the twice the highest frequency component of message signal. i. e.

$$Fs \leq 2fm.$$

17. Write about numerical transformer differential protection? (APRIL/MAY-2017)

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

- In differential relay, the currents are summed up, which enter and leave the equipment, and any difference is then taken as being due to an internal fault.
- This difference during external faults can be quite large because of the difference in the dynan1ic behavior of the CTs on the two sides of the transformer.

18.What is phase comparator? (Nov/Dec 2017)

The phase comparator compares the phase angle between the two inputs.

19.What are the basic circuits used in static relay? (Apr/May 2018)

The circuits such as comparators, level detectors, zero crossing detectors etc, designed using electronic components are used in the static relays for measurement and comparison of electrical quantities.

PART B

Static Relays

It is seen that the conventional electromagnetic relays use moving parts such as armature in their control circuitry. The relays which do not use moving parts and use the solid state electronic components such as diodes, transistors etc are called **static relays.** The circuits such as comparators, level detectors, zero crossing detectors etc, designed using electronic components are used in the static relays for measurement and comparison of electrical quantities. The static relay is designed in such a way that whenever a quantity under consideration exceeds a particular level, the static circuit produces a response without any moving parts such as armature. This response is then manipulated and given to a tripping circuit which may be electronic or electromagnetic. **Thus static relay response circuit does not have moving parts and made up** of **electronic components but its tripping circuit may be** electronic **or electromagnetic.** Let us study the basic elements of a static relay.

1. Explain the basic elements of static relays?

The relays which do not use moving parts and use the solid state electronic components such as diodes, transistors etc are called static relays.

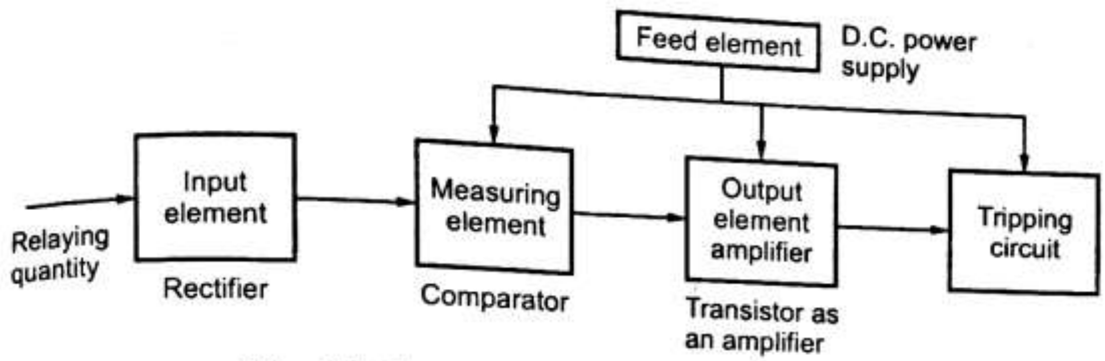


Fig. 8.7 Block diagram of a static relay

Input element: The relaying quantity can be the output of C.T. or P.T. or it may be the output of a transducer or it may be combination of various signals. Thus an electronic circuit such as rectifier is required as an input element to get the input signal in a convenient form before applying it to a measuring element. Some mixing circuits such as op-amp adder may also be required as an input element.

Measuring Element: This is the heart of the static relay. It compares the output of an input element with a set value and decides the signal to be applied to the output element which ultimately drives the tripping circuit. Thus measuring element is a deciding signal generator.

Measuring element can be classified as,

- Single input device
- Two input device
- Multi-input device

Single input device

The single input devices, depending on the protection and control schemes are further classified as,

a) Noncritical Repeat Function (All or Nothing Relay)

As the name suggests, these devices are completely unenergized or energized much higher than the marginal condition required, to produce very fast response. It can be represented as shown in the Fig. 8.8. The input R is either zero or too higher than the marginal operating level. Such devices are instantaneous response time less than 20 ms.The switching power gain associated with thern generally 10^3. Such devices have multiple output contacts.

The main functions of such devices in the protection are,

- To produce final tripping signal to the circuit breaker.

- To produce signals to perform supplementary functions such as **alarming** inter tripping etc.
- To act as intermediate switching stages in a complex protection scheme

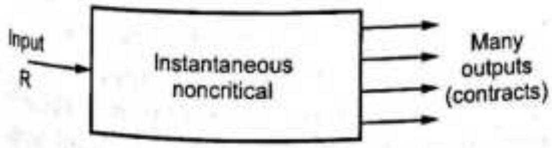


Fig. 8.8 Noncritical repeat function

b) Critical Measuring Function :

This device is a sort of on-off controller. It activates when the input signal reaches to some critical level decided by the protection scheme. Such a device is shown in the Fig. 8.9.

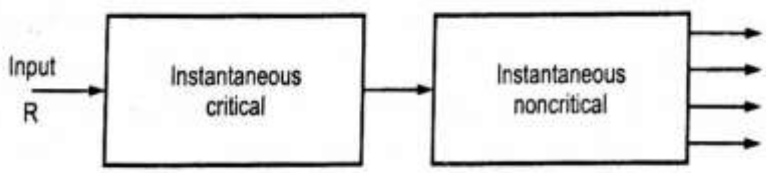


Fig. 8.9 Instantaneous critical function

Thus when input R is greater than some critical value P, it operates. While for reset, input R must be less than kP (k < 1).

It has only one output and switching gain need not be high. The output of such device then can be connected to instantaneous noncritical to obtain multiple outputs.

The various requirements of critical function devices are,

- High accuracy.
- Long term consistency.
- Fast and reliable operation.
- High controllable reset ratio.

c. Definite or Fixed Time Function:

This is nothing but a delay function element. It produces a define time delay between its input and the output. The delay may be provided between the application of input and activation of output or between removal of input and resetting of output.

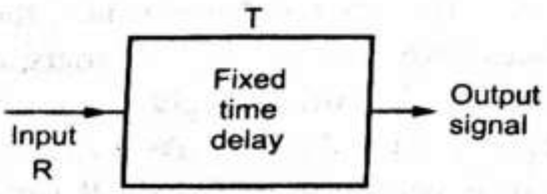


Fig. 8.10 Definite time function

d.Input Dependent Time Function:

This function depends on the input characteristics and decides the timeaccordingly.

The common form of input dependent time function characteristics is

$$t = f(R^n) \qquad where\ R = input, n = negative$$

The function and its characteristics are shown in the Fig. 8.11.

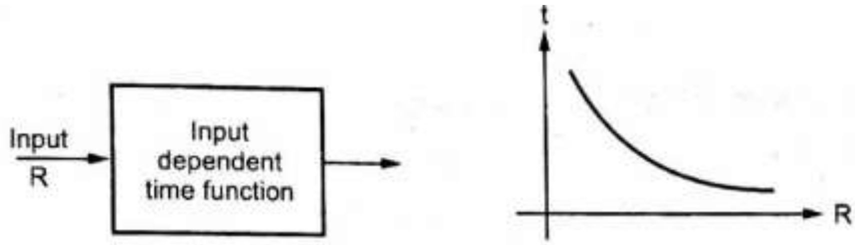


Fig. 8.11 Input dependent time function

As n is negative, as the input increases the operating time decreases. So operating time is inversely proportional to some power of the input. The examples of such relays are inverse definite minimum time lag overcurrent and earth fault relays.

The two input devices are very common such as comparators, level detectors etc. while multiple input devices are extension of two input devices to extend the range of characteristics.

Output Element: The signals obtained from the measuring element are required to be amplified before applying to the tripping circuit. Thus output element is an amplifier.
Feed element: The feed element provides the d.c. voltage required by the various elements.

2. Compare static and electromagnetic relays. State the advantages of static relays.(Apr/May 2018)

Comparison of Static and Electromagnetic Relays

The conventional electromagnetic relays use the moving parts such as an armaturedisc etc. Thus they are bulky in size. These relays are robust and highly reliable. Theseare subjected to differential forces under fault conditions and hence required to havedelicate setting of small contact gaps, special bearing arrangements, clutch assembliesetc. Thus there are lot of manufacturing difficulties and problems related**to**mechanical stability associated with electromagnetic relays. The current and**potential**transformers are subjected to high burdens in case of electromagnetic relays.

The static relays are commonly using the transistor circuits and called transistor relays.This is because transistor can be used as an amplifying device as well as a switching device.Hence any functional characteristics as per the requirement can be obtained by the staticrelays. The transistor circuits can perform functions like summation, integration, comparisonetc.

Advantages of Static Relays (Nov/Dec 2017)

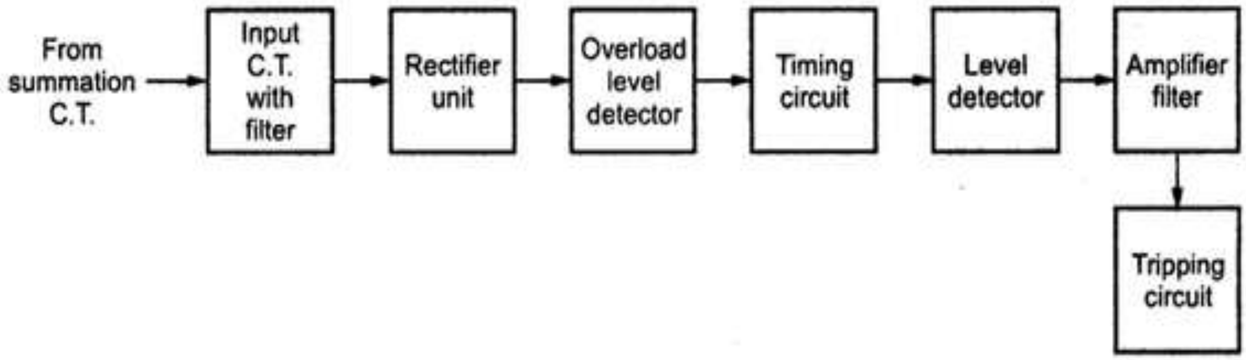
- The moving parts are absent
- The burden on current transformers gets considerably reduced
- The power consumption is very low
- The response is very quick
- Minimum maintenance is required
- No bearing friction or contact troubles exist
- Resetting time can be reduced and overshoots can be reduced due to absence of mechanical inertia and thermal storage
- Sensitivity is high
- Testing and servicing is simplified.

Limitations of Static Relays

- Electronic components are temperature dependent
- Reliability is unpredictable
- low short timeoverload capacity
- Additional d.c. supply is required
- Susceptible to the voltage fluctuations and transients
- Less robust

3. Draw and explain the block diagram of static time-current relay.(Nov/Dec 2017)

Static Time Current Relay:



Block diagram of time current static relay

- When the voltage across the timing capacitor reaches to a critical value then it triggers the level detector.
- The charging of capacitor in a timing circuit achieved by a voltage derived from CT current. This voltage is obtained across a nonlinear resistor by passing rectified current through it.
- The proper selection of nonlinear resistor and RC timing circuit allows to obtain desired shape of time current characteristics of the static relay.
- The current at which the level detector trips is called **threshold current**

Thus for an overcurrent relay,

When $I_{in} < I_{threshold}$ level detector does not trip

When $I_{in} \geq I$ threshold level detector trips

Static Time-Current Characteristics

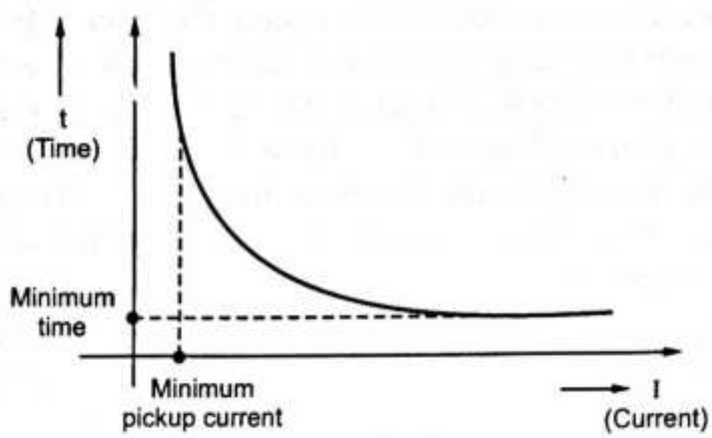


Fig. 8.13 Inverse time-current characteristics

t = Time of operation in seconds

K = Design constant of relay

TMS = Time multiplier setting

I = Tap current multiplier

I_p = Multiple of tap current at which pickup occurs

n = Characteristic index of relay

The shape of the characteristics and degree of inverse nature is standardized. According to British standards,

For standard inverse characteristics (IDMT),

Kx(TMS) = 0.14, n = 0.02 and I_p = 1 A

For standard very inverse characteristics,

Kx(TMS) = 13.5, n = 1 and I_p = 1 A

or extremely inverse characteristics,

Kx(TMS) = 80, n = 2 and I_p =1 A

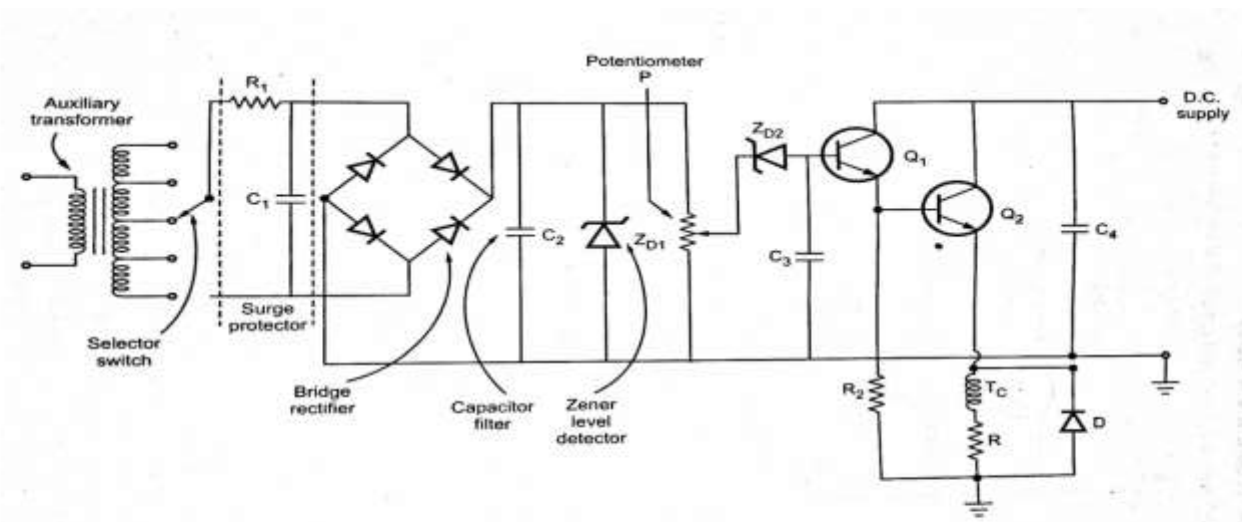
It can be seen that the curve is asymptotic about both the axes. Due to this, there exists minimum pickup current below which relay cannot be operated. While there exists minimum definite time of operation below which it cannot be reduced.

4. Draw and explain the circuit diagram of static instantaneous over current relay.

Static Instantaneous Over-current Relay(Nov/Dec 2017)(Apr/May 2018)

- Auxiliary transformer gives output voltage proportional to the fault current.
- Main circuit is protected from the voltage surges by using R1 C1 circuit at the input. This is surge protector.
- Output voltage from the transformer is then rectified and smoothened using capacitor filter C_2 .

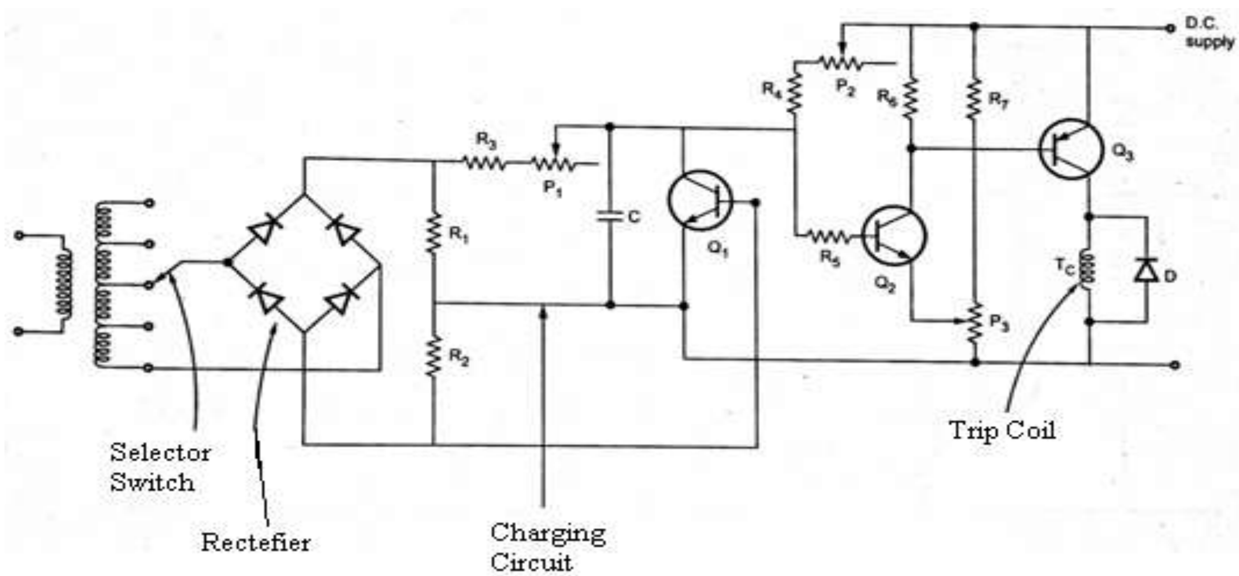
- Zener limits the rectified voltage to a safe value though the fault current is very high.
- When the rectified voltage is greater than voltage of Z_{D2}, the transistor Q1 conducts. This increases drop across R2 due to which Q2 conducts.
- This energizes the trip coil Tc of the relay.



5. Draw and explain circuit diagram of static inverse time over current relay.

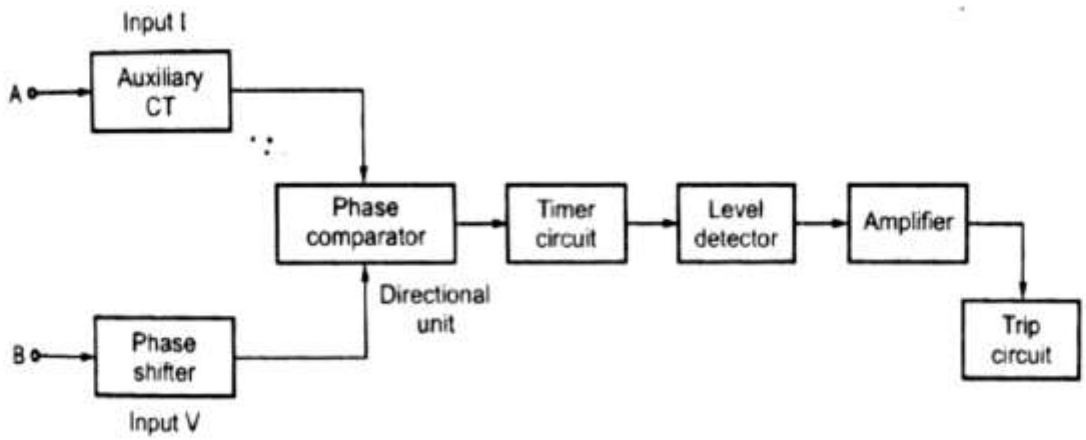
Inverse Time-Current Relay

- Under normal conditions, Q1 gets biasing from d c supply
- Hence capacitor C is short circuited.
- When fault current exceeds a pick up value set by thepotentiometer P2 and selector switch then the transistor Q1 becomes OFF.
- The capacitor C starts charging through R.
- When voltage across the capacitor reaches to a determined level set by the potentiometer P3 then the transistor Q3 conducts.
- This energizes the trip coil and the circuit breaker opens.



6. Draw and explain the circuit diagram of static directional overcurrent relay.

Directional Static Over-current Relay



- The directional relay is nothing but a directional power relay which operates whenthe power in the circuit flows in a particular direction.
- The input A is proportional to the system current supplied to a directional unit through auxiliary transformer.
- The input B is proportional to the system voltage, supplied to a directional unit through phase shifter.
- Let this angle is ϕ while the relay characteristics angle is θ. Let I_p be the current setting magnitude. Then the relay operates when,

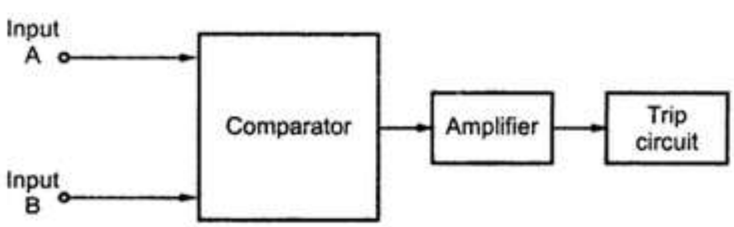
$$\mathbf{Ip \leq I\cos(\phi - \theta)}$$

- The phase comparator compares the phase angle between the two inputs.
- The output of the phase comparator is applied to a level detector
- The static directional overcurrent relays are very sensitive

7. Draw and explain the circuit diagram of static differential relay.

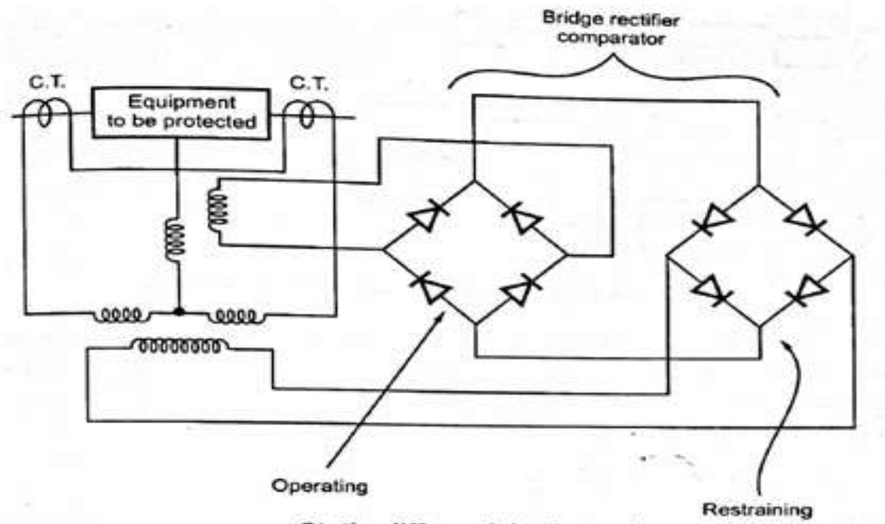
Static Differential Relay

- A differential relay is the relay which operates when the phasor difference of two or more similar electrical quantities exceed a predetermined value.



Static differential relay

- In normal conditions, the two quantities balance each other and the comparator output is zero and the relay is inoperative.
- For any internal fault conditions, the comparator senses the phase difference between the two quantities and produces the output. This is amplified and given to the trip circuit which operates the relay.
- This scheme is used for protection of the generators and transformers against any type of internal fault.



Static differential relay scheme

Let n_0 and n_r be the number of turns of operating and restraining coils respectively. Then the relay operates when,

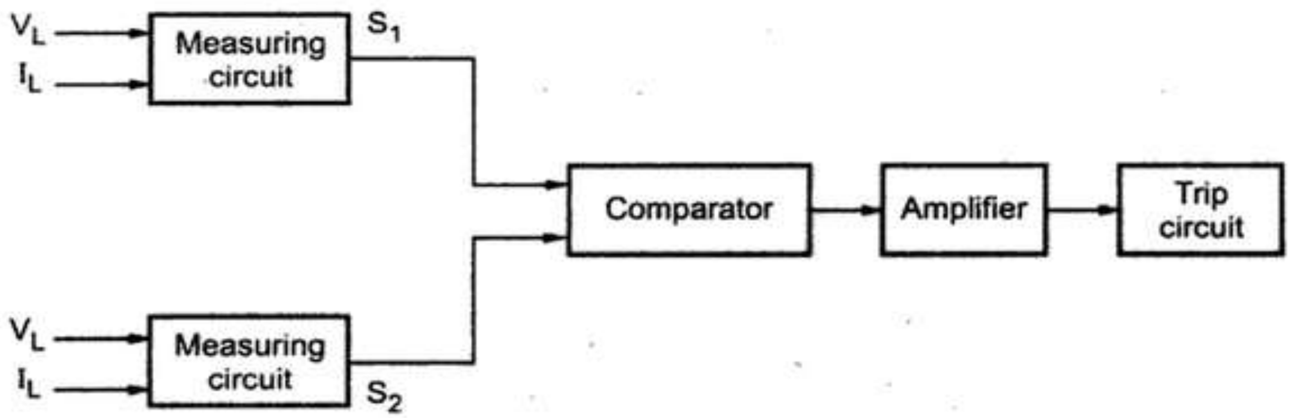
$$K_1 \; n_0 \; I_0 > K_2 \; n_r I_r + K'$$

Where k_1 and k_2 are design constants while K' is the spring control torque.

