EE6702
Protection & Switchgear

DEPARTMENTS: EEE {semester 07}

Regulation : 2013

Collected by

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Book Reference:

1. Principles of power systems by V.K.Metha
2. Power system engineering by Rajput
3. Switchgear & Protection by Badri Ram
4. Protection & Switchgear by U.A.Bakshi

EE6702 PROTECTION & SWITCHGEAR R2013 Syllabus

UNIT I PROTECTION SCHEMES 9

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

UNIT II ELECTROMAGNETIC RELAYS 9

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 9

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 9

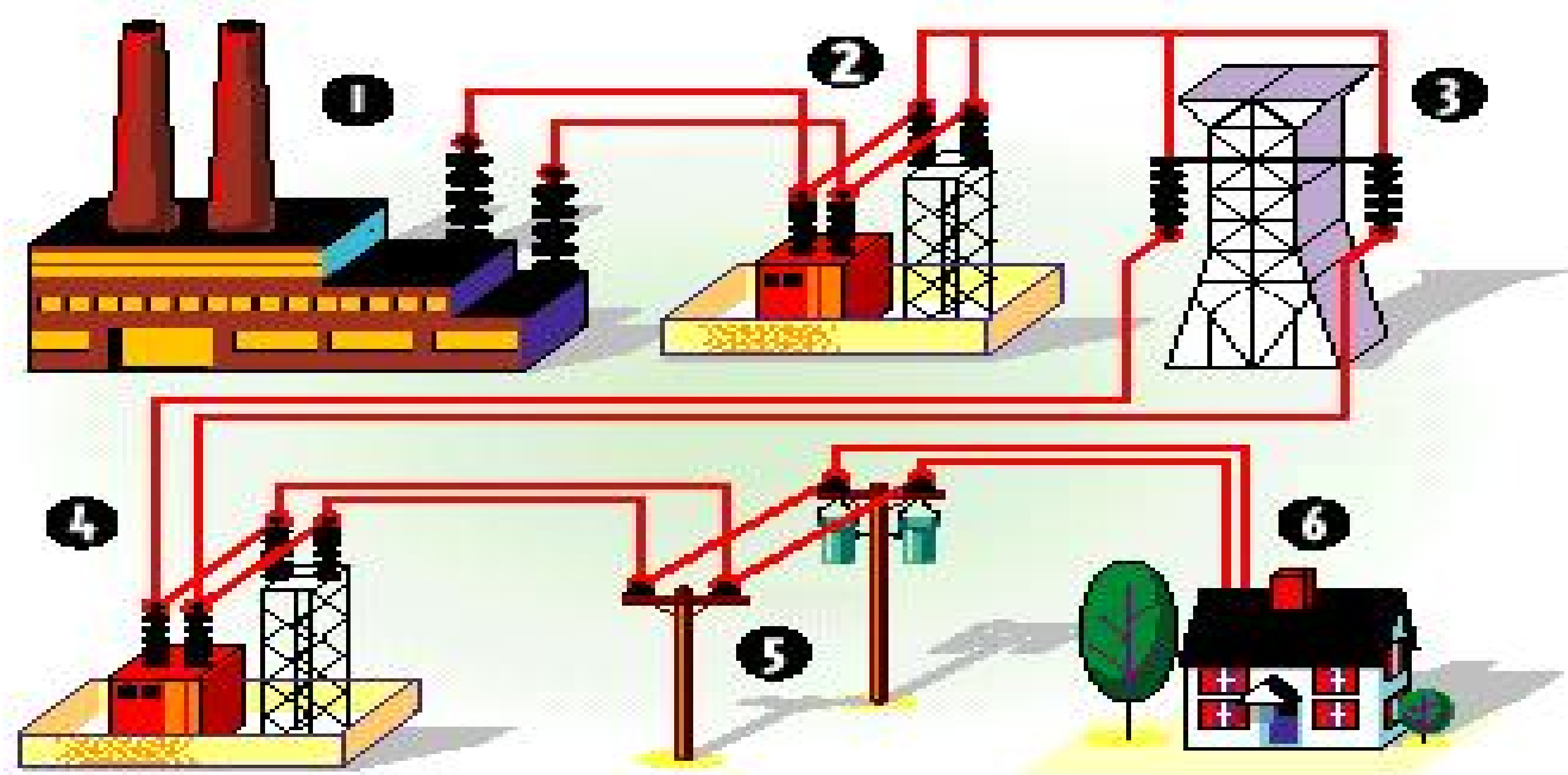
Static relays – Phase, Amplitude Comparators – Synthesis of various relays using Static comparators – Block diagram of Numerical relays – Overcurrent protection, transformer differential protection, distant protection of transmission lines.

UNIT V CIRCUIT BREAKERS 9

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.

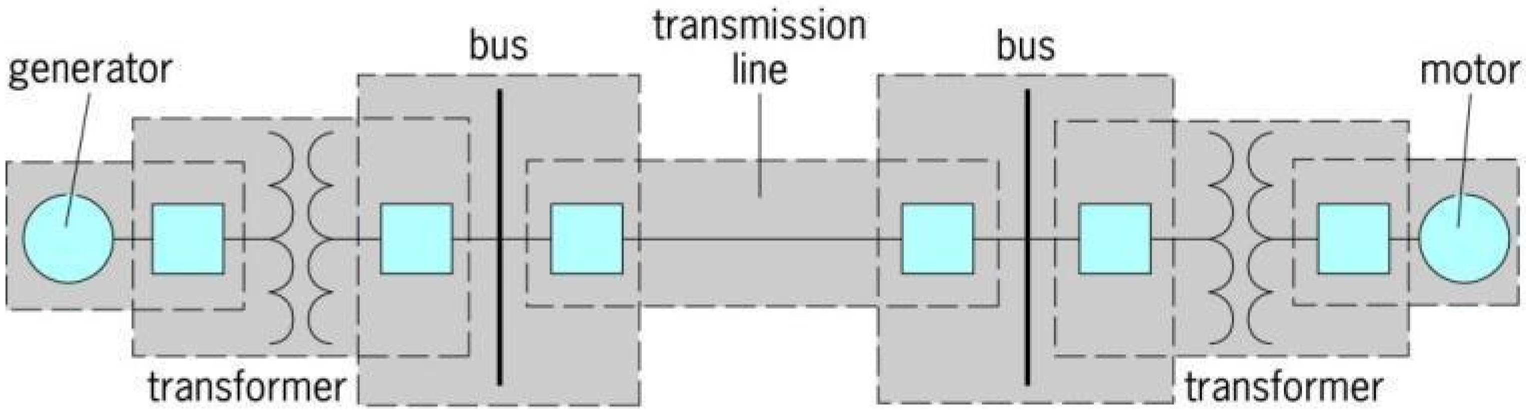
Power system basics

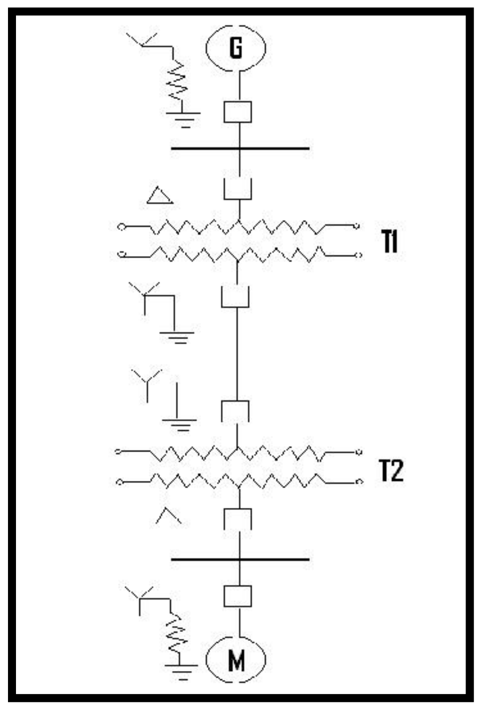
Electric Power System



Electricity is generated at a power plant (1),
voltage is "stepped-up" for transmission(2)
Energy travels along a transmission line to the area where the power is needed (3)
voltage is decreased or "stepped-down," at another substation (4),
& a distribution power line (5)
carries that electricity until it reaches a home or business (6).

SINGLE LINE DIAGRAM





UNIT
1
INTRODUCTION

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UNIT 1 PROTECTION SCHEMES
Syllabus

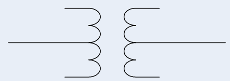
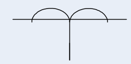
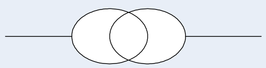
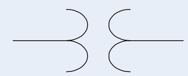
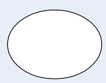
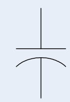
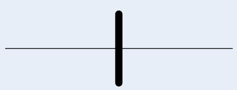
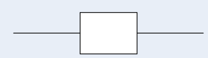
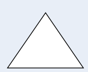
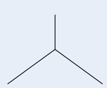
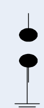
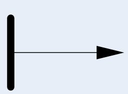
- Principles and need for protective schemes
- Nature and causes of faults
- Types of faults
- Fault current calculation using symmetrical components
- Methods of Neutral grounding 

- Zones of protection and essential qualities of protection 

- Protection schemes

Principles & need for protective schemes

PROTECTION SYMBOL

	two-winding transformer		current transformer
	two-winding transformer		voltage transformer
	generator		capacitor
	bus		circuit breaker
	transmission line		circuit breaker
	delta connection		fuse
	wye connection		surge arrestor
	static load		disconnect

Primary Equipment & Components

- **Transformers** - to step up or step down voltage level
- **Breakers** - to energize equipment and interrupt fault current to isolate faulted equipment
- **Insulators** - to insulate equipment from ground and other phases
- **Isolators (switches)** - to create a visible and permanent isolation of primary equipment for maintenance purposes and route power flow over certain buses.
- **Bus** - to allow multiple connections (feeders) to the same source of power (transformer).