8. Write a note on static distance relays.

<u>Static Distance Relays</u>

- Operation is dependent on the ratio of the voltage and current, which is expressed in terms of impedance.
- The relay operates when the ratio V /I i.e. impedance is less than a predetermined value.



Basic static distance relay scheme

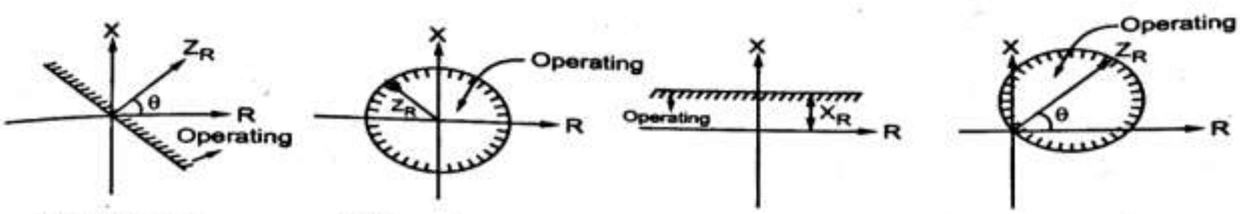
The line voltage V_L and the line current I_L are given as the inputs for the two measuring circuits. The circuits produce the outputs S_1 and S_2 depending upon their characteristics. Thus

$$\boldsymbol{S_1 = K_1 V_L + K_2 I_L}$$
$$\boldsymbol{S_2 = K_3 V_L + K_4 I_L}$$

- Where K1, K2, K3 and K4 are to be selected according to the requirement of the characteristics.

The various type of derived voltages S1 and S2 for amplitude and phase comparators to obtain particular characteristics are given in below table

No.	Amplitude comparator		Phase comparator		Distance relay scheme
	Operating	Restraining	Operating	Restraining	
1	$\left\lvert I_L + \frac{V_L}{Z_R} \right\rvert$	$\left\lvert I_L - \frac{V_L}{Z_R} \right\rvert$	$I_L Z_R$	V_L	Directional
2	$\lvert I_L \rvert$	$\frac{\lvert V_L \rvert}{\lvert Z_R \rvert}$	$I_L Z_R - V_L$	$I_L Z_R + V_L$	Impedance
3	$\left\lvert I_L - \frac{V_L}{X_R} \right\rvert$	$\frac{\lvert V_L \rvert}{\lvert X_R \rvert}$	$I_L Z_R - V_L \sin\theta$	$I_L Z_R$	Reactance
4	$\lvert I_L \rvert$	$\left\lvert I_L - \frac{V_L}{Z_R} \right\rvert$	$I_L Z_R - V_L$	V_L	Mho



(a) Directional (b) Impedance (c) Reactance (d) Mho

9. Explain the different types of amplitude comparators?

Amplitude Comparators:

If two input signals are S_1 and S_2 the amplitude comparator gives positive output only if $S_2/S_1<K$.
S_1=Operating Quantity
S_2=Restraining Quantity

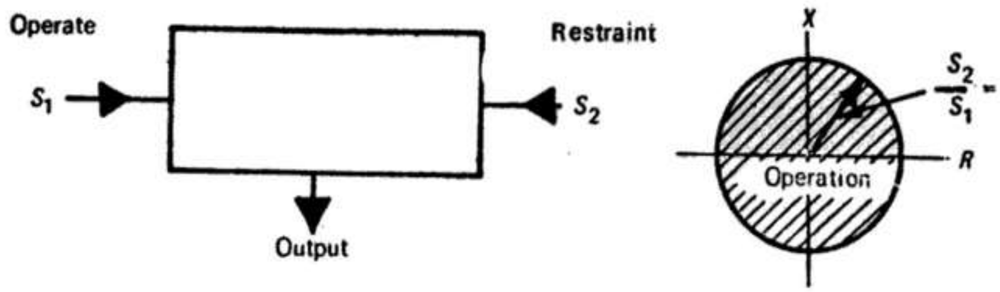


FIGURE 11.1 Amplitude comparator. Output when $|S_2/S_1| < K$.

Types:

i). Integrating comparator
ii). Instantaneous comparator
iii). Sampling comparator

i) Integrating comparator

Two currents i_1 and i_2 are rectified and their difference is averaged. The output is obtained only if the average value is positive.

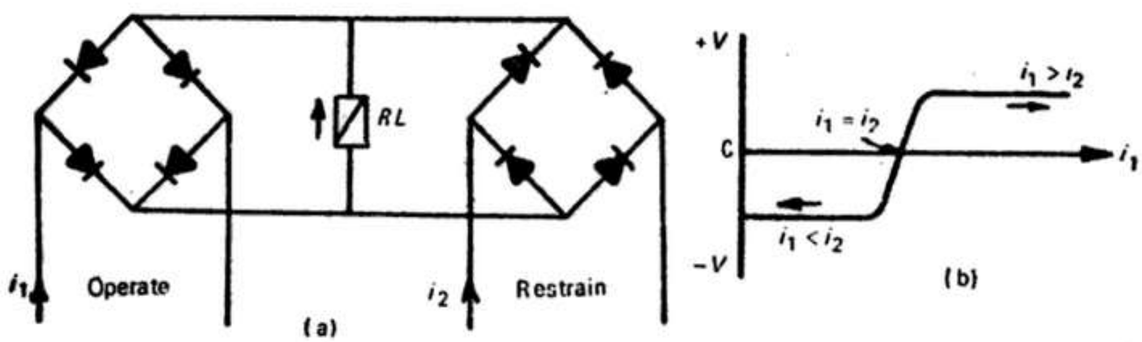


FIGURE 11.2 Circulating current type rectifier bridge comparator: (a) basic circuit; (b) output voltage. RL—polarized relay operates in direction shown.

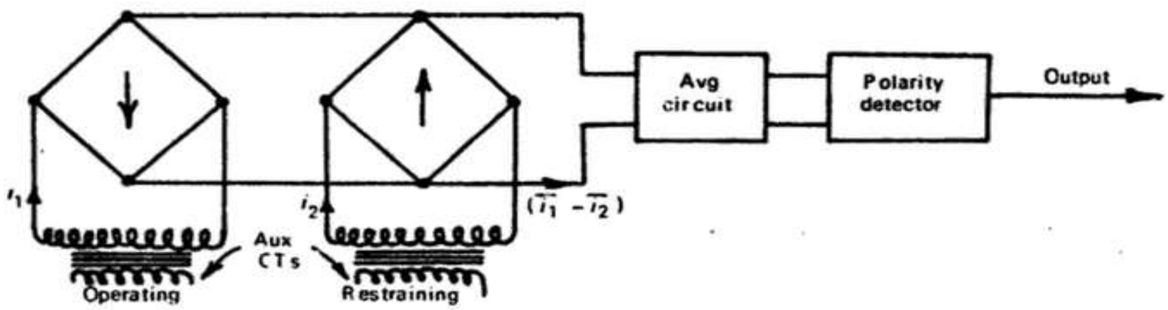


FIGURE 11.3 Rectifier bridge comparator with static output device.

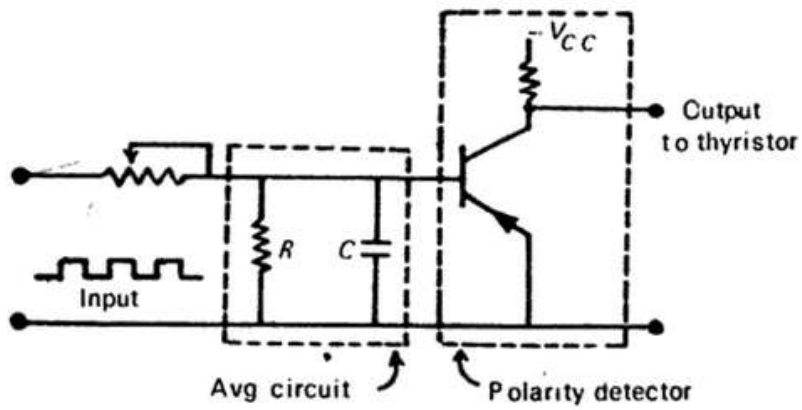


FIGURE 11.4 Integrating circuit.

- The tripping occurs when the capacitor voltage reaches the setting value of the level detector and triggers a thyristor.

ii) <u>Instantaneous comparator</u>

- The restraining signal is rectified and smoothed completely in order to provide a level of restraint.
- The tripping signal is provided if the operating signal exceeds the level of restraint.

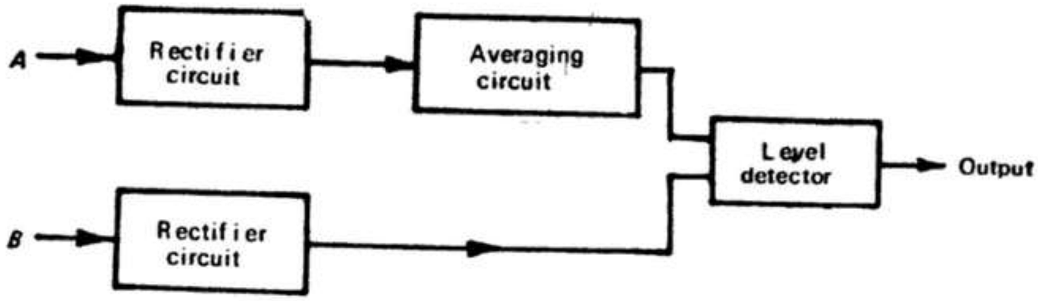
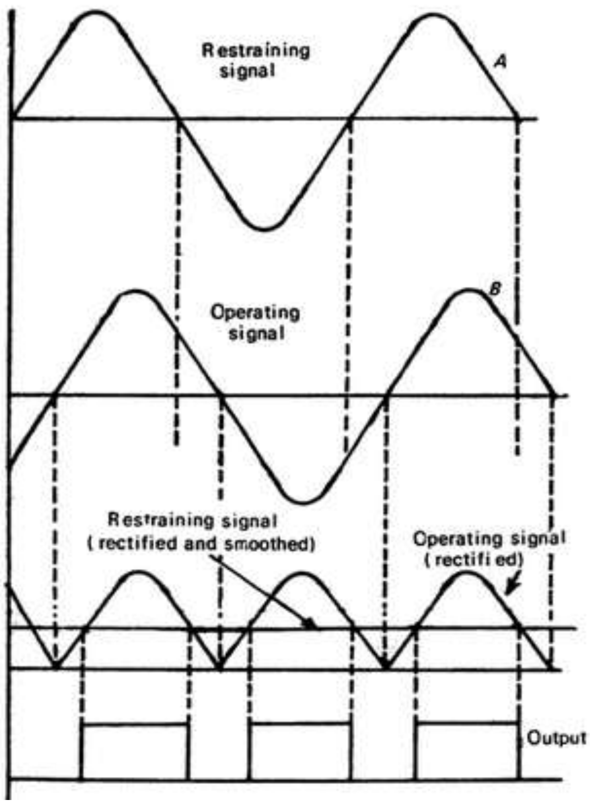


FIGURE 11.6 Block diagram of averaging type instantaneous amplitude comparator.



iii) <u>Sampling comparator</u>

- The instantaneous magnitude of one signal at a certain moment is compared with the instantaneous magnitude of the second signal at that very moment.

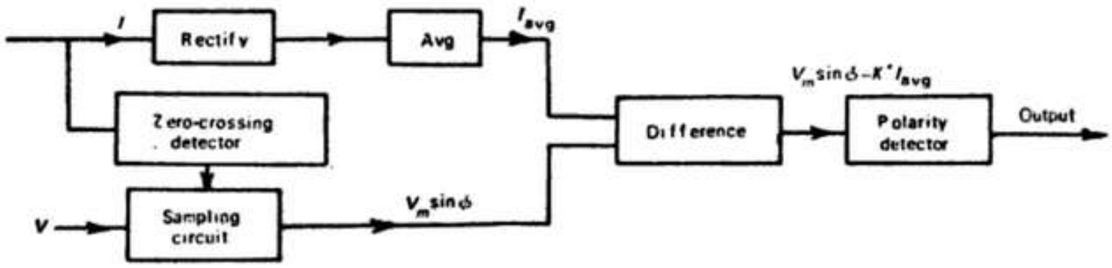
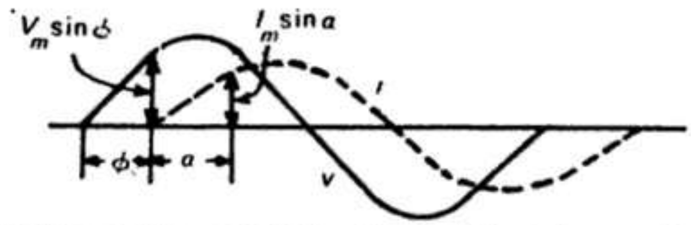


FIGURE 11.9 Block diagram for a reactance relay comparing the instantaneous value of voltage at current zero with average current.



Voltage and current waveforms of reactance relay.

10. Explain the different types of Phase comparators?

<u>Phase Comparators:</u>

- If two input signals are S_1 and S_2, the output occurs when the inputs have a phase relationship lying with in specified limits.

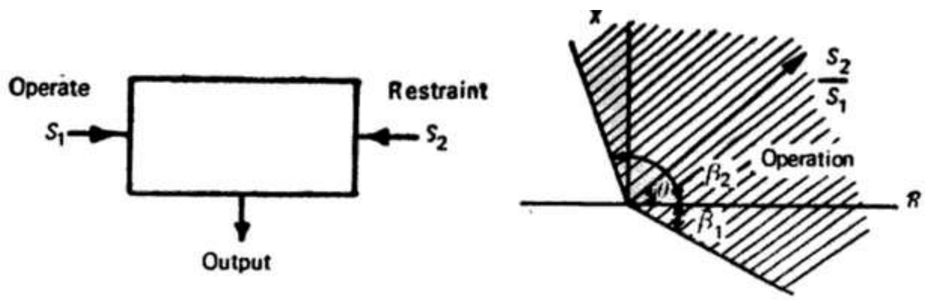


FIGURE 11.13 Phase comparator output when angle θ between S_1 and S_2 is within limits β_1 and β_2.

The condition of operation can be put mathematically as

$$-\beta_1 \leqslant \theta \leqslant +\beta_2$$

<u>Types:</u>

i). Vector product comparator
ii). Coincidence type phase Comparator

i.) <u>Vector product comparator</u>

a)Magneto-resistivity comparator

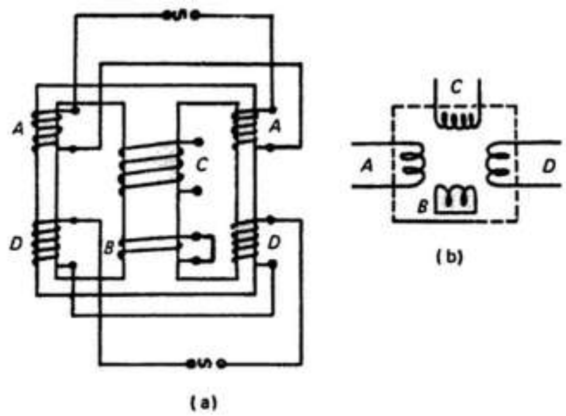


FIGURE 9.2 (a) Single core transductor; (b) diagramatic representation of transductor. A—operating winding; B—coupling winding; C—control winding; D—output winding.

b) Hall effect Phase comparator

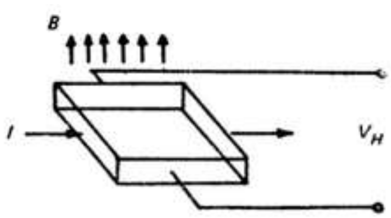


FIGURE 9.5 Basic Hall generator.

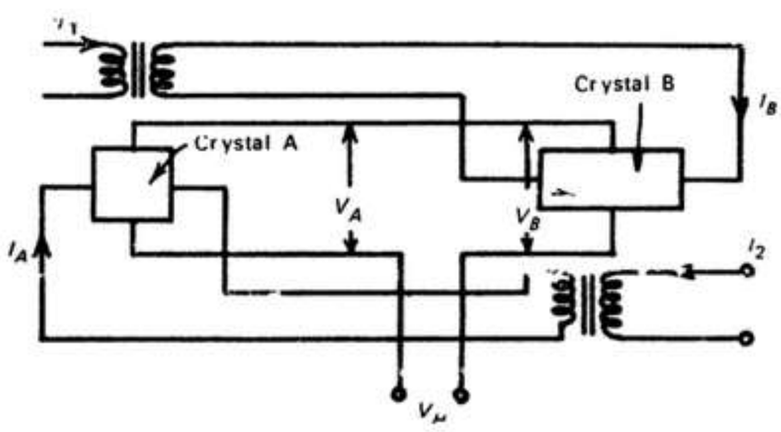


FIGURE 9.6 Cross-connection of two Hall generators.

ii). <u>Coincidence typephase comparator</u>

The period of coincidence of signals S_1 and S_2 will depend on the phase difference between S_1 and S_2.

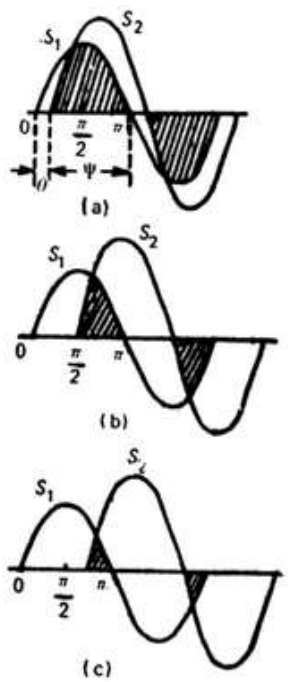


FIGURE 11.14 Coincidence of signals: (a) S_2 lagging S_1 by less than $\pi/2$; (b) S_2 lagging S_1 by $\pi/2$; (c) S_2 lagging S_1 by more than $\pi/2$.

SYNTHESIS OF VARIOUS RELAYS USING STATIC COMPARATORS

- Using static comparators, it is possible to synthesize (produce) a variety of relays. A purely geometric method is developed for deriving inputs suitable for the synthesis of various distance relays.
- The method consists of locating two phasors, involvingZ_r the impedance seen by the relay and Z_n, the setting of the relay, such that the phase angle - between them crosses ± 90° as the impedance seen by the relay moves from the trip to the restrain region.
- These two phasors, in principle, are suitable for driving a phase comparator (cosine-type), then convert these two phasors into two voltages suitable for feeding a practical electronic circuit.

11. With a neat sketch discuss in detail about the synthesis of mho relay using phase comparator?(Dec-2016)

SYNTHESIS OF MHO RELAY USING STATIC PHASE COMPARATOR

- The mho relay to be synthesized has a setting of $|Z_n| \angle \theta_n$. The characteristic to be synthesized is thus a circle with diameter as phasor $\boldsymbol{Z_n}$.
- Figure 4.20 shows the synthesis of a mho relay using a phase comparator. Now, let the impedance seen by the relay be Z_{r1} represented by point A in Figure 4.20. Since the impedance phasor lies within the trip region, the relay must issue the trip output. It can be easily seen from the Figure that the phasor $(Z_n - Z_{r1})$, represented by line AP, leads the phasor Zn by an angle which is definitely less than 90°.
- The Figure 4.20 shows that as the impedance seen by the relay moves towards the boundary between the trip and restrain regions, the angle between $(\boldsymbol{Z_n} - \boldsymbol{Z_r})$ and $\boldsymbol{Z_r}$ moves towards 90°.
- When the phasor representing the impedance seen by the relay, lies on the boundary, this angle is exactly 90°. For all impedances lying outside the trip region, i.e. in the restraining region, the angle between $(\boldsymbol{Z_n} - \boldsymbol{Z_r})$ and $\boldsymbol{Z_r}$ is always greater than 90°.

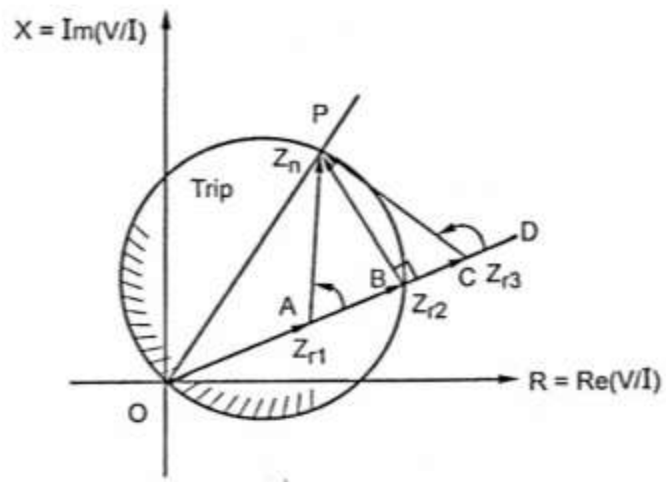


Fig.4.20. Synthesis of mho relay using cosine type phase comparator

$$\mathrm{OA} = |Z_{r1}| \rightarrow Trip \qquad AP = |Z_n - Z_{r1}|$$

$$\mathrm{OB} = |Z_{r2}| \rightarrow Threshold \qquad BP = |Z_n - Z_{r2}|$$

$$\mathrm{OC} = |Z_{r3}| \rightarrow Restrain \qquad CP = |Z_n - Z_{r3}|$$

$$Arg\frac{|Z_n - Z_{r1}|}{|Z_{r1}|} = \angle BAP < 90° \qquad \rightarrow Trip$$

$$Arg\frac{|Z_n - Z_{r2}|}{|Z_{r2}|} = \angle CAP < 90° \qquad \rightarrow Threshold$$

$$Arg\frac{|Z_n - Z_{r3}|}{|Z_{r3}|} = \angle DCP < 90° \qquad \rightarrow Restrain$$

Trip law

$$If\ Arg\frac{|Z_n - Z_r|}{|Z_r|} < 90°\,; then\ trip$$

Even if the impedance seen by the relay is on the other side of Zn as shown in Figure 4.21, as long as it is in the trip region, the angle between (Z_n - Z_t) and $Z_r$is always greater than -90°.

The angle hits 90° for boundary conditions and becomes less than -90° as the impedance seen by the relay moves into the restraining region.