Primary Equipment & Components

- **Grounding** - to operate and maintain equipment safely
- **Arrester** - to protect primary equipment of sudden overvoltage (lightning strike).
- **Switchgear** – integrated components to switch, protect, meter and control power flow
- **Reactors** - to limit fault current (series) or compensate for charge current (shunt)
- **VT and CT** - to measure primary current and voltage and supply scaled down values to P&C, metering, SCADA, etc.
- **Regulators** - voltage, current, VAR, phase angle, etc.

Why A System Needs Protection?

- There is no '**fault free**' system.
- Ensure safety of personnel.
- Usually faults are caused by breakdown of insulation due to various reasons: system over current, over voltage, lighting, etc.

PROTECTION SYSTEM

A series of devices whose main purpose is to protect persons and primary electric power equipment from the effects of faults

BLACKOUTS

Characteristics

Loss of service in a large area or population region

Hazard to human life

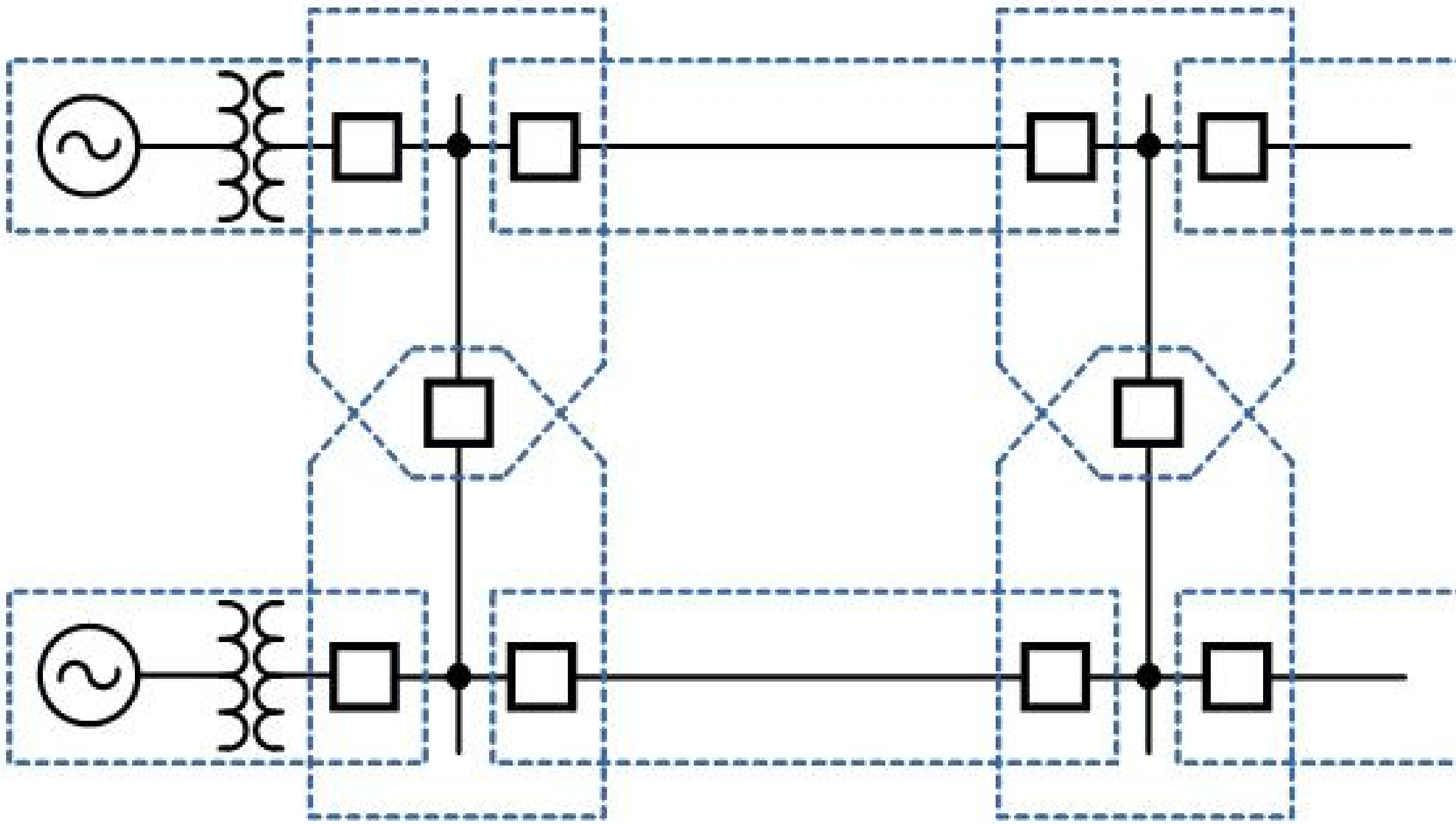
May result in enormous economic losses

Main Causes

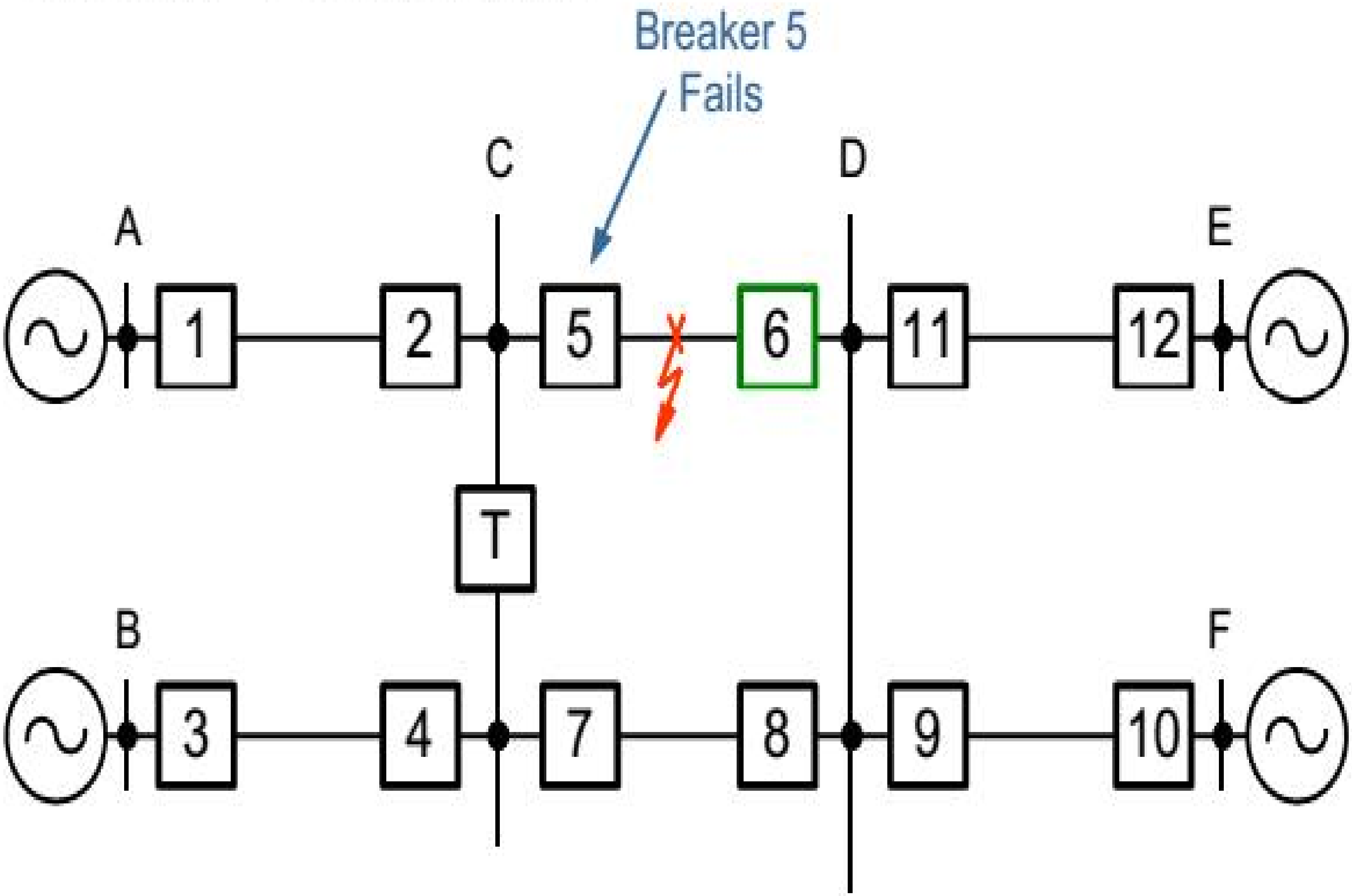
Overreaction of the protection system

Bad design of the protection system

PRIMARY PROTECTION



BACKUP PROTECTION



POWER SYSTEM WITHOUT PROTECTION

- Short circuits and other abnormal conditions often occur on the power system. The heavy current associated with short circuits is likely to cause damage to the equipment

Element of protection system

(1)Current and Voltage Transformers

(2)Relays

(3)Circuit breakers

(4)Batteries

(5)Fuses

(6)Lighting Arresters

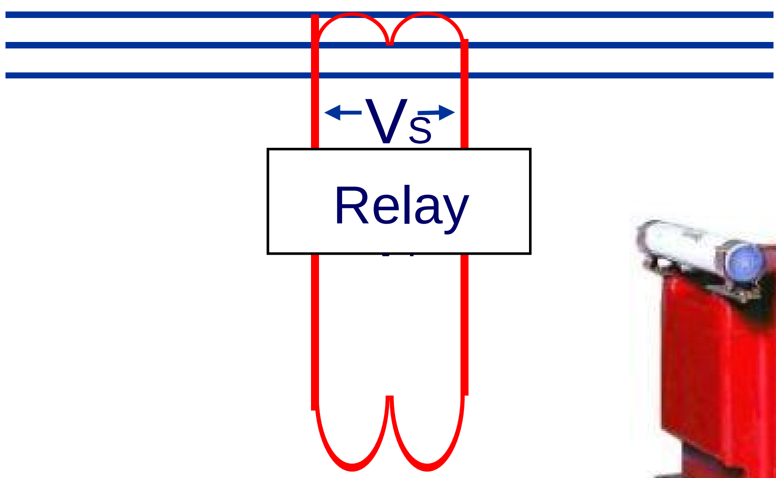
Current transformer

- Current transformer consists at least of two secondary windings.
- The first winding is usually designed for measuring, the second is used for protection.
- The secondary of current transformers are almost connected in star




Voltage transformer

- Voltage transformer is often consists of two windings.
- The first winding is connected in star, and the stare point must be earthed.
- The second winding is connected as open delta.



Relay Purpose

- Isolate controlling circuit from controlled circuit.
- Control high voltage system with low voltage.
- Control high current system with low current.
- Logic Functions

Advantages for Using Protective Relays

- Detect system failures when they occur and isolate the faulted section from the remaining of the system.
- Mitigating the effects of failures after they occur.
- Minimize risk of fire, danger to personal and other high voltage systems.

CIRCUIT BREAKER

- Low voltage circuit breaker
- Magnetic circuit breaker
- Medium voltage circuit breaker
- High voltage circuit breaker

Battery bank

- Battery bank are called as backbone of protection system
- Emergency use for power system

Fuse

- Fuses are selected to allow passage of normal current and of excessive current only for short periods.
- It is used to protect the low voltage or current rating devices

Lighting arrester

- A lightning arrester is a device used on electrical power system to protect the insulation damaging effect of lightning.
- All lighting arrester are earthed

What is Switchgear ?

- **Switchgear** is the combination of switches, fuses or circuit breakers(CB) used to control , protect & isolate electrical equipment.
- It is used de-energize equipment & clear faults.

Different elements of switchgear

- **Circuit breaker**

  Air ckt breaker **ACB**
  Vacuumed ckt breaker **VCB**
  Oil filled ckt breaker **OCB**
  SF_6 Ckt Breaker

- **MCCB** (Moulded Case Ckt Breakers)

- **MCB**

  (Miniature Circuit Breaker)
- **RCCB**

Residual current circuit breaker

- Load Breaking Switch **LBS**
- By pass and changeover switches
- Isolators(**switches**)
- Fuses

Function wise categories

- Automatic & Manual operation

  { **example:** **Circuit breaker ,MCB , MCCB** }

- Only automatic operation

  Fuse

- Only manually activated / operated

  Isolator, LBS

Voltage wise switchgear categories

- Low voltage Switchgear
  up to 11KV
- Medium voltage switchgear
  up to 66KV
- High Voltage switchgear
  up to 400KV
- Extra High Voltage switchgear
  up to 765KV
- HVDC Switchgear

Nature and causes of faults

Types of faults

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NATURE & CAUSES OF FAULTS

•Insulation failure.

•Conducting path failure.

•Over voltages due to lightening or switching surges.

•Puncturing or breaking of insulators.

•Failure of conducting path due to broken conductors.

•Failure of solid insulation due to aging, heat, moisture, overvoltage , accidental contact with earth or earth screens, flash over voltages and etc.,

FAULT IN POWER SYSTEM

- A power system fault may be defined as any condition or abnormality of the system which involves the electrical failure of primary equipment such as generators, transformers, busbars, overhead lines and cables and all other items of plant which operate at power system voltage.
- Electrical failure generally implies one or the other (or both) of two types of failure, namely insulation failure resulting in a short-circuit condition or conducting path failure resulting in an open-circuit condition, the former being by far the more common type of failure.

FAULT IN POWER SYSTEM

- **Symmetrical fault**

  Faults giving rise to equal currents in lines displaced by

  equal phase angles i.e 120^o in three phase systems.