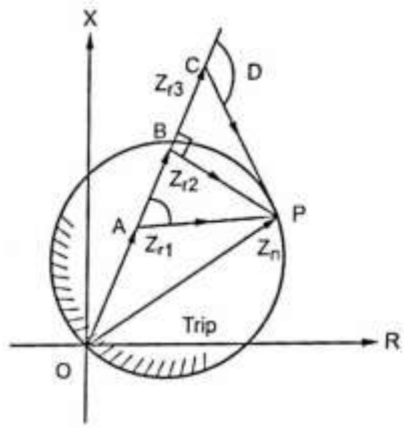


Fig. 4.21.Synthesis of mho relay using phase comparator

$$OA = |Z_{r1}| \rightarrow Trip \qquad AP = |Z_n - Z_{r1}|$$

$$OB = |Z_{r2}| \rightarrow Threshold \qquad BP = |Z_n - Z_{r2}|$$

$$OC = |Z_{r3}| \rightarrow Restrain \qquad CP = |Z_n - Z_{r3}|$$

$$Arg\frac{|Z_n - Z_{r1}|}{|Z_{r1}|} = \angle PAB < -90° \qquad \rightarrow Trip$$

$$Arg\frac{|Z_n - Z_{r2}|}{|Z_{r2}|} = \angle PAC = 90° \qquad \rightarrow Threshold$$

$$Arg\frac{|Z_n - Z_{r3}|}{|Z_{r3}|} = \angle PCD < -90° \qquad \rightarrow Restrain$$

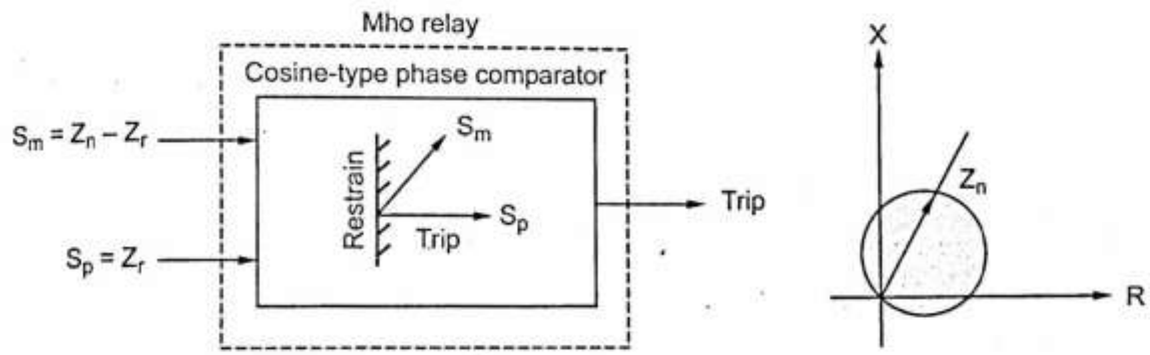
Trip law

$$If\ Arg\frac{|Z_n - Z_r|}{|Z_r|} > -90°\,; then\ trip$$

Thus, the phasor (Z_n-Z_r) and Z_r obey the law of cosine-type phase comparison. Therefore, if (Z_n-Z_r) and Z_r are used as inputs to a cosine comparator, the resulting entity would behave exactly like a mho relay

However, there is a practical problem here. The problem is that the electronic circuit of the comparator accepts only voltage signals at its input. Therefore, need to convert these two impedance phasor into voltage signals.

- If multiply both (Z_n -$\boldsymbol{Z_r}$)and$\boldsymbol{Z_r}$ by the current at the relay location I_r, then resultant will be (I_rZ_n - I_rZ_j) and$\boldsymbol{Z_rI_r}$**.** Note that$\boldsymbol{Z_rI_r}$ is nothing but the voltage at the relay location V_r.
- The two modified signals therefore are:(I_rZ_n - V_r) and V_r
- The two voltage signals **($\boldsymbol{I_fZ_n}$ - $\boldsymbol{V_r}$)** and V_r, fed to a cosine-type comparator for synthesis of a mho relay with a setting of Zn is depicted in Figure 4.22.



$$(Z_n - Z_r)I_r = Z_nI_r - V_r = S_m$$

$$Z_rI_r = V_r = S_p$$

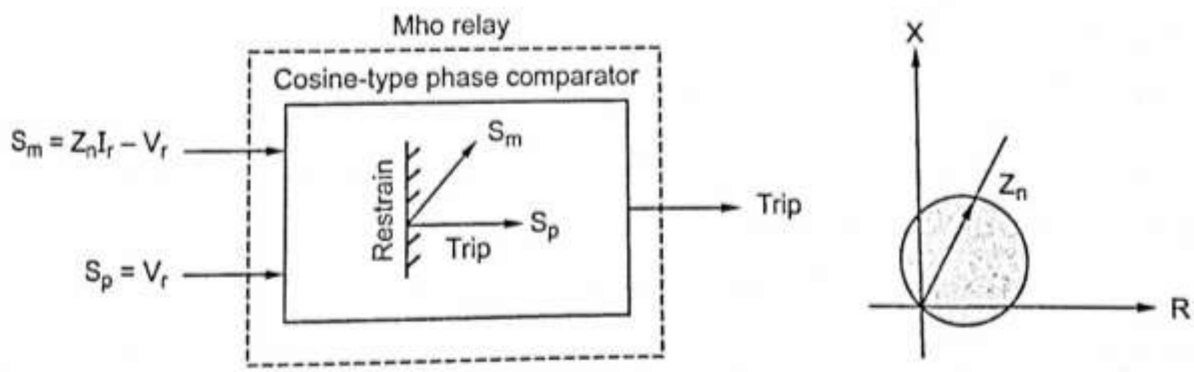


Fig. 4.22. Deriving signals for mho relay synthesis-cosine type phase comparator

At the relay location, the signals V_r and I_r are readily available. In order to form S_P and S_m inputs suitable for synthesis of mho relay, its needs to be mixed using suitable hardware to get the required signals. The circuit arrangement for mixing the relay voltage and current signals is shown in Figure 4.23.

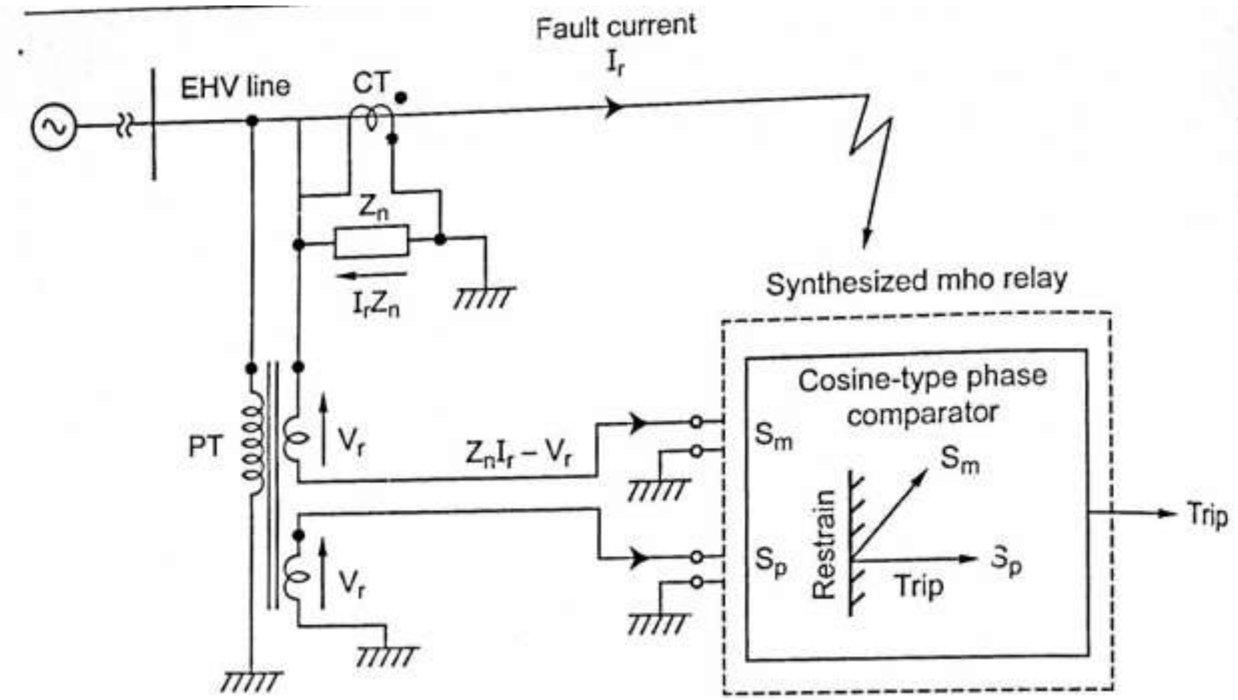


Fig. 4.23. Mho relay synthesis using cosine-type phase comparator-Arrangement for mixing the relay voltage and current signals

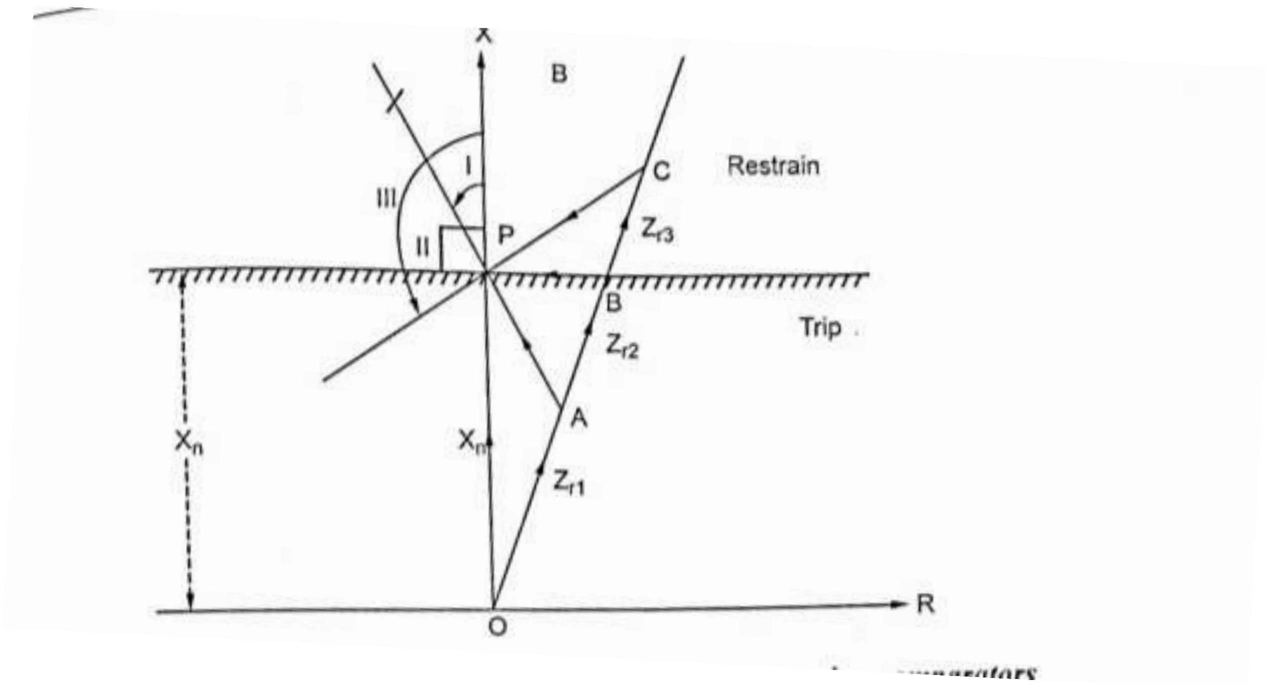
12. With a neat sketch discuss in detail about the synthesis of Reactance relay using phase comparator? (May-2017)

SYNTHESIS OF REACTANCE RELAY USING COSINE TYPE PHASE COMPARATOR

The synthesis of a reactance relay using a phase comparator is depicted in Figure 4.24. The reactance relay to be synthesized has a setting of jX_n. Thecharacteristic to be synthesized is thus a straight line parallel to the R-axis (abscissa), with an intercept of $|X_n|$ on the X-axis (ordinate).

Let the impedance of the relay be Z_{r1} which lies within the trip region at point A. Let construct the phasor (X_n -Z_{r1}) represented by line AP. (X_n - Z_{rl}) leads X_n by an angle which is definitely less than 90° is clearly depicted.

Now, as the impedance seen by the relay moves towards the boundary of the trip region, the angle between (X_n- Z_{r1}) and X_n approaches 90°. When the impedance lies on the boundary, the angle becomes exactly equal to 90°. For all points lying in the restraining region, the angle becomes greater than 90°.



$$OP = |X_n| = setting$$

$$OA = |Z_{r1}| \rightarrow Trip \qquad AP = |X_n - Z_{r1}|$$

$$OB = |Z_{r2}| \rightarrow Threshold \qquad BP = |X_n - Z_{r2}|$$

$$OC = |Z_{r3}| \rightarrow Restrain \qquad CP = |X_n - Z_{r3}|$$

$$Arg\frac{|X_n - Z_{r1}|}{|X_n|} = \angle OPA \angle I < 90° \qquad \rightarrow Trip$$

$$Arg\frac{|X_n - Z_{r2}|}{|X_n|} = \angle OPB\ \angle\ II = 90° \qquad \rightarrow Threshold$$

$$Arg\frac{|X_n - Z_{r3}|}{|X_n|} = \angle OPC\ \angle\ III > 90° \qquad \rightarrow Restrain$$

Trip law

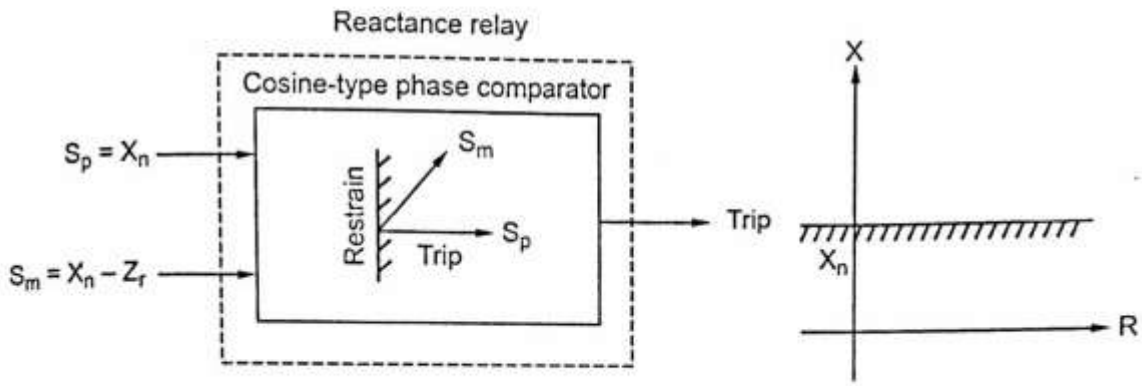
$$If \quad Arg\frac{|X_n - Z_r|}{|X_n|} < 90° \qquad ; then\ trip$$

Similar analysis is shown in fig 4.25, the impeadance of the relay lies to the left of the jX_nphasor, the angle between $(X_n - Z_{r1})$ and $X_n$is greater than -90°, as long as the impeadance falls within the trip region. It is exactly equal to 90° for impeadance lying on the boundary and is less than -90° for all impeadances lying in the restraining region to the left of the jXnphasor.

Note that $Z_{r1}I_r$ is nothing but the voltage at the relay location, i.e. V_r

Thus, the final inputs to the cosine comparator for synthesis of reactance relay are

S_p = XnIr and Sm = $(X_nI_r - V_r)$



$X_nI_r=S_p$

$(X_n-Z_r)I_r=X_nI_r-V_r=S_m$

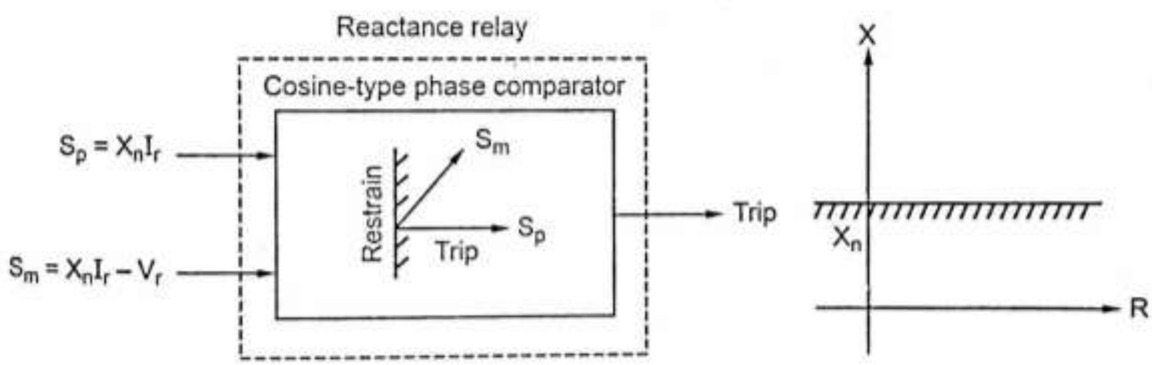


Fig.4.26. Deriving practical signals for reactance relay synthesis using comparator

13. With a neat sketch discuss in detail about the synthesis of Impeadance relay using amplitude comparator?

SYNTHESIS OF IMPEDANCE RELAY USING AMPLITUDE COMPARATOR

The impedance relay is inherently based on an amplitude comparator. If the magnitude of the relay impedance $|Z_r|$ is less than the setting of the relay $|Z_n|$, then the relay issues a trip output. Thus, the simple impedance relay can be most easily synthesized by an amplitude comparator with the following signals

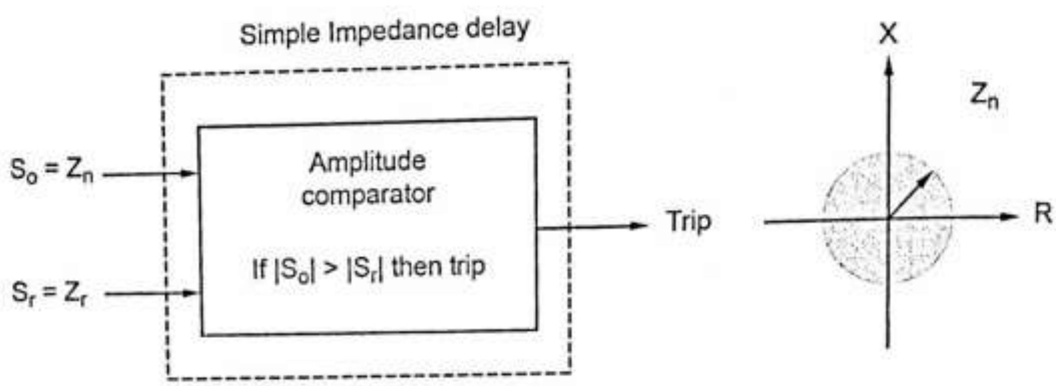
Operating Signal $S_0 = Z_n$

Restraining Signal $S_r = Z_r$

In order to make the inputs suitable for driving an electronic amplitude comparator circuit multiply each of them by Ir to get the modified signals as shown in the figure 4.27

$S_0 = Z_n I_r$ and

$S_r = Z_r I_r = V_r$



$S_0=Z_nI_r$

$S_r=Z_rI_r=V_r$

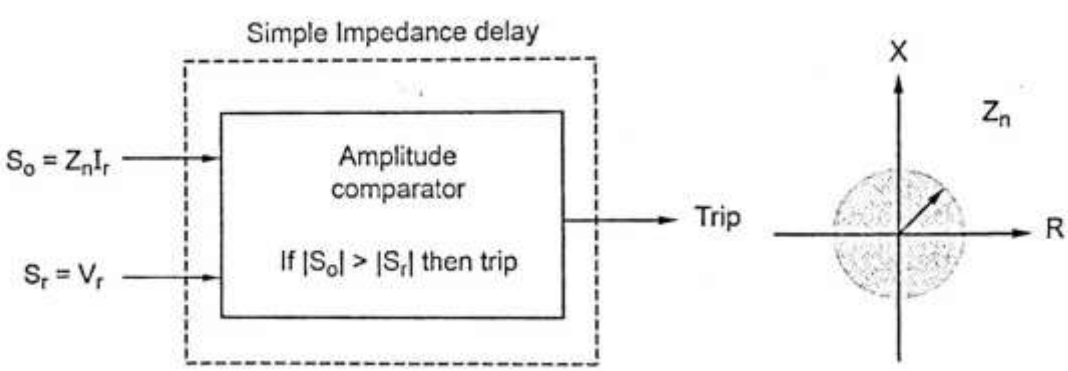


Fig.4.27. Synthesis of impedance relay using amplitude comparator

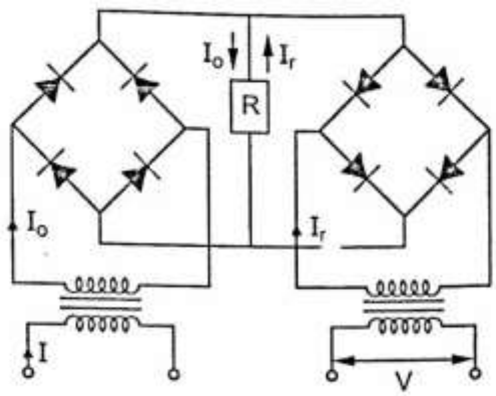


Fig. 4.28. Static impedance relay using amplitude comparator

Rectifier bridge - current comparator is used to realise an impedance relay characteristic. Since it is an amplitude comparator, I is compared with V. I is an operating quantity and V the restraining quantity. As the rectifier bridge arrangement is a current comparator, it is supplied with the operating current I_0 and restraining current Ir, as shown in Figure 4.28. I_0 is proportional to the load current I, and Ir is proportional to the system voltage V.

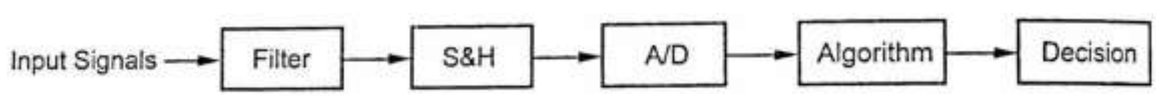
14. Explain the block diagram of numerical relay with necessary diagrams? (APRIL/MAY-2017)(Apr/May 2018)

<u>NUMERICAL RELAY- BLOCK DIAGRAM</u>

Numerical relay is the relay in which the measured AC quantities are sequentially sampled and converted into numerical data that is mathematically and/or logically processed to make trip decisions.

A numerical relay consists of the following main subsystems

1. Microprocessor
2. Analog input system
3. Digital output system
4. Power supply

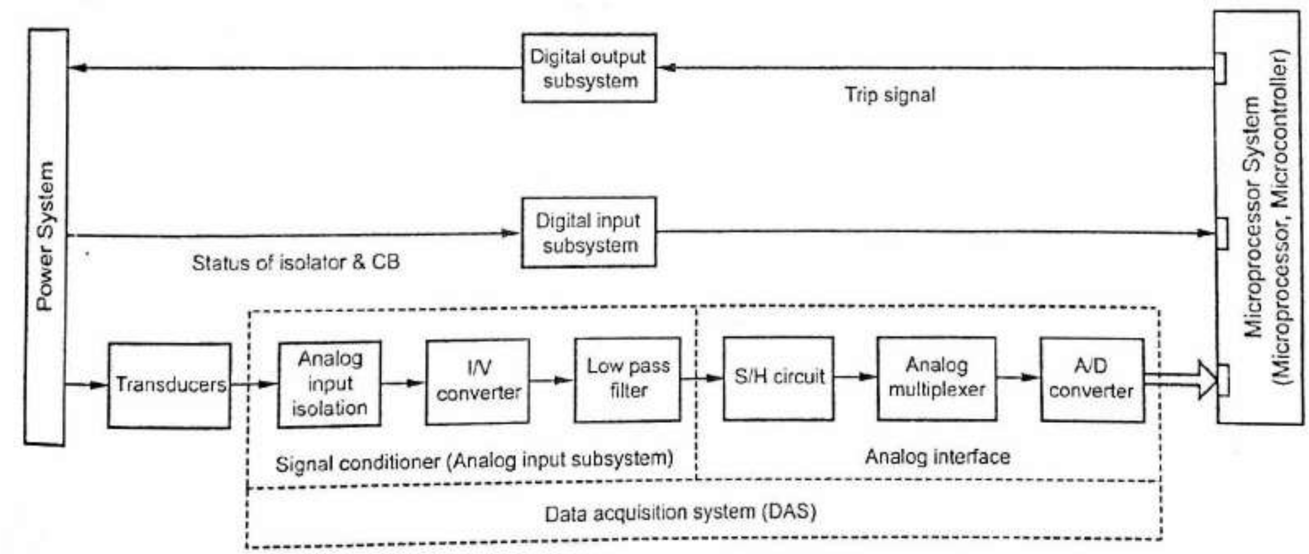


S & H - Sample and Hold, A/D - Analogue to digital converter

Fig. 4.43. Block diagram of a typical digital/numerical relay

The generalized numerical relay concept is directly derived from open system relaying - different relay functions can be obtained from the same hardware just by modifying microprocessor programming.

The following hardware modules and functions constitute the generalized numerical relay. Figure Below shows the detailed block diagram in numerical/digital relay.



Block diagram of typical Numerical relay

- Numerical relays operate on sampled signals and adopt digital computations.
- Sampling is the process of converting analog input signals, such as current and voltage, into digital input signals.
- These analog input signals, in case of electromechanical and static relays, are directly fed into the electromagnetic winding or electronic circuits.
- The microprocessor containing the relay algorithm is the controller of the relay.
- The microprocessor most often performs all control, computation, self-test, and communication functions.
- The algorithm functions as a digital filter to extract the fundamental component of the input signal, based on which the relay operation is carried out.
- The signal from the digital filter is compared with the pre-set threshold in the digital output system. The relay operation is decided based on this comparison.
- Different components of numerical relay are
  1. Isolation transformer and surge protection circuit
  2. Multiplexor and S/H circuits
  3. Anti-Aliasing Filters
  4. Digital Input and Output systems
  5. Central Processing unit
  6. Event Storage system
  7. Signal conditioning circuit

8. Communication Peripherals
9. Power Supply Block
10. Sampling Clock

- **Isolation transformer and surge protection circuit**
  Since the digital circuits are highly vulnerable to switching and lightening surge therefore, proper isolation of the circuits with isolation transformer and surgeprotection circuit is required.
- **Multiplexors and S/H Circuits**
  Multiplexors and sample and hold (S/H) circuits are required for converting the analog signals to digital. The widely accepted Shannon's sampling theorem is used for sampling the analog signal.
- **Anti-Aliasing Filter**
  The anti-aliasing filters are basically low pass filters are basically low pass filters which block unwanted frequencies.
- **The Digital input output system**
  This system actually gathers data and status reports of C.B. contacts status, other relay states, reset signals etc. Also the output systems generate and provide the tripping, alarm and any other control signal.
- **Central Processing Unit**
  It is the core component of the system which performs all the logics andalgorithms regarding different characteristics, maintains timing function andcommunicates with the external device. Therefore, this the most vital block of the numerical system.
- **Event Storage System, RAM, ROM, EPROM**
  The RAM stores the input sample data temporarily and buffer data permanently. It is processed during the execution of relay algorithm. The ROM stores the relay algorithm permanently. EPROM is used to store certain parameters such as the relay

15. With a neat sketch discuss in detail about Numerical over current relay?(Dec 2016)

<u>NUMERICAL OVER-CURRENT RELAY</u>

Overcurrent relays are the least complex type of relay to be implemented by numeric means. Due to the relative slow operation of an overcurrent relay compared with say, a distance relay, there is little performance benefit to be gained from a numeric implementation.

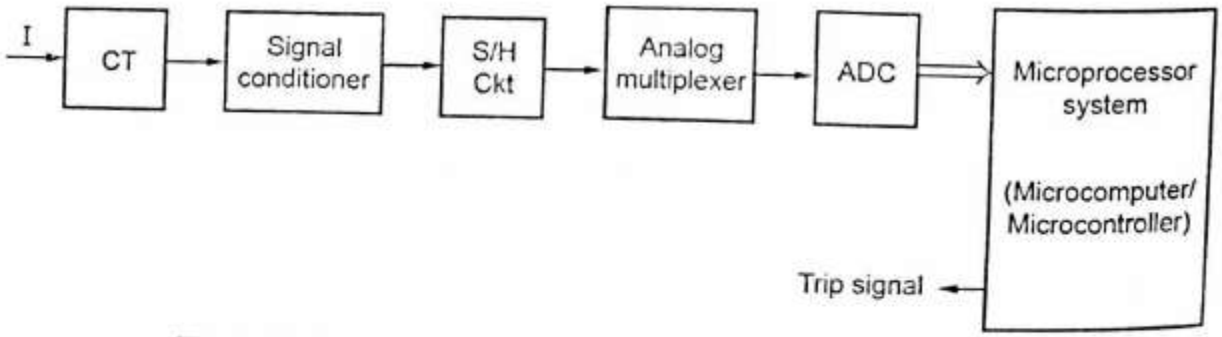


Fig. 4.54. Block diagram of a typical numerical overcurrent relay

The main benefit of numeric overcurrent relays is lower cost and the ability to provide a full range of characteristics in one product, the required characteristic being selected by switches on the relay front panel.

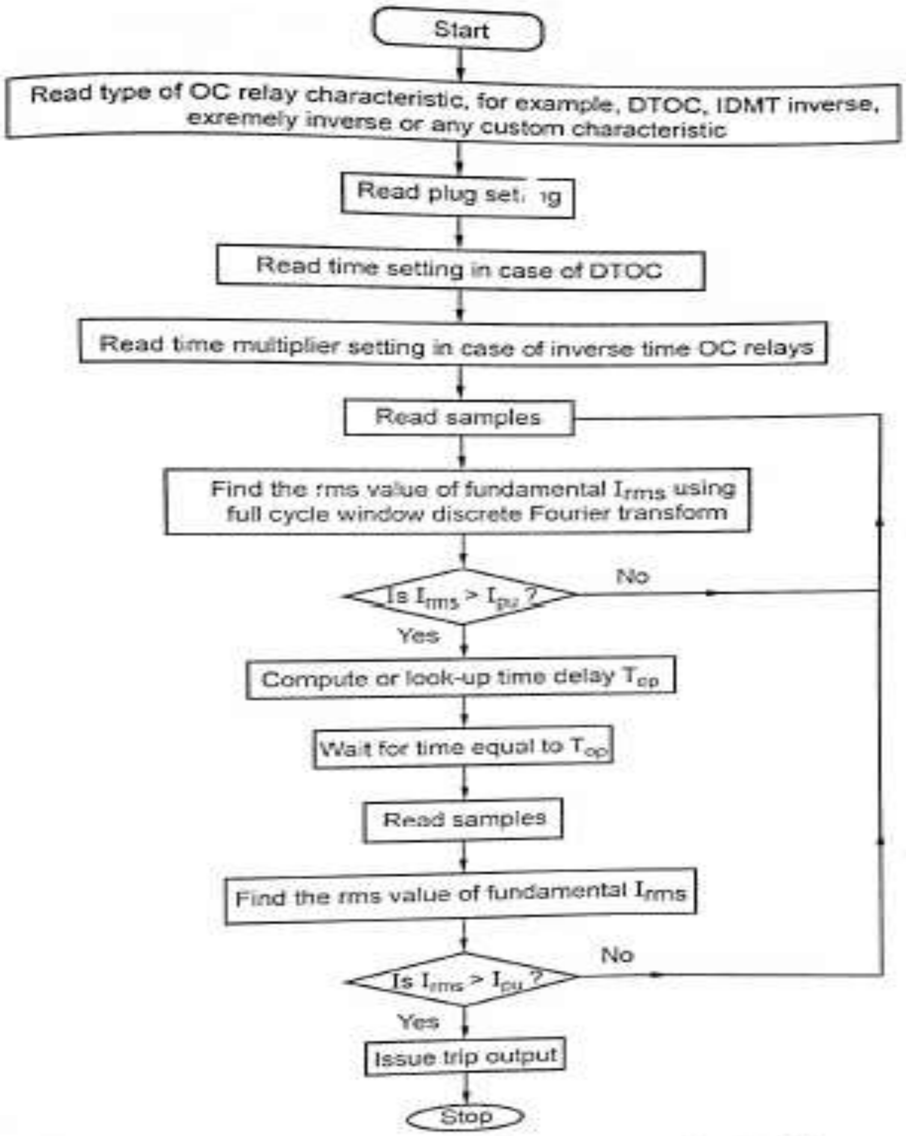


Fig. 4.53. Flowchart for a numerical over-current relay algorithm

- Timer and counter are used to count the number of successive periods of 3.2 ms between peaks.
- When a peak is detected, the counter is reset and begins tocount from zero.
- The nun1ber of 3.2 ms counts is then multiplied by the increment number to form a value which is added to the *trip time register,* this also occurs every time a peak is detected.
- If the trip tin1e register exceeds a value *K* then the relay will trip.
- The value of *K* is effectively the *time setting multiplier* of the relay.
- The characteristic of the relay, i.e. whether it is inverse, very inverse, instantaneous etc., is determined by the look-up table which sets the increment number.

16. With a neat sketch discuss in detail about differential protection of transformer using numerical relay in transformer?(Dec-2016)

TRANSFORMER PROTECTION – CONCEPT

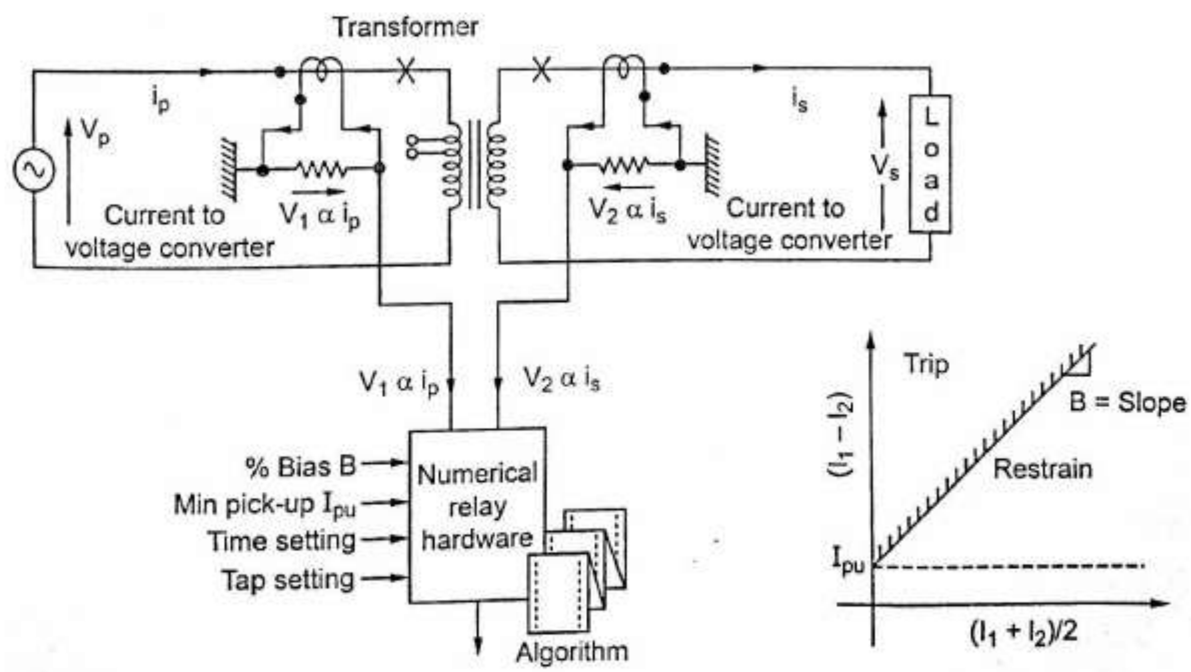


Fig. 4.57. Block diagram of numerical protection of transformer

The conceptual block diagram for numerical protection of a transformer is presented in Figure 4.57. The hint is to estimate the phasor value of the current. on both sides of the transformer and find the phasor difference between the two. If the magnitude of this difference is substantial, an internal fault is indicated and the tripsignal should be issued.

The above is a description of the simple differential scheme. Therefore, the numerical relay algorithm should be made to implement the percentage differential relay.

Algorithm for percentage differential relay will consist of the following steps

i. Read percentage bias *B* and minimum pick-up Ipu
ii. Read i_p samples -> Estimate phasors I_p using any technique.
iii. Read i_s samples -> Estimate phasors I_s using any technique.
iv. Compute spill current $I_{spill} = I_p - Is$.
v. Compute circulating current I circulating $= (I_p + I_s)/2$.
vi. If $I_{spill} > (B\, I_{circulating} + I_{pu})$ then trip, else restrain.

NUMERICAL DIFFERENTIAL TRANSFORMER – PROTECTION

In differential relay, the currents are summed up, which enter and leave the equipment, and any difference is then taken as being due to an internal fault.

The conventional differential protection of power transformers consists in converting the primary and secondary line currents to a common base by using appropriately connected CTs of suitable ratios and by comparing these currents.

During normal operating conditions:

The difference between these currents is small, resulting from the normal magnetizing current and small CT errors. This difference during external faults can be quite large because of the difference in the dynamic behavior of the CTs on the two sides of the transformer.

During a winding internal fault:

The difference in current may not be very large, if only a small portion of the winding is shorted. The value of bias in the differential relay is chosen to accommodate the CT mismatch, the CT errors under dynamic conditions and relay errors. Allthese factors are assumed to cause an unbalance of currents in the same direction for the purpose of calculating the bias. The large bias thus determined makes the relay insensitive to low level winding faults in the transformer.

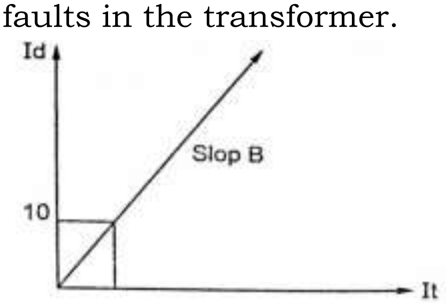


Fig. 4.58. Differential Relay Characteristics

- A relay characteristic is shown in Figure 4.58. Slope B of the operating characteristic is selected to make the relay insensitive to the CT mismatch and the dynamic errors.

- In order to obtain the slope, the maximum estimated CT mismatch and the dynamic errors (both in percentages) are added and the percentage bias is chosen a little above the figure to allow a margin for the bias-related errors of the relay and other minor factors.
- The relay pick-up (Io) is chosen on the basis of the usual magnetizing currents of the transformer. An appropriate allowance for the pick-up-related errors of the relay and other minor factors is made.
- The CT mismatch is the per unit mismatch in the CT secondary currents caused by a lack of match in the ratios of the CTs on the two sides of the transformer.
- In order to eliminate the effect of harmonics and noise in the currents, the differential frequency components are extracted by using digital filters and then used to the relay operation logic.
- The relay calculates the second and fifth harmonics of the differential current as also the harmonic restraint factor H_F from their magnitudes by using the following definition

$$\boldsymbol{H_F} = \frac{\text{Second harmonic component} + \text{Fifth harmonic component}}{\text{Fundamental frequency component}}$$

- These pertain to the differential current. The relay restrains if HF exceeds a selected threshold value. This threshold value is chosen so as to stop tripping on magnetizing in-rush currents and over-excitation conditions.
- For the extraction of different frequency components of the differential and through currents, a simplified cosine transform algorithm is used.
- In the filter algorithm, instantaneous real components obtained are rectified and conveyed over a period of half-cycle or eight sampling instants.

As an example, we can consider a 50 MVA, 11/130 KV, delta/wye transformer with CTs shown as connected in Figure 4.59. Let the pick-up current be 5 per cent and the bias 25 per cent.
The flow chart for the relay application is shown in Figure 4.60.

For modern transformer core materials, the value of the second harmonic component of magnetizing in-rush current is at least 20 per cent of the fundamental frequency component. Hence, even assuming a negligible fifth harmonic component, the minimum value of the restraint factor has to be 20 percent

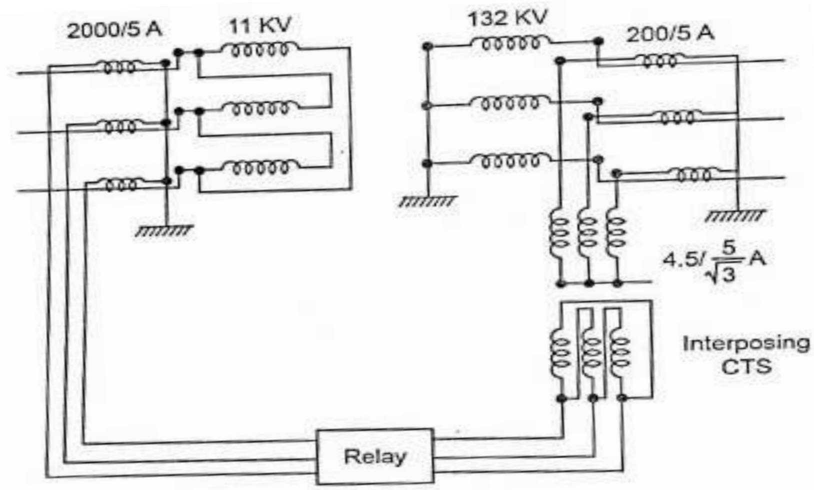


Fig. 4.59. Differential Relay Connection

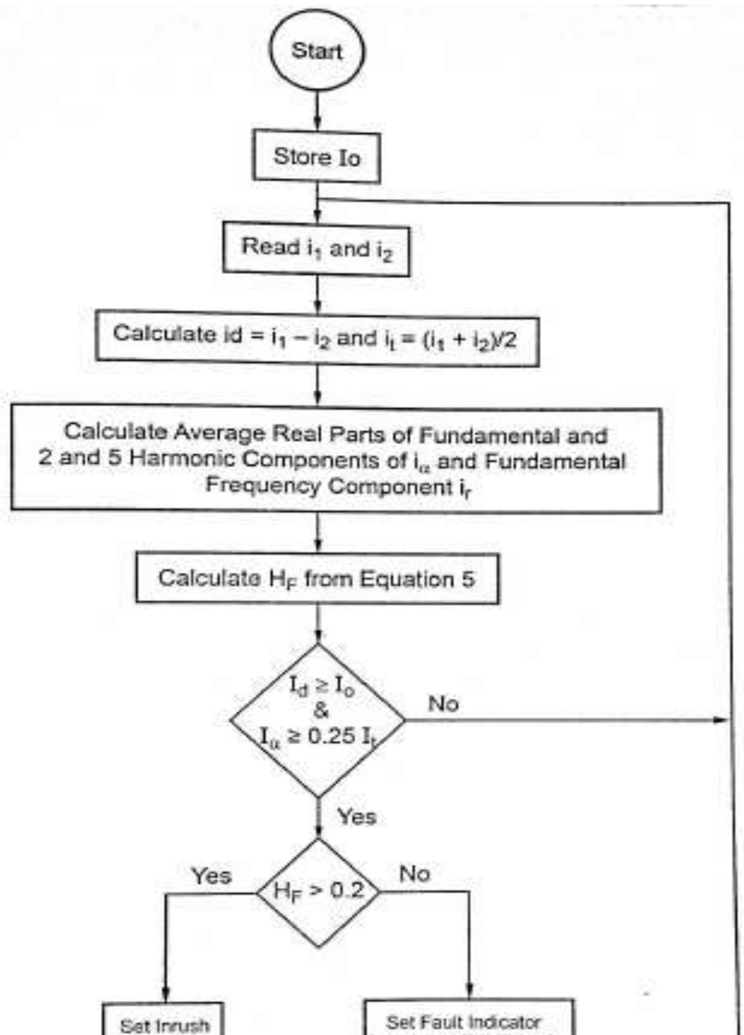


Fig. 4.60. Flow Chart for the relay application – Differential

17. With a neat sketch discuss in detail about distance protection of transmission line using numerical relay in transformer?

NUMERICAL DISTANCE PROTECTION OF TRANSMISSION LINES

Numeric distance relays differ from more conventional static types in that they calculate an actual numeric value for the apparent impedance at the relaying point This impedance is subsequently compared against an impedance plane-based characteristic in order to make a relaying decision. In static distance protection, e.g. by using a block-average comparator, the relay functions by directly combining the voltage and current inputs in the comparator to form the relaying decision.

Advantages apply to the numeric relay distance protection

- Since both the phase and amplitude information of the input signals areused,the security of the relay is higher than if only, say, the phase information is used;
- Any shape of characteristics can be easily programmed into the relay;
- Zones of protection are easily incorporated since, once the impedance has been calculated, extra zones may be added with little processing penalty;
- The characteristic may be set with ohmic values, not K values, thus simplifying commissioning.

Distance protection is a widely used protective scheme for the protection oftransmission and sub-transmission lines. It employs a number of distance relays which measure the impedance or some components of the line impedance at the relaylocation. Since the measured quantity is proportional to the distance (line-length)between the relay location and the fault point, the measuring relay is called a distance relay.

A distance protection scheme which incorporates numerical distance relays forthe protection of lines is known as a numerical distance protection scheme or numerical distance protection.

In a numerical distance relay, the analog voltage and current signals monitored through primary transducers (VTs and CTs) are conditioned, sampled at specified instants of lime and converted to digital form for numerical manipulation, analysis display and recording. The voltage and current signals in the form of discrete numbers are processed by a numerical filtering algorithm to extract the fundamental frequency components of the voltage and current signals and make trip decisions.

The extraction of the fundamental frequency components from the complex postfault voltage and current signals that contain transient dc offset component and harmonic frequency components, in addition to the power frequency fundamental components, is essential because the impedance of a linear system is defined in terms of the fundamental frequency voltage and current sinusoidal waves.

The numerical filtering algorithms based on DFT. FWHT, RHT and BPF can be used for extraction of the fundamental frequency components of the voltage and current signals.

Using the computed values of ***R*** and X the relay examines whether the fault point lies within the defined protective zone or not. If the fault point lies in the protective zone of the relay, the relay issues a trip signal to the circuit breaker.

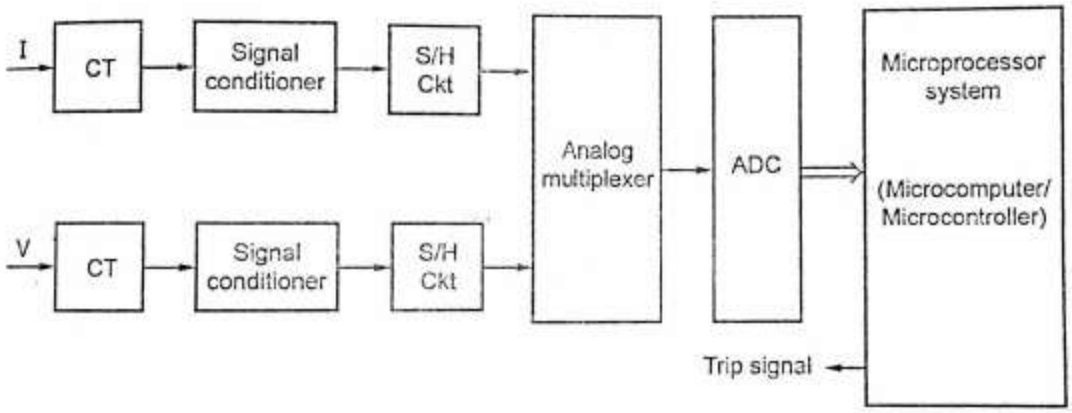


Fig. 4.61. Block diagram of a typical numerical distance relay

Important Questions:

1. Write in detail what is static relay with the help of block diagram? (refer key notes)
2. Write short notes on amplitude comparator and phase comparators(refer key notes)
3. Explain in detail about numerical relay? Also explain numerical over current relay with flow chart (refer key notes)
4. Explain the protection of transformer using numerical relay by differential protection (refer key notes)

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

1. **What is resistance switching?(Dec-2013)**
   It is the method of connecting a resistance in parallel with the contact space (arc).The resistance reduces the re-striking 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? (May/June 2007).**
   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? (May/June 2013).**
   Arc is a phenomenon occurring when the two contacts of a circuit breaker separate under heavy load or fault or short circuit condition.

5. **List out the methods of arc interruption? (Nov/Dec 2012,May-15).**
   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 re-striking voltage?(May-2017)(Dec-2016)**
   It is the transient voltage appearing across the breaker contacts at the instant of arc being extinguished.

7. **What is meant by recovery voltage? (Nov/Dec 2012), (May/June 2013).**
   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?(May-15)**
   It is the rate of rise of re-striking voltage, expressed in volts per microsecond. It is closely associated with natural frequency of oscillation.

9. **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.

10. **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

11. **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.

12. **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

13. **What is circuit breaker?**
    It is a piece of equipment used to break a circuit automatically under faultConditions. It breaks a circuit either manually or by remote control under normalConditions and under fault conditions.

14. **Write the classification of circuit breakers based on the medium used for arc extinction?(Nov/Dec-12)**
    - Air break circuit breaker
    - Oil circuit breaker
    - Minimum oil circuit breaker

- Air blast circuit breaker
- SF6 circuit breaker
- Vacuum circuit breaker

15. 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.

16. What are demerits of MOCB?

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

17. 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

18. 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.

19. What are the types of air blast circuit breaker?

1) Arial blast type, 2)Cross blast, 3)Radial blast

20. 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

21. 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.

22. What are the characteristic of SF6 gas?

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. What are the indirect methods of circuit breaker testing?

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

24. Give the difference between Fuse, isolator and CB.(May/June13, Nov/Dec-12,May-14)

Fuse

Is a type of low resistance resistor that acts as a sacrificial device to provide over current protection, of either the load or source circuit?

Isolator

Which used to make the circuit are close the circuit without load

Circuit breaker

Circuit breaker is the device used to make the circuit are close the circuit either manually or automatically under up normal conditions.

25. State The Advantage Of Sf6 Circuit Breaker. (May/June-13,May-15)

- Closed gas enclosure keeps the interior dry so that there is no moisture problem.
- SF_6 breakers are totally enclosed and sealed from atmosphere, they are particularly suitable where explosion hazard exists.
- There are no carbon deposits.
- Gives noiseless operation due to its closed gas circuit.
- Due to superior arc quenching property of sf_6 , such breakers have very short arcing time.
- There is no risk of fire as sf6 is non inflammable.
- Dielectric strength of sf6 gas is 2 to 3 times that of air, such breakers can interrupt much larger currents.
- Low maintenance cost, light foundation requirements and minimum auxiliary equipment.