  Example: short circuit of **all three phase** conductors of a cable at a single location

- **Unsymmetrical fault**

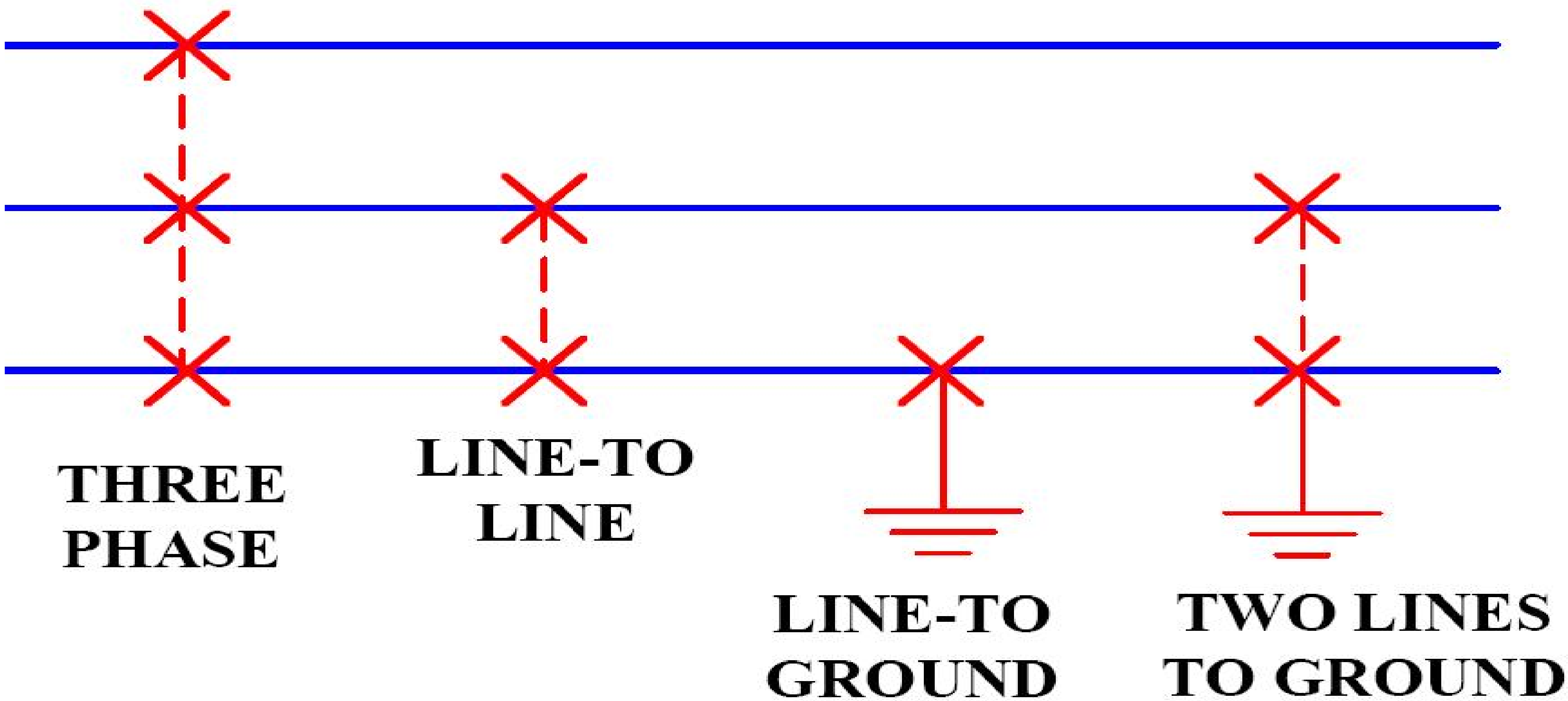
  Faults in which not all the line currents are equal and not all have the same phase.

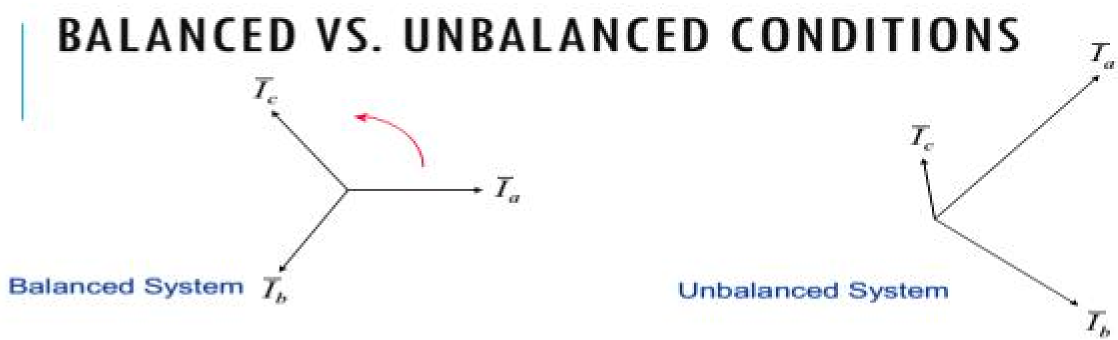
  Example (any one): single phase line to ground fault (**L-G**), two phase to ground (**LL-G**) fault and phase to phase (**L-L**) fault.