26. Enumerate The Breaking Capacity Of Circuit Breaker. (Nov/Dec 2017)

It is current (r.m.s) that a circuit breaker is capable of breaking at given recovery voltage and under specified conditions (e.g., power factor, rate of rise of restriking voltage).

27. Write the ratings of the circuit breaker.(Dec-2013)

The duties of circuit breaker perform under short circuit,

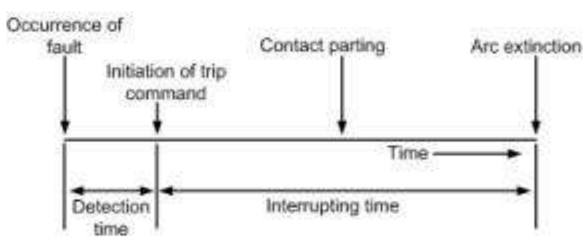
1. It must be capable of opening on the occurrence of fault and clearing the fault.
2. It must capable of being closed on to a fault.
3. It must capable of carrying fault current for short time while another circuit breaker is clearing the fault.

The duties are:

1. Breaking capacity,
2. Making capacity,
3. Short time capacity

28. Define the operating time of circuit breaker.(M-14)

A typical circuit breaker operating time is given in Fig below once the fault occurs, the protective devices get activated. A certain amount of time elapses before the protective relays determine that there is over current in the circuit and initiate trip command. This time is called the **detection time**.



29. What is rupturing capacity? (May-2017)

Breaking capacity of the **circuit breaker** refers to the maximum current in rms value the **circuit breaker** can interrupt. This is also in the order of kA.

30. State the difference between DC and AC circuit breaking?(Dec-2016)

- The amount of energy to be dissipated during the short internal of breaking is high is compared to A.C. breaking.
- The natural current zero does not occur as in the case of A.C. circuit breaking.

31.StateSlepians Theory for arc interruption.(Nov/Dec 2017)

- In this theory the restriping voltage play an important role in ARC extinction.
- After a every zero current, there will be a residual column of ionized gas.
- The rate at which the gap recovers its dielectric strength is compared to the rate at which the re-striking voltage rises.

32. What are the factors responsible for increase in arc resistance?(Apr/May 2018)

(a) Degree of ionization
(b) Length of arc
(c) Cross section of arc

Part -B

1. Explain briefly the theory of ARC interruption? OR
With neat diagram describe the Recovery rate theory energy balance theory of arc interruption in a circuit breaker.(Dec-14)

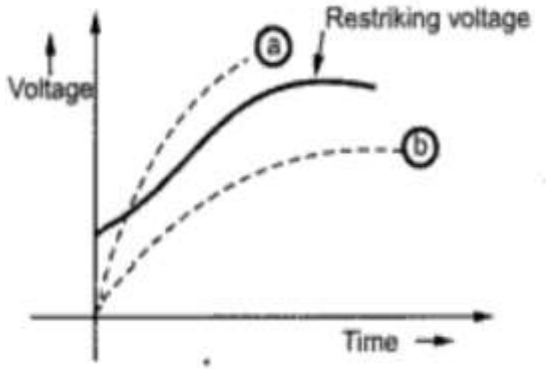
There are two main theories which explain the current interruptions of arc.

- slepias theory (or)Recovery rate theory
- Cassia's theory (or)energy balance theory.

(a) SLEPIANS THEORY

- In this theory the restriping voltage play an important role in ARC extinction.
- After a every zero current, there will be a residual column of ionized gas.
- The rate at which the gap recovers its dielectric strength is compared to the rate at which the re-striking voltage rises.
- If dielectric strength builds up greater then Re-striking voltage , are does not prestrike.
- If dielectric strength is less, the arc will restrike.

  a)Di-electric strength
  b) Re-striking voltage
  c) di- electric strength



From graph

If di-electric strength of contact graph than the re-striking voltage the arc gets extinguished.

Shows the value of re-striking voltage.

Di-electric strength of contact gaps are losses than re-striking voltage

The arc retakes. Limitations of this theory sleepiness)

It does not consider the energy relation in the arc extinction.

It does not cover the arcing phase hence it is in-complete.

(b) Carrier theory (or) energy balance theory.

This theory suggests the restriping of arc (or0 interruption of arc both energy balance process.

If energy input to arc and continuously the arc re-strikes (or) it interrupted.

Following assumption are made in this theory.

As the arc strikes in cross section with its uniform temperature, the energy distribution is uniform. Temperature remains constant.

When the arc strikes cross section ally it will adjust to accommodate to fill the path of arc current. Power dissipation is proportional to cross-sectional area of the arc's.

Energy equations of this theory:

Where,

Q=energy content/length of arc in cm.

E=volts/cm.

N=total power loss/cm.

Arc extinction can be obtained by building di-electric strength of the ARC rapidly at zero current.

This can be obtained by;

i) Lengthening of the gaps.

ii) by using Hydrogen gas b/w the contacts.

iii) by blasting liquids into the contact space will affectingly reduce the Arc's.

2. Derive an expression for restriking rate of rise of recovery voltage? (Dec-2013,May-15) (Dec-2016)

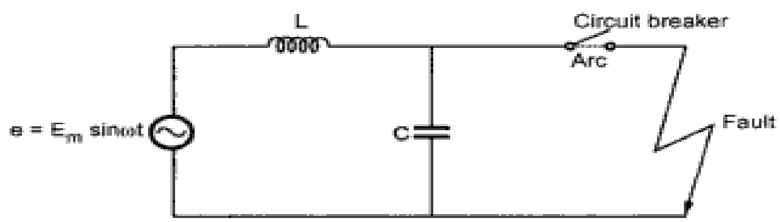
Restriking voltage: It is the transient voltage appearing across the breaker contacts at the instant of arc being extinguished.

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

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. Rate of rise of restriking voltage (RRRv) is the rate at which it is expresses in terms of volts/micro –seconds.
It represents the rate at which the transient recovery voltage.(TRV)is

$$\mathrm{RRRV} = \frac{de}{dt} \text{ volt}/\mu\text{sec}$$

Derivation of restriking voltage;
Consider the circuit shown in the fig.
When current reaches zero at final are extinction a voltage ‘e’ is suddenly impressed across capacitor &therefore it flows across C.B contacts.

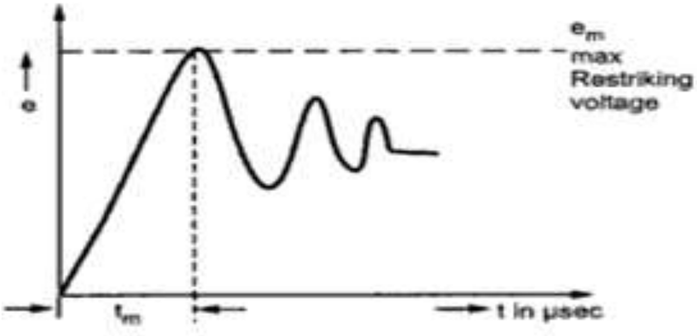


Due to opening of C.B, fault current “I” does not get in jested in capacitor & inductor

$$\therefore \mathbf{i} = \mathbf{i_L} + \mathbf{i_C}$$

$$i = \int e.\,dt + C.\frac{de}{dt}$$

$$\frac{di}{dt} = \frac{e}{L} + C\frac{d^2e}{dt^2}$$



When, t=0 & correspondingly at I=0, &further e=E cosωt
I=will be'

$$i = \frac{E_m}{\omega L}\ sin\omega t$$

After opening of circuit breaker,

$$\frac{\mathrm{di}}{\mathrm{dt}} = \frac{E_m}{\omega L}\omega cos\omega t$$

$$= \frac{E_m}{L}cos\omega t \qquad\qquad at\ t = 0$$

$$\frac{E_m}{L}cos\omega t = \frac{\mathrm{e}}{\mathrm{L}} + \mathrm{C}\frac{\mathrm{d}^2\mathrm{e}}{\mathrm{dt}^2}$$

This is standard equation and solution of this equation is

$$\boldsymbol{e} = E_m\left[1 - cos\left(\frac{t}{\sqrt{LC}}\right)\right]$$

Here ,

- E_M=peak value of Recovery voltage.
- t= time in seconds.
- L=Inductance in Henry's
- C= capacitance in farads.
- e= restriping voltage in volts.

RRRV will be maximum, When its derivative $\frac{\mathrm{d}^2\mathrm{e}}{dt^2} = 0$

$$\boldsymbol{e} = E_m\left[1 - cos\left(\frac{t}{\sqrt{LC}}\right)\right]$$

if "e" is to be maximum

$$cos\left(\frac{t_m}{\sqrt{LC}}\right) = -1 \qquad where\ t = t_m$$

$$\frac{t_m}{\sqrt{LC}} = \pi$$

$\therefore Time\ at\ which\ maximum\ restriking\ voltage\ occurs\ is, t_m = \pi\sqrt{LC}$

And peak value of restriking voltage, $e_m = 2E_m$

Where $E_m$is equal to active recovery voltage (i.e instantaneous value of recovery voltage at current zero).

Now

$$RRRV = \frac{de}{dt} = \frac{d}{dt}\left[E_m\left(cos\left[\frac{t}{\sqrt{LC}}\right]\right)\right]$$

$$RRRV = \frac{E_m}{\sqrt{LC}}sin\ \frac{t}{\sqrt{LC}}$$

$$maximum\ RRRV = \frac{E_m}{\sqrt{LC}}$$

when

$$sin\ \frac{t}{\sqrt{LC}} = 1$$
$$\frac{t}{\sqrt{LC}} = \frac{\pi}{2}$$

Peck Re-striking voltage is equal to,

$$\mathrm{e = Em(1 - cos\pi) = 2.Em}$$

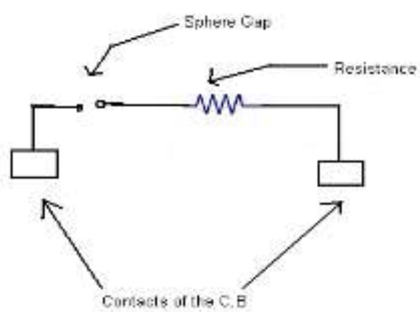
It is observed from eqn, that,

$$\mathrm{(RRRVMAX)} = 2\pi Emfn$$

Maximum rate of rise of re-sticking voltage is proportional to the natural frequency of the circuit. Greater the fn, greater the rate of rise of T.R.V.

3. **What is resistance switching? (Nov/Dec 2017)**

To reduce Re-striking voltage, RRRV and severity of the transient oscillation, a resistance is connected across the contacts of the circuit breaker. This is known as resistance switching.



The resistances may be automatically switched in with the help of a sphere gap. Resistance switching is of great help in switching out capacitor current or low inductive current.

This process is mainly used in reducing or avoiding the restriking voltage. Equivalent analysis of the circuit is given by circuit analysis for resistance switching is given as.

Equivalent circuit:

Voltage equation is gn by,

$L\frac{\mathrm{di}}{\mathrm{dt}} + \frac{1}{\mathrm{C}}\int \mathrm{ic} * \mathrm{dt} = \mathrm{Eand}$ $\quad$ $i = I_C + i_r$

Above equ becomes,

$$L\frac{\mathrm{d(ic + iR)}}{\mathrm{dt}} + \mathrm{Vc = E}$$
$$\mathrm{L}\ \frac{\mathrm{dic}}{\mathrm{dt}} + \mathrm{L}\frac{\mathrm{dir}}{\mathrm{dt}}\mathrm{Vc} = E$$

$$\text{Ic} = \frac{\text{dr}}{\text{dt}} = \frac{\text{d(C.Vc)}}{\text{dt}}$$

Therefore,

$$\frac{\text{dic}}{\text{dt}} = \frac{\text{d}^2\text{(C.Vc)}}{\text{dt}} = \text{C.}\frac{\text{d}^2\text{Vc}}{\text{dt}^2}$$

$$\frac{\text{dic}}{\text{dt}} = \frac{\text{d}(\frac{\text{Vc}}{\text{R}})}{\text{dt}} = \frac{1}{\text{R}}\frac{\text{dVc}}{\text{dt}}$$

Substuting these values in the main equation we get,

$$\text{LC}\frac{\text{d}^2\text{Vc}}{\text{dt}^2} + \frac{\text{L}}{\text{R}}.\frac{\text{dVc}}{\text{dt}} + \text{Vc} = \text{E}$$

Taking laplace transformer we get,

$$\text{LCS2.Vc(s)} + \frac{\text{L}}{\text{R}}\text{SVc(s)} + \text{Vc(s)} = \frac{\text{E}}{\text{S}}$$

At (Vc, t)=0

$$\text{LcVc(s)}\left[\text{s}^2 + \frac{1}{\text{RC}}\text{S} + \frac{1}{\text{LC}}\right] = \frac{\text{E}}{\text{S}}$$

$$\text{Vc(s)} = \frac{\text{E}}{\text{SLC}\left[\text{s}^2 + \frac{1}{\text{RC}}\text{S} + \frac{1}{\text{LC}}\right]}$$

Root of Quadratic equation in the denominator should be real. For this the following conditions should be satisfied.

$$R^2 \leq \frac{\text{Lc}}{4\text{c}^2}; \text{R} \leq \frac{1}{2}\sqrt{\frac{\text{L}}{\text{C}}}$$

If the values of the Resistance connected across the contacts of C.B is equal to 'or' less than the $1/2\sqrt{\frac{\text{L}}{\text{C}}}$, there will not be any transient but.

If the 'R' value is greater then $1/2\sqrt{\frac{\text{L}}{\text{C}}}$ transient oscillations may occur.

If, $R = 1/2\sqrt{\frac{\text{L}}{\text{C}}}$,it is a Critical resistance.

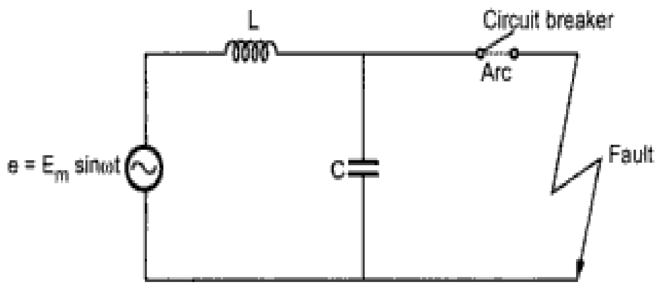
For a Damping oscillation, the frequency values are given by,

$$F = \frac{1}{2\pi}\sqrt{\frac{1}{\text{LC}} - \frac{1}{4\text{c}^2\text{R}^2}}$$

4. **Briefly describe current chopping?(Dec-2013,May-15)(May-2017)(Nov/Dec 2017)**

It's a phenomenon of current interruptions before the natural current zero is reached. Current chopping mainly occurs in abed because they retain the same extinguishing power irrespective of magnitude of current interrupted.

When braking low current (Tr. Magnetizing current) with breakers the powerful demonizing effect of air blast cause the current to fall abruptly to zero. well before the natural current zero reached .this phenomena is current chopping it produced high voltage transient occur the contacts of CB.
Current chop occur at current i.



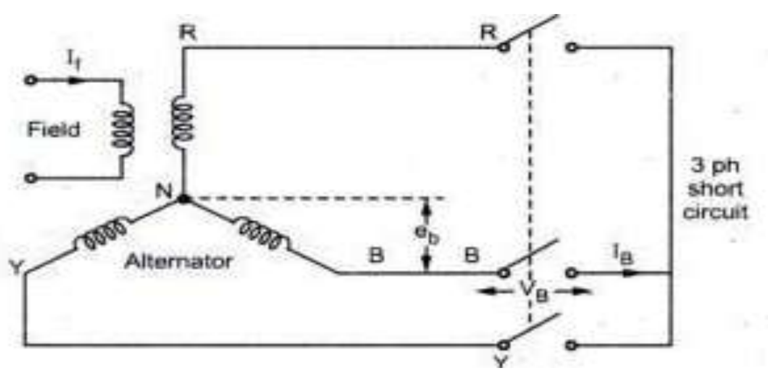
Energy stored in inductance is $1/2LI^2$ this energy will be transferred to the capacitance C is charging the latter is prospective voltage e is very high as composed to dielectric strength gained by the gap. The demonizing force still in action .therefore chop occurs gain but arc current this time is smaller than the previous case.

This induce a low prospective voltage to re-ignite the arc .infect ,several chops may occurs until or low enough current is interrupt which produce insufficient induced voltage to restripes across the breaker gap.

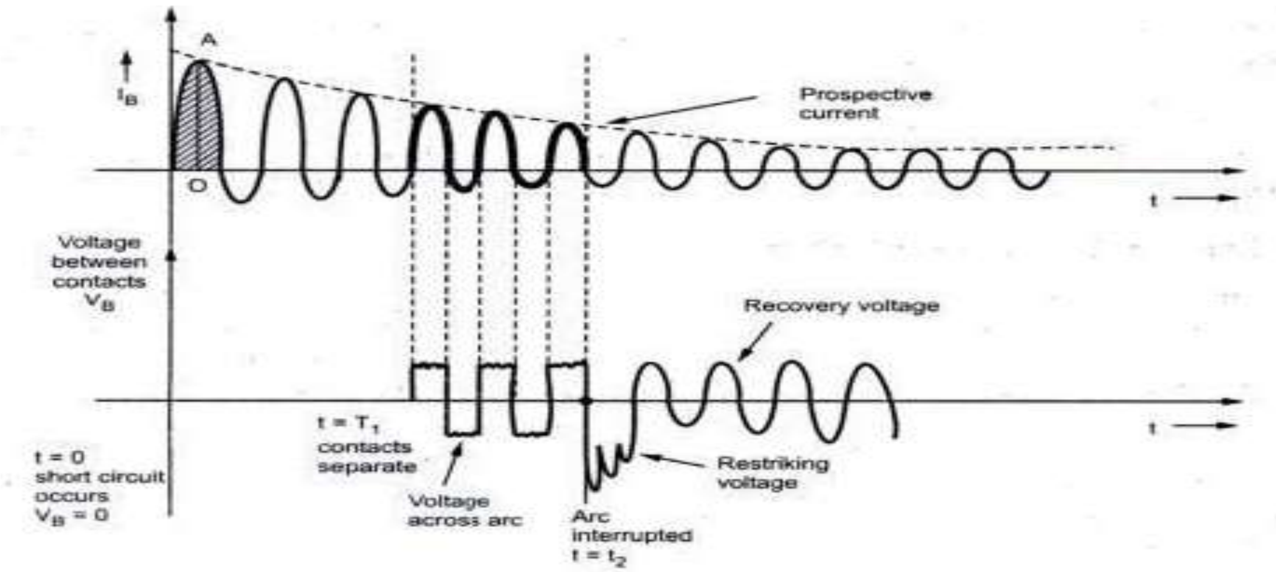
Excessive voltage surge due to current chopping are prevented by starting the contact of breaker with a resistor (resistance switching)

5. What is A.C. circuit breaking?

The arrangement of C.B connected to a generator on No-load at rated terminal voltage was considered as gnu below.



When "B" phase voltage with respect to neutral is zero, the C.B is closed. at this instant, B phase current will have maximum D.C component.
It 's current wave form will be un-symmetrical about normal zero- axis.
This is depicted in fig 4.5.



Current and Voltage during fault clearing:

- The generator is on No Load before (t=0). Hence the current is zero before (t=0), the S.C is applied & the current increases to a high value during first quarter cycle.
- The peak of current loop is OM. This is the maximum value of intendances current during the S.C.
- The instantaneous value of the first major current loop is called Making current.
- Contact of circuit breaker separates after form cycle since the relay and the operating mechanism takes at least a couple of cycle.
- Assuming that C.B contacts separate at (t=T1)
- The r.m.s value of short circuit current at the instant of contact getting separated is called as “Breaking Current”.

After the separation of contact of C.B and are is drawn b/w the contacts. They are current various sinusoids dally for few cycle.

At =T2, a particular current the dielectric strength of the ARC space builds cup sufficiently to present the confirmation of the ARC.

The Power frequency system voltage appearing b/w the pole after ARC extrication is called Recovery voltage.

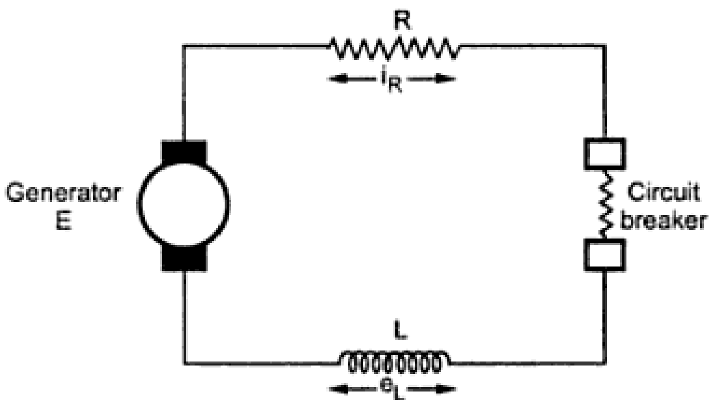
If contract space breakdown with in a period of $(1/4)^{th}$of a cycle of initial arc extinction, this phenomenon is called “Re-ignition”

If contact space breakdown occurs after one forth of a cycle, the phenomenon is called as “RESTRIKE”

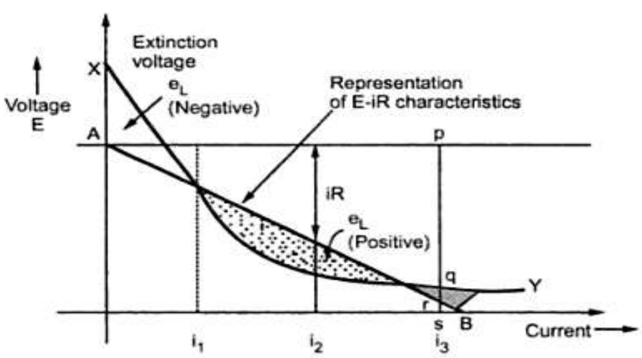
6. What is D.C circuit breaking?

D.C Circuit breaker can be explained by considering the GENERATOR ARRANGEMENTS. as given below.

D.C. circuit breaking:



Waveform:

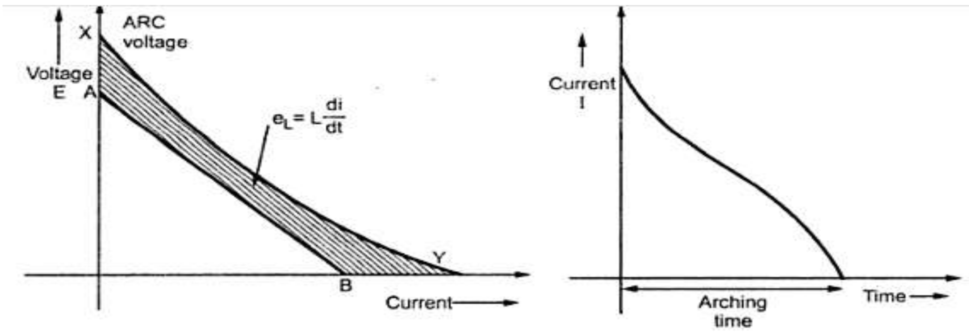


When C.B starts opening it carriers the load current[$\mathbf{I} = \frac{\mathbf{E}}{\mathbf{R}}$]The current is shown to reduce to i_1,$i_2$and $i_3$respectively.

'Pr' portion represents voltage drop iR undersea 'qs' represents are voltage which is greater than available voltage.

The arc becomes unstable &the difference in voltage is greater than available voltage. The arc becomes unstable &the difference in voltage is supplied by inductance 'L' across which the voltage is$e_L = L.\frac{di}{dt}$

For decreasing values of current this voltage is –ve&according to Lenz's law it tries to maintain the arc. The operation in case of d.c. circuit breakers is said to be ideal if the characteristics of the arc voltage goes above the curve AB, even at the current region of $i_1$and i_2 as shown in fig given below.



It can be seen that arc voltage is greater [E-IR] &the balance B/W the voltage is supplied by the voltage across the inductance $e_L$which is proportional to rate of change of current $\frac{di}{dt}$.

Thus the function of C.B is to raise the arc characteristics without affecting its stability.

Major problem of D.C. circuit breaking ARC;

- ✓ The amount of energy to be dissipated during the short internal of breaking is high is compared to A.C. breaking.
- ✓ The natural current zero does not occur as in the case of A.C. circuit breaking.