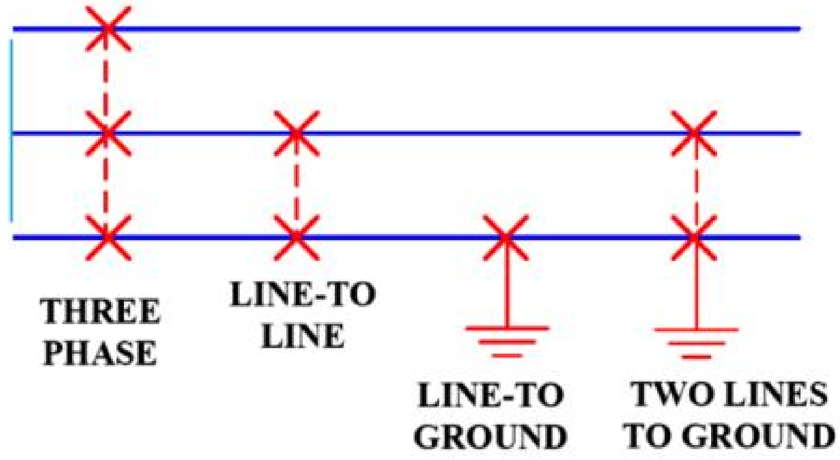
Abnormalities in Power Systems

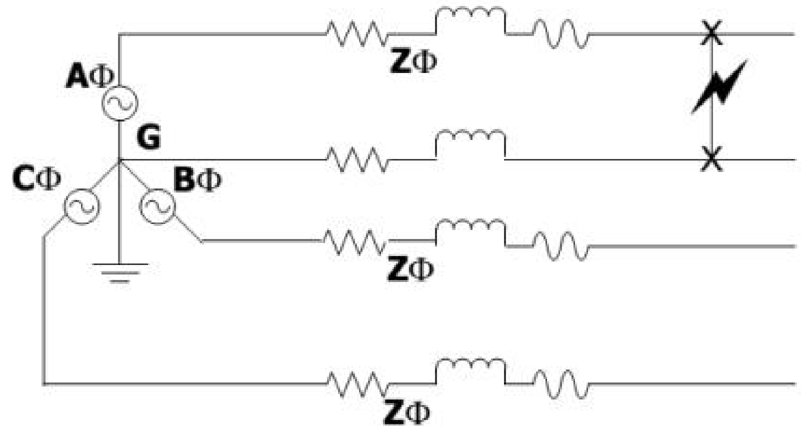
- Overcurrent **(overload, short circuit, open circuit)**
- Ground Potential **(ungrounded equipment, touch potentials, step potentials)**
- Surge Voltages **(lightning strokes, switching surges, harmonics)**

Fault Types (Shunt)