7. Explain how the arc is initiated and sustained when the circuit breaker contacts breaks.(nov/dec 2011)

ARC PHENOMENON:

1. When the contacts of a circuit breaker are separated under fault conditions, an arc is struck between them.
2. An instant when the contacts being to separate, the area of contacts decrease which will increase the current density and hence rise in temperature. The heat which is produced in the medium is sufficient enough to ionize air or oil which will act as conductor. Thus an arc struck between the contacts.
3. The potential difference period between the contacts is sufficient to maintain the arc. The arc provides a low resistance path and consequently the current in the circuit remains uninterrupted as long as the arc persists.
4. During the arc period, the current flowing between the contacts depends upon the arc resistance. If the resistance of the arc increase, the current flowing between the contacts decrease. The arc resistance depends on the flowing factor

(a) Degree of ionization:

If the number of ionized particles between the contacts arc less, then the arc resistance increases.

(b) length of arc:
If the length increases, the arc resistance increases.
(c) cross section of arc:
If the area of cross section of the arc decreases, the arc resistance increases.

Initiation of Arc:
There are two methods by which electrons are emitted from the metal of the contacts and initiate an arc in a circuit breaker.

- By high voltage gradient at the cathode, resulting in field emission.
- By increasing of temperature, resulting in thermionic emission.

(a.) By high voltage gradient or field emission:
If any fault occurs, the moving contacts get separated from each other, the area of contacts and pressure between the separating contacts decrease. A high fault current causes potential drop (10^6 V/cm) between the contacts which will remove the electrons from cathode surface. This method is termed as "field emission".
(b.) By increasing of temperature or thermal emission:
If the contacts are separated, the contacts area decreases which will increase the current density and consequently the temperature of the surface which will cause emission of electrons termed as "thermionic emission".
Mostly, the contacts in the circuit breaker are made up of copper which is having less thermionic emission.

Maintenance of arc :
The electrons travel towards anode collides with another electron to dislodge them, ionize the medium and thus arc is maintained after field emission increases.
The ionizing is facilitated by,

- High temperature of the medium around the contacts due to high current densities. Thus the kinetic energy gained by moving electrodes is increased.
- The voltage gradient increased the kinetic energy of moving electrons
- The length of the path increased then the number of neutral molecules increases, the increase free path movement of the electrons

Thermal ionization:
When the temperature of a gas reaches very high, there is always a high probability that the kinetic energy of any particles will be great enough to cause the ionization of another such particle when a collision occurs between them. This process is called thermal ionization.

Electric Arc:

The electric arc is a self-sustained discharge of electricity between electrodes in gas or vapour. Which has a voltage drop at cathode of the order of minimum ionization or minimum existing potential of gas or vapour?

Fig depicts the temperature zones in the arc. When D.C voltage applied to electrons, placed at a small clearance is gradually increased, a flow of current takes place through gas. This phenomenon is called discharge in gas.

The volt-ampere characteristic has several distinct classified as glow discharge, town send discharge and arc discharge. During arc discharge the voltage across the electrode is low and current is high. The current is limited by external impedance. The voltage across arc decreased as the current increases. The arc is self-sustained discharge.

Static characteristic of arc:

Fig (b) shows the voltage across arc reduces as the current increased. The volt-ampere characteristic of a steady arc is given by $V_{arc} = A + Bd + (\frac{c+dD}{i_{arc}})$

Where

d- length of arc

V_{arc}- voltage across arc

i_{arc}- current in arc

A,B,C,D- constants

A+$\left[\frac{C}{I_{arc}}\right]$ –cathode plus anode voltages the energy dissipated in the steady stated arc in the form of heat is given by

E_{arc}=$V_{arc}i_{arc}$t

Where

E_{arc}- Energy in joules

V_{arc}- Voltage in volts

i_{arc}- Arc current in Amps

t- Duration of arc in sec

8. Explain in detail the various methods of arc extinction in a circuit breaker.(nov/dec 2011,dec-2013,May-15)

Arc extinction:

Factors maintaining the arc between contacts:

When the contacts have a small separation, the potential difference between them is sufficient to maintain the arc. One way to extinguish the arc is separate the contacts to such a distance that potential difference becomes inadequate to maintain the arc.

The ionized particles between the contacts tends to maintain the arc. If the arc path is deionized, the arc extinction will be facilitated. This may be achieved by cooling the arc or by bodily removing the ionized particles from the space between the contacts.

Methods of arc extinction or current interruption:

1. High resistance method
2. Low resistance method or current zero method

1.High resistance method:

Arc resistance is made to increase with time so that current is reduced to a value insufficient to maintain the arc. Consequently, the current is interrupted or the arc is extinguished.

The arc resistance may be increased by

i. Lengthening of the arc
ii. Cooling of the arc
iii. Reducing the cross section of the arc
iv. Splitting the arc

2. Low resistance method or current zero method:

In this method, arc resistance is kept low until current zero where the arc extinguishes naturally and is prevented from restricting in spite of the rising voltage across the contacts. All modern power A.C circuit breaker employ this method for arc extinction.

The real problems in A.C arc interruption is to rapidly deionized the medium between contacts as soon as the current becomes zero so that the rising contacts voltage or ristriking voltages cannot breakdown the space between contacts.

The deionization of the medium can be achieved by.

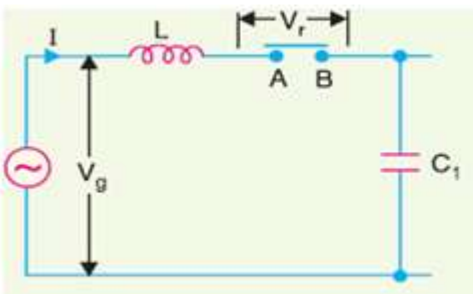
1. **Lengthening of the air gap:**
   By opening the contacts rapidly higher dielectric strength of the medium can be achieved
2. **High pressure:**
   If the pressure in the vicinity of the arc is increased, the density of the particles constituting the discharge also increased. The increased density of particles causes higher rate of dc-ionization and consequently the dielectric strength of the medium between contacts is increased
3. **Cooling:**
   Natural combination of ionized particles takes place more rapidly if they are allowed to cool therefore, dielectric strength of the medium between the contacts can be increased by cooling.

4. Blast effect:

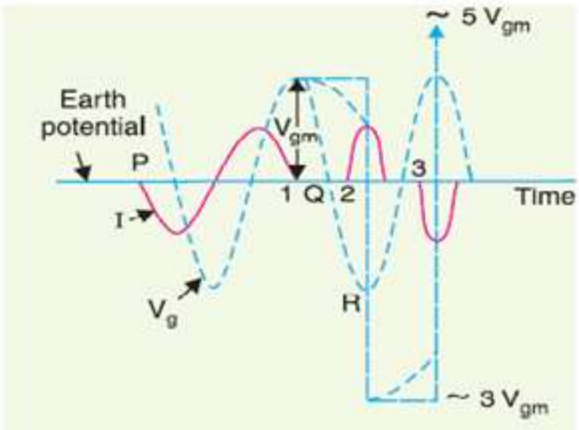
If the ionized particles between the contacts arc swept away and replaced by un-ionized particles, the dielectric strength of the medium can be increased considerably. This may be achieved by a gas directed along the discharge or by forcing oil into the contact space.

9. Explain interruption of capacitive current (May-15)(Dec-2016)(May-2017)

Interruption of capacitive currents is instances of opening of unloaded long transmission line , disconnecting a capacitor bank used for power factor improvement .consider the simple equivalent circuit of unloaded transmission line will actually carry a capacitive current I on the account of appreciable amount of capacitance C between the line and earth.



Suppose that line is opened by the circuit breaker at the instant when line capacitive current is zero. at the instant the generator voltage Vg will be maximum lag behind the current by 90˚.the opening of the line leaves a standing charge on it and capacitor C_1 is charged to V gmax ,the generator end of the line continuous its normal sinusoidal variations. The voltage Vr across the CB will be difference between the voltage on the respective sides. It is initial value is zero and increases slowly in the beginning. but half a cycle latter the potential of the circuit breaker contact A becomes maximum negative which causes the voltage across the breaker Vr become 2Vgmax.this voltage may be sufficient to restrike the arc. two previously separated parts of the circuit will now be joined by an arc of very low resistance. The line capacitance discharge at once to reduce the voltage across the CB.the setting up high frequency transients will be twice the voltage at that instant i.e -4Vgmax.this will cause the transmission voltage to swing to -4Vgmax to +Vgmaxi.e -3Vgmax.



The re-strick arc current quickly reaches its first zero as it varies at natural frequency. The voltage on the line is now -3Vgmax and once again the two halves of the circuit are separated and line is isolated at this potential. After about half a cycle further, the aforesaid events are repeated even on more formidable scale and the line may be left with a potential of 5Vgmax above the earth potential .theoretically this phenomenon may proceed infinitely increasing the voltage by successive increment of 2 times Vgmax.

While the above description relates to the worst possible conditions, it is obvious that if the gap breakdown strength does not increase rapidly enough, successive re-strikes can build up a dangerous voltage in the open circuit's line. However due to leakage and corona loss, the maximum voltage on the line in such cases is limited to 5Vgmax.

10. From the following data of a 50Hz generator: $e.m.f.$ to neutral $7.5kV(rms)$, reactance of generator and connected system 4 ohms, distributed capacitance to neutral $0.01\mu F$ resistance negligible; find (a) the maximum voltage across the contacts of circuit breaker when it breaks a short – circuit current at zero current, (b) the frequency of the transient oscillation and (c) the average rate of rise of voltage up to the first peak of the oscillation.

Given Data:F=50Hz, $e.m.f. = 7.5kV(rms)$,X=4Ω,C=0.01μF

Formula used:$V = \sqrt{2} \times kV$,$f_n = \frac{1}{2\pi\sqrt{LC}}$, $Since\ V_s = v\left(1 - cos\frac{1}{\sqrt{LC}}\right)$

Solution:

$$(a)\quad Active\ recovery\ voltage\ (phase\ to\ neutral)$$

$$V = \sqrt{2} \times 7.5kV$$

$\therefore Maximum\ re - striking\ voltage\ (phase - to - neutral)$

$$= \left(7.5 \times \sqrt{2}\right) \times 2 = 21.2kV$$

$(b) f_n = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{\frac{4}{314} \times \frac{0.01}{10^6}}} = 14.1 kHz$

$(c) \quad Since\ V_s = v\left(1 - cos\dfrac{1}{\sqrt{LC}}\right)$

$\therefore Maximum\ re - striking\ voltage\ would\ occur\ when$

$cos\dfrac{t}{\sqrt{LC}} = -1$

$or \qquad cos\dfrac{1}{\sqrt{LC}} = cos\pi$

$or \quad t = \pi\sqrt{LC} = \dfrac{\pi}{2\,\pi f_n} = \dfrac{1}{2f_n}$

$\therefore Average\ rate\ of\ rise\ of\ re - striking\ voltage$

$= \dfrac{21.2}{2 \times 14.1 \times 10^3} = 600{,}000 kV/s.$

11. A 50Hz 3 phase generator with an earthed neutral has an inductance of $1.58mH$ per phase and is connected to the bus – bars by means of an oil circuit breaker. The capacitance to earth of the circuit between the generator and the breaker is $0.0028\mu F$ per phase. Due to a short on the bus – bars the breaker opens when the rms value of the current is $7000\ amps$. Draw a curve showing the re – striking voltage which appears across the breaker and determine the maximum rate of rise of voltage.

Given data: f=50Hz, L= $1.58mH$, c= $0.0028\mu F$, I= $7000\ amps$.

Formula used: $X = 2\pi fL, V_s = 3.47\sqrt{2}\left(1 - cos\frac{t}{\sqrt{LC}}\right),$

$$V_s = 4.9(1 - cos0.477t)$$

Solution: $Reactance = 2\pi fL$

$$= 2\pi(50)(1.58 \times 10^{-3}) = 0.496\ ohm$$

$$Active\ recovery\ voltage\ (phase - to - neutral\ value)$$

$$= (7000 \times 0.496 \times 10^{-3}) \times \sqrt{2}$$

$$= 3.47 \times \sqrt{2}\ kV$$

$$\therefore\ V_s = 3.47\sqrt{2}\left(1 - cos\frac{t}{\sqrt{LC}}\right)$$

$$= 4.9\left(1 - cos\frac{t}{\sqrt{LC}}\right) kV$$

$$\sqrt{LC} = 2.1 \times 10^{-6}$$

$$When\ t\ is\ \mu - secs,$$

$$cos\frac{t}{\sqrt{LC}} = cos\frac{t}{2.1} = \cos(0.477t)$$

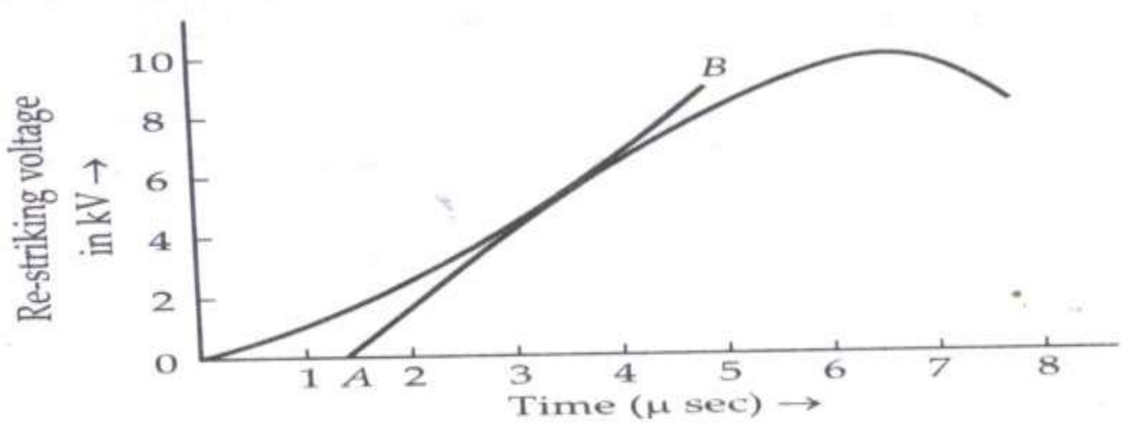
$$\therefore\ V_s = 4.9(1 - cos0.477t)$$

$$where\ V_s\ is\ in\ kV\ and\ t\ in\ \mu - secs.$$

$$V_s = 4.9(1 - cos\varphi)$$

t	$cos\varphi$	$1 -\ cos\varphi$	$V_s = 4.9(1 - cos\varphi)$
0	$cos0°$	$1 - 1 = 0$	0
1.1	$cos30°$	0.134	0.655
2.2	$cos60°$	0.5	2.45
3.3	$cos90°$	0.1	4.9
4.4	$cos120°$	1.5	7.35
5.5	$cos150°$	1.866	8.836
6.6	$cos180°$	2	9.8

Plot a curve with t along $x - axis\ and\ V_s$ along $y - axis$ from the data obtained in the above table. Draw the maximum slope line AB to this curve. The maximum slope gives the maximum $R.R.R.V.$ which is $= 2340V/\mu\ sec$.



12. In a short circuit test, with earthed neutral, on a $132kV\ 3-phase\ circuit\ breaker, the\ p.f.$ of the fault was0.3, the recovery voltage was $0.95\ of\ full\ line\ value$, the breaking current was symmetrical and the re-striking transient had a natural frequency of $16000\ Hz$. Estimate the rate of rise of the re-striking voltage.

Given data: kv= $132kV$,pf=0.3, recovery voltage = 0.95 $of\ \ line\ value$

F= 16000 Hz.

Formula used: $maximum\ voltage\ = \frac{kv}{\sqrt{3}} \times \sqrt{2},\ t = \frac{1}{2f_n} secs$

$Active\ recovery\ votlage\ (line\ to\ neutral)$=$K_2K_3V_{max} \sin\varphi$,

Solution:

Assume the fault is grounded.

$System\ voltage, line\ to\ line = 132kV(rms).$

$$System\ voltage, line-to-neutral\ maximum\ value = \frac{132}{\sqrt{3}} \times \sqrt{2}$$

$$\therefore Active\ recovery\ votlage\ (line\ to\ neutral)$$

$$= K_2K_3V_{max} \sin\varphi$$

$$where\ K_2 = 1, K_3 = 0.95\ and\ sin\varphi = sin(\cos^{-1} 0.3) = 0.954$$

$$V = 0.95 \times \frac{132}{\sqrt{3}} \times \sqrt{2} \times 0.954$$

$$Maximum\ re-striking\ voltage$$

$$= 2v = 2 \times 0.95 \times \frac{132}{\sqrt{3}} \times \sqrt{2} \times 0.954$$

$$This\ maximum\ re-strike\ value\ is\ reached\ in\ t = \frac{1}{2f_n} secs.$$

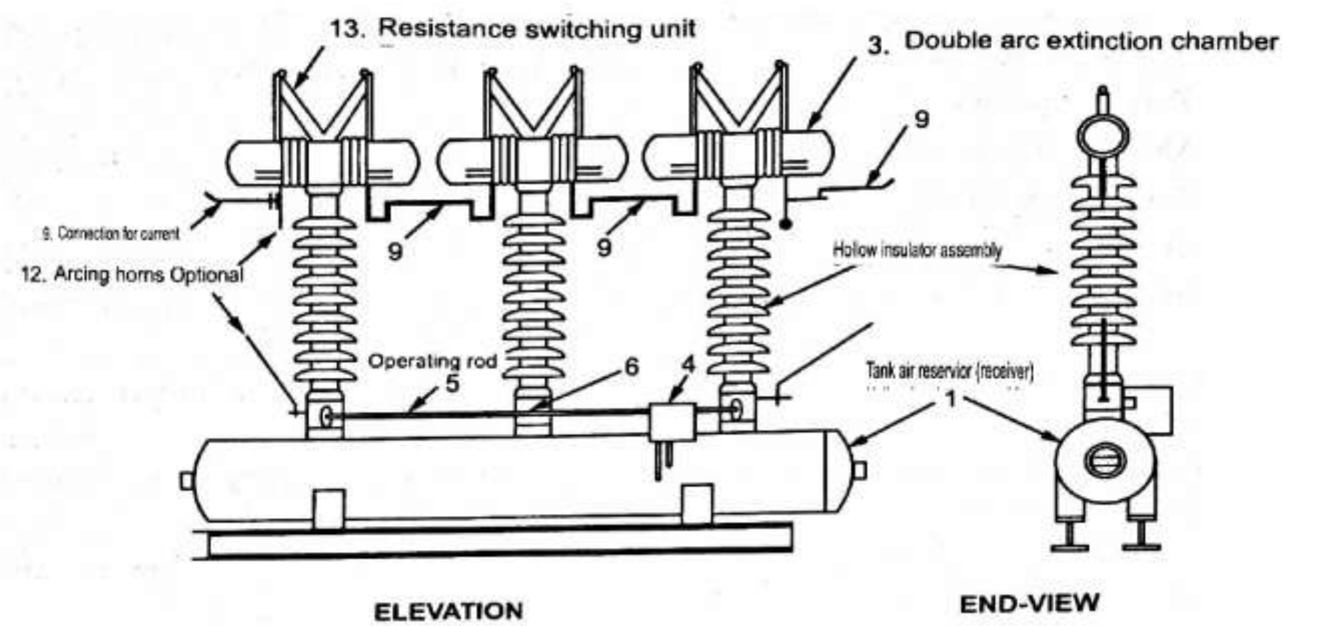
$$\therefore \quad R.R.R.V. = \frac{2 \times 0.95 \times \frac{132}{\sqrt{3}} \times \sqrt{2} \times 0.954}{\frac{1}{16000 \times 2} \times 10^6} = 6.25kV/\mu - secs.$$

13. Explain with neat diagram Air blast circuit breaker (APR/MAY 2010, APR/MAY 2011, Dec-2013,May-15)(May 2017) (Nov/Dec 2017)

- Fast operations, suitability for repeated operation, auto reclosure, unit type multi break constructions, simple assembly, and modest maintenance are some of the main features of air blast circuit breakers.
- A compressors plant necessary to maintain high air pressure in the air receiver. The air blast circuit breakers are especially suitable for railways and arc furnaces, where the breaker operates repeatedly.
- Air blast circuit breakers is used for interconnected lines and important lines where rapid operation is desired.
- High pressure air at a pressure between 20 to 30 kg/ cm^2 stored in the air reservoir. Air is taken from the compressed air system.

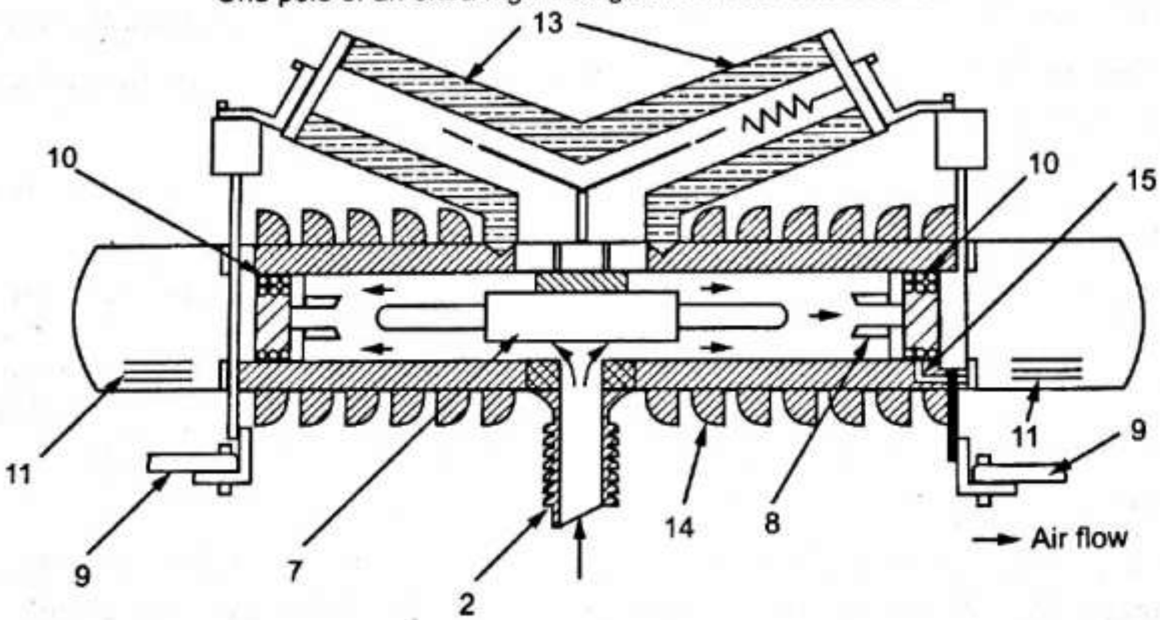
- Three hollow insulator columns are mounted on the reservoir with valves at their basis. The double arc extinguished chambers are mounted on the top of the hollow insulator chambers.
- The current carrying parts connect the three arc extinction chambers to each other in series and the pole to the neighboring equipment.
- Since there exists a very high voltage between the conductor and the air reservoir, the entire arc extinction chambers assembly is mounted on insulators.

Construction:



1. Tank air reservior (receiver)
2. Hollow insulator assembly
3. Double arc extinction chamber
4. Pneumatic operating mechanism
5. Operating rod
6. Pneumatic value
7. Fixed contact (in 3)
8. Moving contact (in 3)
9. Connection for current
10. Compression springs
11. Openings for air outler
12. Arcing horns Optional
13. Resistance switching unit
14. Enclosure
15. Port

One pole of an extra high voltage air blast circuit-breaker



Details of double arc extinction chamber

Operation:

Since there are three double arc extinction poles in series, there are six breaks per pole. Each arc extinction chamber consists of one twin fixed contact. There are two moving contacts. The moving can move axially so as to open or close. Its position open or close depends on air pressure and spring pressure.

The operating mechanism operates the rod when it gets a pneumatic or electrical signal. The valves open so as to send the high pressure air in the hollow of the insulator. The high pressure air rapidly enters the double arc extinction chamber. As the air enters into the arc extinction the pressure on the moving contacts becomes more than spring pressure and contacts open.

The contacts travel through a short distance against the spring pressure. At the end of the contact travel the port for outgoing air is closed by the moving and the entire arc extinction chamber is filled with high pressure air as the air is not allowed to go out. However, during the arcing period the air goes out through the openings and takes away the ionized air of the arc.

While closing, the valve is turned so as to close connection between the hollow of the insulator the reservoir. The valve lets the air from the hollow insulator to the atmosphere. As a result of the pressure of air in the arc extinction chamber is dropped down to the atmospheric pressure and the moving contacts close over the fixed contacts by virtue of the spring pressure.

The opening is fast because the air takes a negligible time to travel from the reservoir to the moving contact. The arc is extinguished within a cycle.
Therefore, air blast circuit breaker is very fast in breaking the current.

Closing is also fast because the pressure in the arc extinction chamber drops immediately as the valve operates and the contacts close by virtue of the spring pressure.

Advantages

- There is no chance of fire hazard caused by oil.
- The breaking speed of circuit breaker is much higher during **operation of air blast circuit breaker.**
- Arc quenching is much faster during **operation of air blast circuit breaker.**
- The duration of arc is same for all values of small as well as high currents interruptions.
- As the duration of arc is smaller, so lesser amount of heat realized from arc to current carrying contacts hence the service life of the contacts becomes longer.
- The stability of the system can be well maintained as it depends on the speed of operation of circuit breaker.
- Requires much less maintenance compared to oil circuit breaker.

Disadvantages

- In order to have frequent operations, it is necessary to have sufficiently high capacity air compressor.
- Frequent maintenance of compressor, associated air pipes and automatic control equipment's is also required.
- Due to high speed current interruption there is always a chance of high rate of rise of re-striking voltage and current chopping.
- There also a chance of air pressure leakage from air pipes junctions.
- As we said earlier that there are mainly two types of ACB, plain air circuit breaker and air blast circuit breaker. But the later can be sub divided further into three different categories.
    - Axial Blast ACB.
    - Axial Blast ACB with side moving contact.
    - Cross Blast ACB.

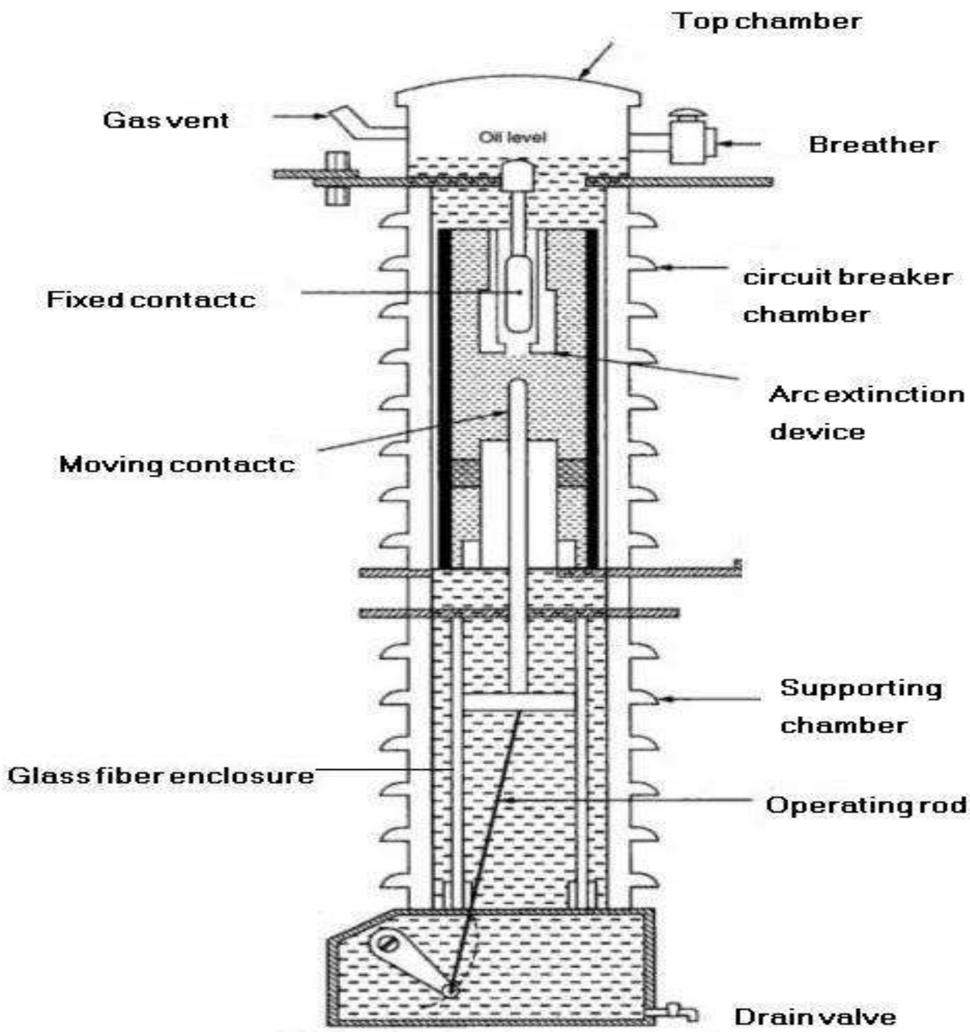
14. Explain briefly about Bulk Oil Breakers?(APR2011,MAY/JUNE-12)

OR

Explain Construction, Principle Of Operation Of A Oil Circuit Breaker, What Are The Advantage And Disadvantage.(MAY/JUNE-13,Dec-2013)

- Bulk oil circuit breakers are enclosed in metal-grounded weatherproof tanks that are referred to as dead tanks. The original design of bulk OCBs was very simple and inexpensive.
- Example of such a breaker, called plain break oil circuit breaker, the arc was drawn directly inside of the container tank without any additional arc extinguishing but the one provided by the gas bubble surrounding the arc.
- Plain break breakers were superseded by arc controlled oil breakers. The arc controlled oil breakers have an arc control device surrounding the breaker contacts. The purpose of the arc control devices is to improve operating capacity, speed up the extinction of arc, and decrease pressure on the tank.
- The arc control devices can be classified into two groups: cross-blast and axial blast interrupters. In an oil circuit breaker with simple interruption under oil, the duration of arcing is 0.02-0.05 sec. To extinguish the arc more efficiently, arc-quenching chambers are used.
- In a longitudinal blast chamber the vapors and gases evolved travel upward along the arc, thus cooling it.
- In addition, the arc is in contact with the cold oil that fills the annular slots of the chamber, which also accelerates cooling of the arc. In a transverse blast chamber a drastic pressure increase within the gas bubble causes a stream of oil and gases to flow across the arc, thus accelerating the cooling process.

Construction:



Operation:

➢ In terms of design, a distinction is made between tank-type oil circuit breakers and oil-minimum, or low-oil-capacity, circuit breakers. In the first type, the main contacts and the arc-quenching devices are located in a grounded metal tank; in the second type they are in an insulating or ungrounded metal enclosure filled with oil.
➢ Tank-type oil circuit breakers are inferior to other types of high-voltage breakers in many regards. However, their low cost and high reliability have led to their continued use in the USSR, the USA, and Canada.
➢ In the USSR, tank-type oil circuit breakers are manufactured for voltages from 6 to 220 kilovolts (kV); maximum rated current, 3.2 kilo-amperes (kA); breaking current, 50 kA. For voltages of 10 kV or less and breaking currents of 15 kA or less, all three poles of the oil circuit breaker are located in the same tank.
➢ For higher voltages and breaking currents, each pole is located in a separate tank. Oil-minimum circuit breakers are used in the USSR, the Federal Republic of Germany, and France.

➢ They are manufactured for 3 to 420 kV; since the late 1960's they have also been manufactured for higher voltages.

Advantages

A low oil circuit breaker has following advantages compared to bulk oil circuit breaker

1. It requires lesser quantity of oil
2. It requires smaller space
3. There is reduced risk of fire
4. Maintenance problems are reduced

Disadvantages

A low oil circuit breaker has following disadvantages compared to bulk oil circuit breaker

1. Due to smaller quantity of oil, the degree of carbonization is increased
2. There is a difficulty of removing the gases from the contact space in time
3. The dielectric strength of oil deteriorates rapidly due to high degree of carbonization.

Also, the gas in the arc chamber escapes to the gas expansion chamber, so that a type of heat dissipation by convection is created, thus the rate at which heat is dissipating is increasing.

Near current zero, the thermal power generated by the current (in the arc) approaches zero. If the heat dissipation outwards is sufficiently large, the temperature in the arc zone can be reduced in such a manner that the arc would lose conductivity and extinguish.

An arc in hydrogen has a short thermal time constant, so that the conditions are favorable for quenching. There are two other situations that may occur under certain conditions: thermal Restriping of Arc, resignation.

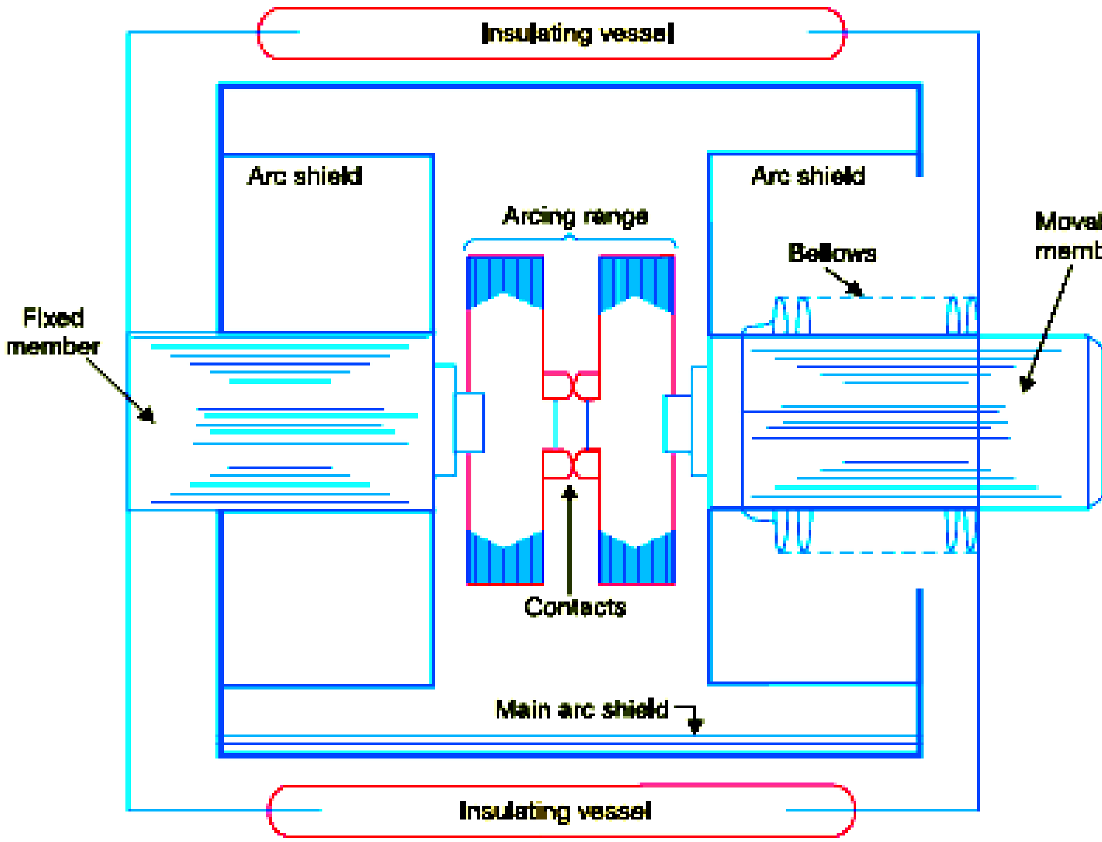
Thermal restriping is when the post-arc current rises again and passes into the next half cycle of SCC, as the arc plasma heats up due to the insufficiency of heat dissipation to make conductance of the arc zone equal to zero.

Resignation happens when there striking voltage of the system causes a renewed formation of the arc, (after completion of the first interruption) and continuation of flow of current.

The arcing chamber designs are either of the axial or radial venting type. Often, a combination of both is used in the design of minimum oil, MV CB's. The axial venting process generates high gas pressures and has high dielectric strength. This is used mainly for interruption of low currents. The radial venting is used for high current interruptions, as the gas pressures developed are low and the dielectric strength is low.

15. Elaborately discuss Vaccum CB? With Neat Diagram (APR/MAY 2010,APR/MAY-2011,May-15)(may 2017)(Dec-2016) (Apr/May 2018)

Construction:



In this breaker, vacuum is being used as the arc quenching medium. Vacuum offers highest insulating strength, it has far superior arc quenching properties than any other medium.

When contacts of a breaker are opened in vacuum, the interruption occurs at first current zero with dielectric strength between the contacts building up at a rate thousands of times that obtained with other circuit breakers.

Principle of operation:

When the contacts of the breaker are opened in vacuum (10 -7 to 10 -5 tore), an arc is produced between the contacts by the ionization of metal vapours of contacts.

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

As soon as the arc is produced in vacuum, it is quickly extinguished due to the fast rate of recovery of dielectric strength in vacuum. It consists of fixed contact, moving contact and arc shield mounted inside a vacuum chamber. The movable member is connected to the control mechanism by stainless steel bellows. This enables the permanent sealing of the vacuum chamber so as to eliminate the possibility of leak.

A glass vessel or ceramic vessel is used as the outer insulating body.
The arc shield prevents the deterioration of the internal dielectric strength by preventing metallic vapours falling on the inside surface of the outer insulating cover.

Working:

When the breaker operates the moving contacts separates from the fixed contacts and an arc is struck between the contacts. The production of arc is due to the ionization of metal ions and depends very much upon the material of contacts.

The arc is quickly extinguished because the metallic vapours, electrons and ions produced during arc are diffused in short time and seized by the surfaces of moving and fixed members and shields. Since vacuum has very fast rate of recovery of dielectric strength, the arc extinction in a vacuum breaker occurs with a short contact separation.

Advantages:

a. They are compact, reliable and have longer life.
b. There are no fire hazards
c. There is no generation of gas during and after operation
d. They can interrupt any fault current. The outstanding feature of a VCB is that it can break any heavy-fault current perfectly just before the contacts reach the definite open position.
e. They require little maintenance and are quiet in operation
f. Can withstand lightning surges
g. Low arc energy
h. Low inertia and hence require smaller power for control mechanism.

Applications:

For outdoor applications ranging from 22 kV to 66 kV.Suitable for majority of applications in rural area.

16. With neat block diagram, explain the construction, operating principle and application of SF_6circuit breakers. What are the advantage of over other CB?(NOV/DEC-10,NOV/DEC-12,May-14,May-15)

I. This is one of the best circuit breaker amongst different Circuit Breaker Types, sf6 Circuit Breaker uses sculpture hexafluoride (SF6) gas as an arc quenching medium.
II. The sf6 gas has a strong tendency to absorb free electrons because it is an electro negative gas in nature.
III. The contacts of the breaker are opened in a high pressure flow of sf6 gas and an arc is struck between them.
IV. The conducting free electrons in the arc are rapidly captured by the gas to form relatively immobile negative ions.
V. This loss of conducting electrons in the arc quickly builds up enough insulation strength to extinguish the arc. The sf6 circuit breakers are very effective for high power and high voltage service.

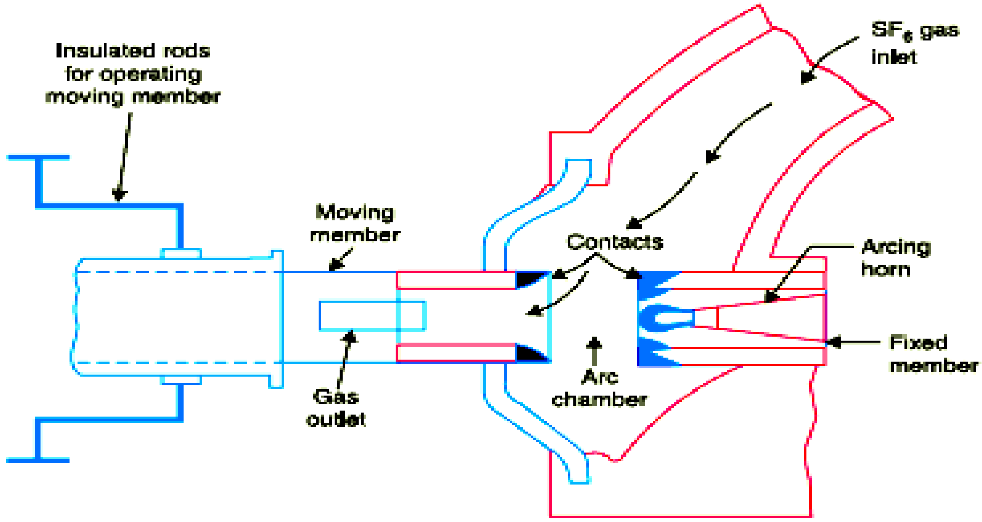
Construction:

As figure shows below the parts of a typical sf6 circuit breaker. It consists of fixed and moving contacts enclosed in a chamber called arc interruption chamber containing sf6 gas.

This chamber is connected to sf6 gas reservoir. When the contacts of breaker are opened the valve mechanism permits a high pressure sf6 gas from the reservoir to flow towards the arc interruption chamber.

The fixed contact is a hollow cylindrical current carrying contact fitted with an arc horn. The moving contact is also a hollow cylinder with rectangular holes in the sides to permit the sf6 gas to let out through these holes after flowing along and across the arc.

The tips of fixed contact, moving contact and arcing horn are coated with copper-tungsten arc resistant material. Since sf6 gas is costly, its reconditioned and reclaimed by a suitable auxiliary system after each operation of the breaker.



Working :

i. In the closed position of the breaker the contacts remained surrounded by sf6 gas at a pressure of about 2.8 kg/cm^2.
ii. When the breaker operates the moving contact is pulled apart and an arc is struck between the contacts.
iii. The movement of the moving contact is synchronized with the opening of a valve which permits sf6 gas at 14 kg/cm^2 pressure from the reservoir to the arc interruption chamber.
iv. The high pressure flow of sf_6 rapidly absorbs the free electrons in the arc path to form immobile negative ions which are ineffective as charge a carriers.
v. The result is that the medium between the contacts quickly builds up high dielectric strength and causes the extinction of the arc.
vi. After the breaker operation the valve is closed by the action of a set of springs.

Advantages over oil and air circuit breakers :

- Gives noiseless operation due to its closed gas circuit.
- Due to superior arc quenching property of sf_6, such breakers have very short arcing time.
- There is no risk of fire as sf6 is non inflammable.
- Dielectric strength of sf_6 gas is 2 to 3 times that of air, such breakers can interrupt much larger currents.
- Low maintenance cost, light foundation requirements and minimum auxiliary equipment.
- Closed gas enclosure keeps the interior dry so that there is no moisture problem.
- sf_6 breakers are totally enclosed and sealed from atmosphere, they are particularly suitable where explosion hazard exists.

- There are no carbon deposits.

Disadvantages:

- SF_6 gas has to be reconditioned after every operation of the breaker, additional equipment is required for this purpose.
- SF_6 breakers are costly due to high cost of sf6 gas.

Applications:

SF_6 Circuit Breaker have been used for voltages 115kV to 230 kV, power ratings 10 MVA to 20 MVA and interrupting time less than 3 cycles.

18. Discuss the Selection of Circuit Breaker for Different Ranges of System Voltage (NOV/DEC-12)

IEEE C37.04-1999 defines a general rating structure for high voltage circuit breakers 1000 V AC and above. The rating structure comprises of indoor and outdoor circuit breakers. ANSI/IEEE C37.06 states preferred rating for the circuit breakers. Ratings structure establishes the basis for rating s to be assigned to circuit breakers including electrical and mechanical characteristics.

General Rating Structure:

IEEE C37.04-1999 is based on symmetrical currents and specifies ratings for three and single phase, indoor and outdoor circuit breakers to be used above 1000V AC. Rating structure used for the circuit breakers is based on usual service conditions that prevail. The rating structure of the circuit breaker includes the following

Recloser Type	PVDR	PVDR
Rated Maximum Voltage	15.5kV	27.0kV
Nominal Voltage	15.5kV	27.0kV
Frequency	60Hz	60Hz
Low Frequency Withstand		
60Hz dry for 1 minute	50kV	60kV
60Hz wet for 10 seconds	45kV	50kV
Fullwave Withstand - B.I.L.	110kV	125kV
Continuous Current Rating @ 60Hz	200A thru 1120A	200A thru 1120A
Standard Duty Cycle	0 + 0 sec + CO + 5 sec + CO	0 + 0 sec + CO + 5 sec + CO
Interrupting Time	5 cycles (3 cycles optional)	5 cycles
Closing Time	4.5 cycles	4.5 cycles
Rated Short Circuit (RMS)	2kA thru 16kA	2kA thru 16kA
Close and Latch Rating		
RMS Asymmetrical	3kA thru 26kA	25.6kA
Peak 5kA thru	43kA	42.5kA
3 Second Short Time Currect Rating (RMS)	2kA thru 16kA	16.0 kA
Reclosing Time	5 or 3 seconds	5 or 3 seconds
Permissible Tripping Delay	2 seconds	2 seconds

Capacitance Current Switching		
General Purpose Duty		
Line Charging Current	2A	2A
Isolated Cable Charging Current	250A	250A
Isolated Capacitor Bank Rating	250A	250A
Transient Recovery Voltage Peak	29kV	50.5kV
Time to Crest of Transient Recovery Voltage	36 microseconds	52 microseconds
Number of Operations		
Load Current Switching	2500 Before Servicing	2500 Before Servicing
Full Fault Unit Operations	18 Before Servicing	18 Before Servicing
Control Voltage	DC: 48V, 125V, 250V AC: 120V, 240V (60Hz)	DC: 48V, 125V, 250V AC: 120V, 240V (60Hz)

Ratings important for TRV:

The above is general rating structure and is provided on nameplate of every circuit breaker. Rating that are important from the point of view of Transient recovery voltages depend on the voltage level it is used at and application. IEEE C37.011 is a application guide for transient recovery voltage for AC high voltage circuit breakers. In addition the to the peak of the recovery voltage the following ratings are referred to

1. Peak TRV in KV
2. Time to Peak of TRV In μs.
3. Rate of Rise of Recovery Voltage (RRRV)

These ratings of the circuit breaker are contingent upon application. To cater to various possible applications the standard specifies three different TRV characteristics envelopes

1-Cosine waveform
2. Exponential Cosine TRV waveform
3. Triangular TRV waveform.

These waveforms are obtained for different applications and depend on the rated maximum operating voltage. TRV capability of the circuit breaker is required to increase as the short circuit current reduces as the TRV depends on the short circuit level of the system. System conditions and grounding of the system are important for TRV ratings to be evaluated.

19. Define The Terms Making Capacity, Short Time Rating, Breaking Capacity(MAY/JUNE-12,NOV/DEC-12)

(*i*) **Breaking capacity.** *It is current (r.m.s.) that a circuit breaker is capable of breaking at given recovery voltage and under specified conditions (e.g., power factor, rate of rise of re-striking voltage).*

The breaking capacity is always stated at the r.m.s. value of fault current at the instant of contact separation. When a fault occurs, there is considerable asymmetry in the fault current due to the presence of a d.c. component. The d.c. component dies away rapidly, a typical decrement factor being 0·8 per cycle. Referring to Fig. 19.24, the contacts are separated at DD′. At this instant, the fault current has

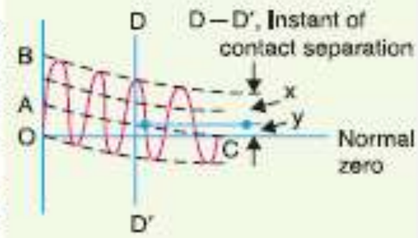


Fig. 19.24

x = maximum value of a.c. component

y = d.c. component

∴ Symmetrical breaking current = r.m.s. value of a.c. component

$$= \frac{x}{\sqrt{2}}$$

Asymmetrical breaking current = r.m.s. value of total current

$$= \sqrt{\left(\frac{x}{\sqrt{2}}\right)^2 + y^2}$$

It is a common practice to express the breaking capacity in MVA by taking into account the rated breaking current and rated service voltage. Thus, if I is the rated breaking current in amperes and V is the rated service line voltage in volts, then for a 3-phase circuit,

$$\text{Breaking capacity} = \sqrt{3} \times V \times I \times 10^{-6} \text{ MVA}$$

In India (or Britain), it is a usual practice to take breaking current equal to the symmetrical breaking current. However, American practice is to take breaking current equal to asymmetrical breaking current. Thus the American rating given to a circuit breaker is higher than the Indian or British rating.

It seems to be illogical to give breaking capacity in MVA since it is obtained from the product of short-circuit current and rated service voltage. When the short-circuit current is flowing, there is only a small voltage across the breaker contacts, while the service voltage appears across the contacts only after the current has been interrupted. Thus MVA rating is the product of two quantities which do not exist simultaneously in the circuit.

Therefore, the *agreed international standard of specifying breaking capacity is defined as the rated symmetrical breaking current at a rated voltage.

(*ii*) **Making capacity.** There is always a possibility of closing or making the circuit under short-circuit conditions. The capacity of a breaker to "make" current depends upon its ability to withstand and close successfully against the effects of electromagnetic forces. These forces are proportional to the square of maximum instantaneous current on closing. Therefore, making capacity is stated in terms of a peak value of current instead of r.m.s. value.

The peak value of current (including d.c. component) during the first cycle of current wave after the closure of circuit breaker is known as **making capacity.**

It may be noted that the definition is concerned with the first cycle of current wave on closing the circuit breaker. This is because the maximum value of fault current possibly occurs in the first cycle only when maximum asymmetry occurs in any phase of the breaker. In other words, the making current is equal to the maximum value of asymmetrical current. To find this value, we must multiply symmetrical breaking current by $\sqrt{2}$ to convert this from r.m.s. to peak, and then by 1·8 to include the "doubling effect" of maximum asymmetry. The total multiplication factor becomes $\sqrt{2} \times 1{\cdot}8 = 2{\cdot}55$.

$\therefore$ Making capacity $= 2{\cdot}55 \times$ Symmetrical breaking capacity

(*iii*) **Short-time rating.** *It is the period for which the circuit breaker is able to carry fault current while remaining closed.*

Sometimes a fault on the system is of very temporary nature and persists for 1 or 2 seconds after which the fault is automatically cleared. In the interest of continuity of supply, the breaker should not trip in such situations. This means that circuit breakers should be able to carry high current safely for some specified period while remaining closed *i.e.*, they should have proven short-time rating. However, if the fault persists for a duration longer than the specified time limit, the circuit breaker will trip, disconnecting the faulty section.

The short-time rating of a circuit breaker depends upon its ability to withstand (*a*) the electromagnetic force effects and (*b*) the temperature rise. The oil circuit breakers have a specified limit of 3 seconds when the ratio of symmetrical breaking current to the rated normal current does not exceed 40. However, if this ratio is more than 40, then the specified limit is 1 second.

Normal current rating. It is the r.m.s. value of current which the circuit breaker is capable of carrying continuously at its rated frequency under specified conditions. The only limitation in this case is the temperature rise of current-carrying parts.

20. Describe the operating principle of air Blast circuit breakers, There are two types of air-blast circuit breaker. They are (1) Axial-Blast Air CB (2) Cross-Blast Air CB.

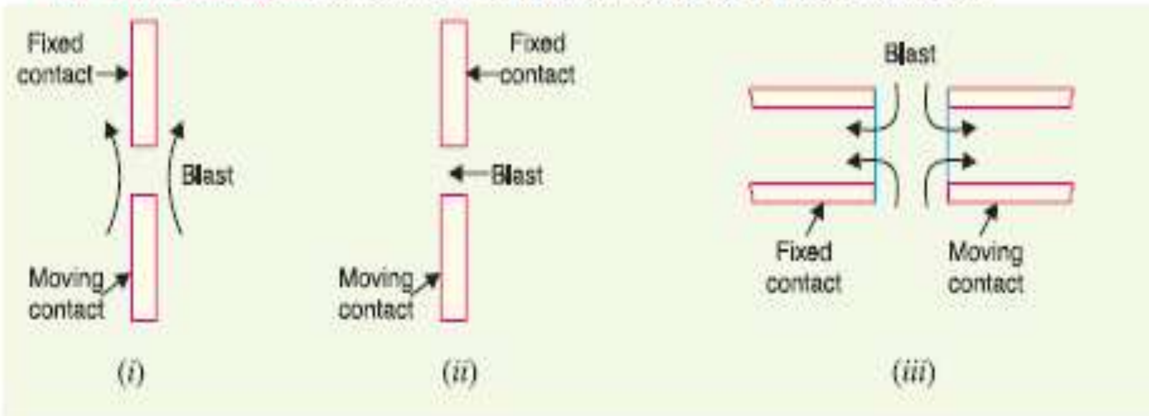
Ans: 1. Axial-blast air circuit breaker:

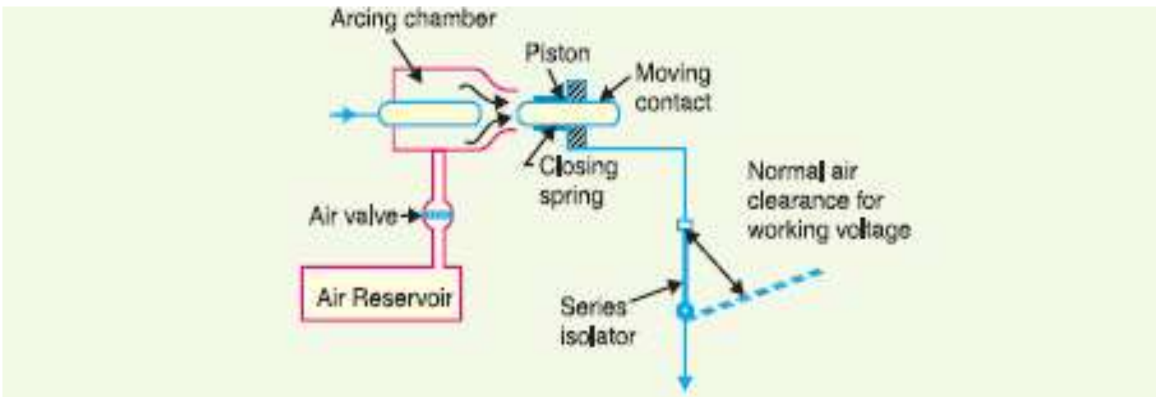
The Gaussian shows the essential components of a typical axial-blast air circuit breaker. The fixed and moving contacts are held in the closed position by spring pressure under normal conditions. The air reservoir is connected to the arcing chambers through an air valve. This valve remains closed under normal conditions but opens automatically by the tripping impulse when a fault occurs on the system.

When a fault occurs, the tripping impulse causes opening of the air valve which connects the circuit breaker reservoir to the arcing chamber. The high pressure air entering the arcing chamber pushes away the moving contact against spring pressure. The moving contact is separated and an arc is struck. At the same time, high pressure air blast flows along the arc and takes away the ionized gases along with it. Consequently, the arc is extinguished and current flow is interrupted.

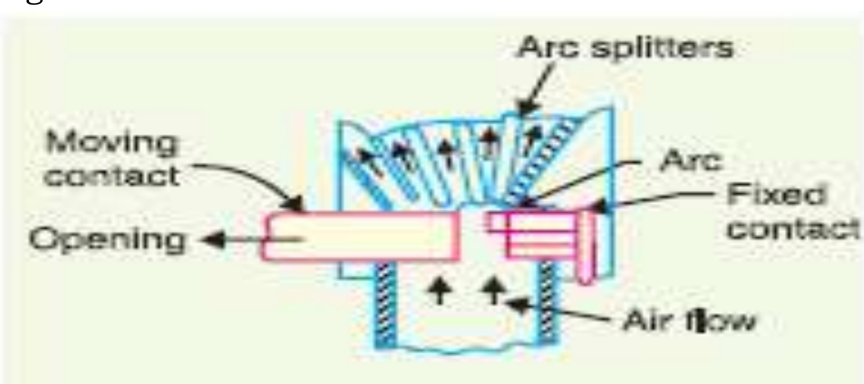
It may be noted that in such circuit breakers, the contact separation required for interruption is generally small (1-75 cm or so). Such a small gap may constitute inadequate clearance for the normal service voltage. Therefore, an isolating switch is incorporated as a part of this type of circuit breaker. This switch opens immediately after fault interruption to provide the necessary clearance for insulation.

(i) *Axial-blast type* in which the air-blast is directed along the arc path as shown





2. Cross-blast air breaker: In this type of circuit breaker, an air-blast is directed at right angles to the arc. The cross-blast lengthens and forces the arc into a suitable chute for arc extinction. The diagram shows the essential parts of a typical cross-blast air circuit breaker. When the moving contact is withdrawn, an arc is struck between the fixed and moving contacts. The high pressures cross-blast force the arc into a chute consisting of arc splitters and baffles. The splitters serve to increase the length of the arc and baffles give improved cooling. The result do that are extinguished and flow of current is interrupted. Since blast pressure is same for all currents, the in efficiency at low currents is eliminated. The final gap for interruption is great enough to give normal insulation clearance so that a series isolating switch is not necessary.



21. Explain the operation bulk oil circuit breaker with suitable diagram.

Bulk Oil Circuit Breaker

Bulk oil circuit breaker use a large quantity of oil. They serve two purposes-finitly, it extinguishes the arc during opening of contacts and secondly, it imulates the current conducting parts from one another and from the earthed tank.

Types

A. Plain break oil circuit breakers.

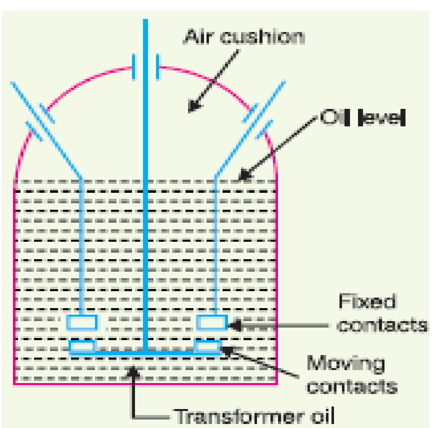
B. Arc control oil breakers.

A. Plain Break Oil Circuit Breakers:

A plain break oil circuit breaker involve the simple process of separating the contacts under the whole of the oil in the tank. There is no special system for arc control other than the increase in the length caused by the separation of contacts. The are extinction occurs when a certain gap between contacts is reached.

It consists of fixed and making contacts enclosed in a strong weather-tight earthed tank containing oil up to a contain level and an air cushion above the oil level. The air cushion provides sufficient room to allow for the reception of the arc gases without the generation of unsafe pressure in the dome of circuit breaker. It also absorbs the mechanical shock of the upward oil movement.

Under normal operating conditions, fixed and moving contacts remain closed and the breaker carries the normal circuit current. When a fault occurs, the moving contacts are pulled down by the protective system and arc is struck which vaporizes the oil into hydrogen gas.



The arc extinction is by following processes:

1. Hydrogen gas bubble generated around the arc cools the arc column and aids the de-ionization of the medium between the contacts.
2. The gas sets up turbulence in the oil and helps in eliminating the arcing produces from the arc path.
3. As the arc lengthens due to the separating contacts, the dielectric strength increases.

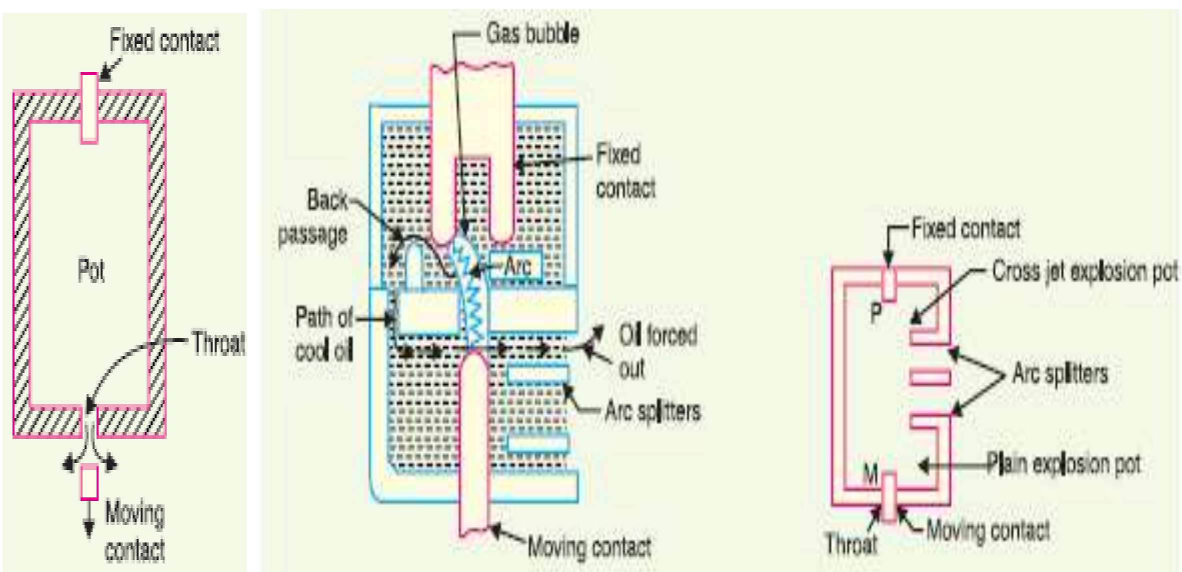
Disadvantage:

1. Long and inconsistent arcing times.
2. Do not permit high speed interruption
3. No special control over the arc.

B. Arc Control Oil Circuit Breakers: Long arc length is needed in order that turbulence in the oil caused by the gas may assist in quenching it. Some Arc control is incorporated and the breakers are called arc control oil circuit breakers.

1. **Self-blast oil circuit breakers:** Arc control is provided by internal means is the arc itself is employed for its own extinction efficiency.
2. **Forced-blast oil circuit breakers:** Arc control is provided by mechanical means external to the circuit breaker.

1. **Self-Blast Oil Circuit Breaker:** The gas produced during arc is confined in a small volume, so a very high pressure developed to force oil and gas to the extinguish arc. The pressure is generated by the arc itself, so called as self-generated oil circuit breakers.



a. Plain Explosion Pot. **b.** Gross Jet Explosion Pot. **c.** Self-Compensated Explosion Pot.

a. **Plain Explosion Pot**: It is rigid cylinder of insulating material and encloses the fixed and moving contacts. The moving contact is a cylindrical rod passing through a restricted opening at the bottom when a fault occurs, the contacts get separated and an arc is struck between them. The high pressure forces the oil to extinguish the arc.
b. **Gross Jet Explosion Pot:** Modification of plain explosion pot and made of insulating material and has channels on one side which act as arc splitters. The arc splitters increase arc length and facilitate arc extinction.
c. **Self-Compensated Explosion Pot:** Combination of plain and cross jet explosion pot. so it can interrupt low as well as heavy short circuit current with accuracy.

2. Forced-Blast Oil Circuit Breaker: In this oil pressure it made by the piston-cylindrical arrangement. The movement is mechanically coupled to moving contact. When fault occurs, the contacts get separated by the system and arc is struck between contacts.

22. Explain the following terms in circuit breaker.

(i) **Arc Voltage.** *It is the voltage that appears across the contacts of the circuit breaker during the arcing period.*

As soon as the contacts of the circuit breaker separate, an arc is formed. The voltage that appears across the contacts during arcing period is called the arc voltage. Its value is low except for the *period the fault current is at or near zero current point. At current zero, the arc voltage rises rapidly to peak value and this peak voltage tends to maintain the current flow in the form of arc.

(ii) **Restriking voltage.** *It is the transient voltage that appears across the contacts at or near current zero during arcing period.*

At current zero, a high-frequency transient voltage appears across the contacts and is caused by the rapid distribution of energy between the magnetic and electric fields associated with the plant and transmission lines of the system. This transient voltage is known as restriking voltage (Fig. 19.1). The current interruption in the circuit depends upon this voltage. If the restriking voltage rises more rapidly than the dielectric strength of the medium between the contacts, the arc will persist for another half-cycle. On the other hand, if the dielectric strength of the medium builds up more rapidly than the restriking voltage, the arc fails to restrike and the current will be interrupted.

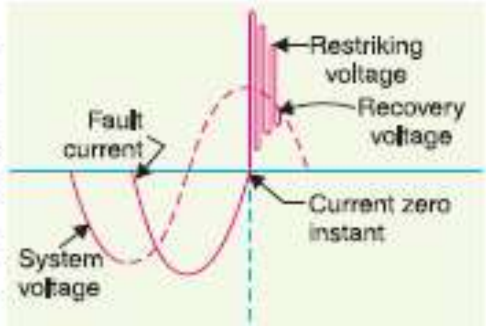


Fig. 19.1

(iii) **Recovery voltage.** *It is the normal frequency (50 Hz) r.m.s. voltage that appears across the contacts of the circuit breaker after final arc extinction. It is approximately equal to the system voltage.*

When contacts of circuit breaker are opened, current drops to zero after every half cycle. At some current zero, the contacts are separated sufficiently apart and dielectric strength of the medium between the contacts attains a high value due to the removal of ionised particles. At such an instant, the medium between the contacts is strong enough to prevent the breakdown by the restriking voltage. Consequently, the final arc extinction takes place and circuit current is interrupted. Immediately after final current interruption, the voltage that appears across the contacts has a transient part (See Fig. 19.1). However, these transient oscillations subside rapidly due to the damping effect of system resistance and normal circuit voltage appears across the contacts. The voltage across the contacts is of normal frequency and is known as recovery voltage.

23. Write the comparative merits and demerits of CB.(May-15)

Types of circuit breaker	**Merits**	**Demerits**
Air blast circuit breaker	1) There is no chance of fire hazard caused by oil. 2) The breaking speed of circuit breaker is much higher during **operation of air blast circuit breaker.** 3) Arc quenching is much faster during **operation of air blast circuit breaker.** 4) The duration of arc is same for all values of small as well as high currents interruptions. 5) As the duration of arc is smaller, so lesser amount of heat realized from arc to current carrying contacts hence the service life of the contacts becomes longer. 6) The stability of the system can be well maintained as it depends on the speed of operation of circuit breaker. 7) Requires much less maintenance compared to oil circuit breaker.	1) In order to have frequent operations, it is necessary to have sufficiently high capacity air compressor. 2) Frequent maintenance of compressor, associated air pipes and automatic control equipments is also required. 3) Due to high speed current interruption there is always a chance of high rate of rise of re-striking voltage and current chopping. 4) There also a chance of air pressure leakage from air pipes junctions.
SF6 CB	1.Gives noiseless operation due to its closed gas circuit. 2. Due to superior arc quenching property of sf6 , such breakers have very short arcing time.	• SF_6 gas has to be reconditioned after every operation of the breaker, additional equipment is required

	3.There is no risk of fire as sf6 is non inflammable. 4.Dielectric strength of sf6 gas is 2 to 3 times that of air, such breakers can interrupt much larger currents. 5.Low maintenance cost, light foundation requirements and minimum auxiliary equipment. 6.Closed gas enclosure keeps the interior dry so that there is no moisture problem. 7. SF_6 breakers are totally enclosed and sealed from atmosphere, they are particularly suitable where explosion hazard exists. 8. There are no carbon deposits.	for this purpose. • SF_6 breakers are costly due to high cost of sf6 gas.
Oil CB	1.It requires lesser quantity of oil 2.It requires smaller space 3.There is reduced risk of fire 4.Maintenance problems are reduced	1.Due to smaller quantity of oil, the degree of carbonization is increased 2.There is a difficulty of removing the gases from the contact space in time 3. The dielectric strength of oil deteriorates rapidly due to high degree of carbonization.
Vacuum CB	a. They are compact, reliable and have longer life. b. There are no fire hazards c. There is no generation of gas during and after operation d. They can interrupt any fault current. The outstanding feature of a VCB is that it can break any heavy fault current perfectly just before the contacts reach the definite open position. e. They require little maintenance and are quiet in operation f. Can withstand lightning surges	

	g. Low arc energy h. Low inertia and hence require smaller power for control mechanism.	

23. A circuit breaker is rated at 1200 amps, $1500\ MVA, 33kV, 3\ \text{sec}, 3\phi$, oil circuit breaker. What are its rated normal current, breaking current, making current, short – time rating? (Apr/May 2018)

Solution:

$$Rated\ normal\ current = 1200\ amps$$

$$Rated\ symmetrical\ breaking\ current = \frac{1500}{\sqrt{3} \times 35} = 26.25\ kA\ (rms)$$

$$Rated\ making\ current = 26.25 \times 2.55 = 67kA$$

$$Short\ time\ rating = 26.25kA\ for\ 3secs.$$

24. Give the reasons for using SF6 in circuit breakers.(Apr/May-15)

The electric power industry has been using Sulfur Hexafluoride (SF6) gas as a dielectric and insulating material for many years. Its popularity is mainly due to its **unique physical and electrical properties including**:

1) Dielectric strength twice that of air.
2) Nontoxic, nonflammable and noncorrosive.
3) Chemically stable with high breakdown strength. SF6 molecules provide excellent arc extinction during electrical operations which minimizes contact wear and maintenance.
4) Excellent thermal conductivity. High heat transfer permits lower operating temperatures.
5) Readily available in many commercial locations.

For distribution voltage switchgear, SF6 provides these important advantages:

1) Size reduction
2) Weight reduction
3) Reliable operation
4) Ease of installation
5) Ease of handling
6) Ease and reduction of maintenance

Question Paper Code : 50494

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2017

Seventh Semester

Electrical and Electronics Engineering

EE6702 – PROTECTION AND SWITCHGEAR

(Regulations 2013)

Time : Three Hours Maximum : 100 Marks

Answer ALL questions

PART – A (10×2=20 Marks)

1. What is primary protection ?
2. Give the types faults.
3. Write the torque equation of the universal relay.
4. Give the principle of negative sequence relay.
5. Why secondary of transformer should not be opened ?
6. List the types of busbar protection.
7. Define static relay.
8. What is phase comparator ?
9. State the slepian theory for arc interruption.
10. Define symmetrical breaking capacity.

PART – B (5×16=80 Marks)

11. a) Explain the various methods of neutral grounding.

(OR)

b) What are the essential qualities of protective relay ? Explain in detail.

12. a) With neat diagram explain the various types of electromagnetic relays.

(OR)

b) Describe the construction and principle of operation of non-directional Induction type over current Relay.

13. a) Give a brief account on the protection of generator using differential and biased differential protection scheme.

(OR)

b) Give a brief account on the faults and protection of transformers.

14. a) Explain with neat block diagram the operation of static relay and list the advantages and disadvantages.

(OR)

b) Describe the operation of static over current relay with neat diagram.

15. a) Write short notes on :

i) Current chopping

ii) Resistance switching

(OR)

b) Describe the construction and principle of operation of Air blast circuit breaker.

Question Paper Code : 41012

B.E./B.Tech. DEGREE EXAMINATION, APRIL/MAY 2018

Seventh Semester

Electrical and Electronics Engineering

EE6702 – PROTECTION AND SWITCHGEAR

(Regulations 2013)

Time : Three Hours | Maximum : 100 Marks

Answer ALL questions

PART – A (10×2=20 Marks)

1. Why protection scheme is needed for power system ?
2. Write down the importance of symmetrical components for fault current calculation.
3. Mention the principle of operation of distance relay.
4. Determine plug setting multiplier of a 5 ampere, 3 second over current relay having a current setting of 125% and a time setting multiplier of 0.6 connected to supply circuit through a 400/5 current transformer when the circuit carries a fault current of 4000 A.
5. What is the cause of over speed and how alternators are protected from it ?
6. What are the protection methods used for transmission line ?
7. List out the general characteristics of numerical protection.
8. What are the basic circuits used in static relays ?
9. What are the factors responsible for the increase of arc resistance ?
10. A circuit breaker is rated as 1500 A, 1000 MVA, 3 second, 3 phase oil circuit breaker. Find rated making current.

41012

(5×16=80 Marks)

PART – B

11. a) i) Explain clearly about the zones of protection in power system. (8)

ii) Briefly discuss about nature and causes of faults. (8)

(OR)

b) Explain in detail about the need and different methods for neutral grounding with suitable diagram. (16)

12. a) i) With neat sketch explain negative sequence relay. (8)

ii) Explain clearly about current balance differential relays. (8)

(OR)

b) Explain impedance relay with suitable R-X diagrams. (16)

13. a) i) Explain clearly about Buchholz relay for the protection of incipient faults in transformers. (10)

ii) 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. (6)

(OR)

b) i) With neat sketch explain the protection schemes for motors. (8)

ii) With suitable diagrams explain bus bar protection. (8)

14. a) Describe the construction, working principle and operation of static over current relay. (16)

(OR)

b) i) Compare static relays with electromagnetic relays. (8)

ii) Explain the advantages of Numerical relays. (8)

15. a) i) With neat sketch explain resistance switching. (8)

ii) Explain current chopping with suitable diagrams. (8)

(OR)

b) Explain the construction, working principle, operation and application of Vacuum circuit breakers. (16)

————————