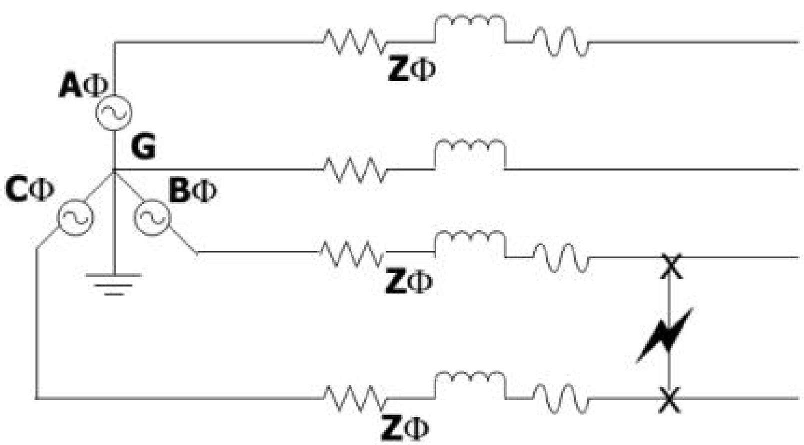




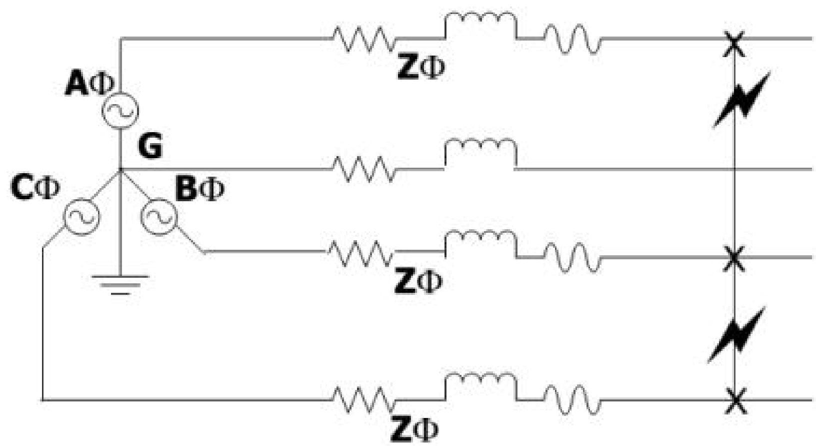




Short Circuit Calculation
Fault Types – Single Phase to Ground



Short Circuit Calculations
Fault Types – Line to Line



Short Circuit Calculations
Fault Types – Three Phase

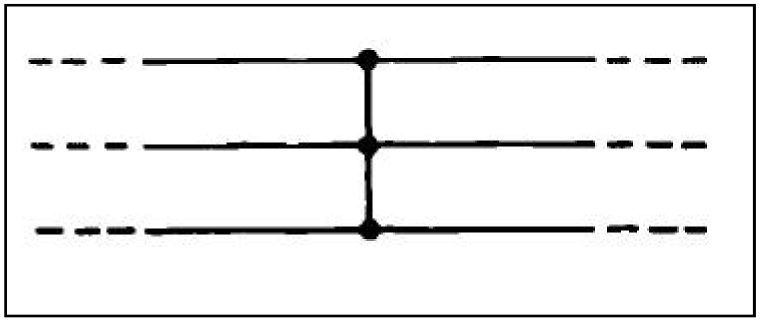
Frequency of Types of Faults

Type of Fault	% Occurrence
SLG	85
LL	8
DLG	5
3L	2 or less

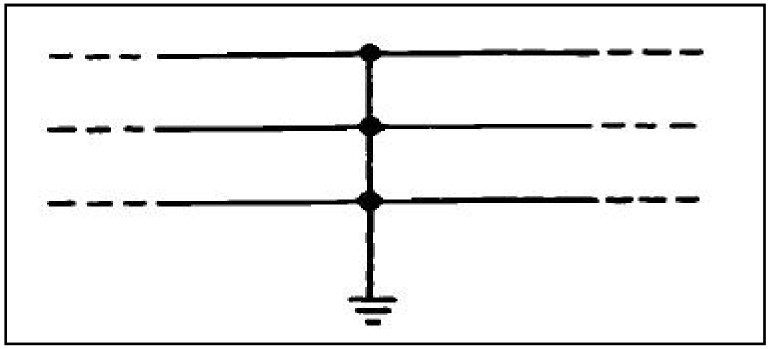
Frequency of Fault Occurrence

Equipment	% of Total
Overhead lines	50
Cables	10
Switchgear	15
Transformers	12
CTs and PTs	2
Control Equipment	3
Miscellaneous	8

SYMMETRICAL FAULT

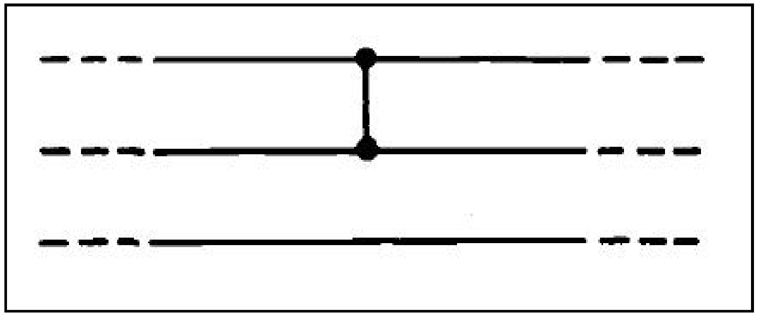


THREE- PHASE FAULT

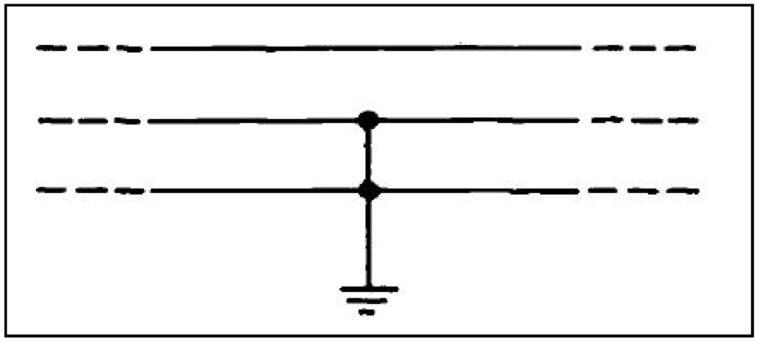


THREE PHASE - EARTH FAULT

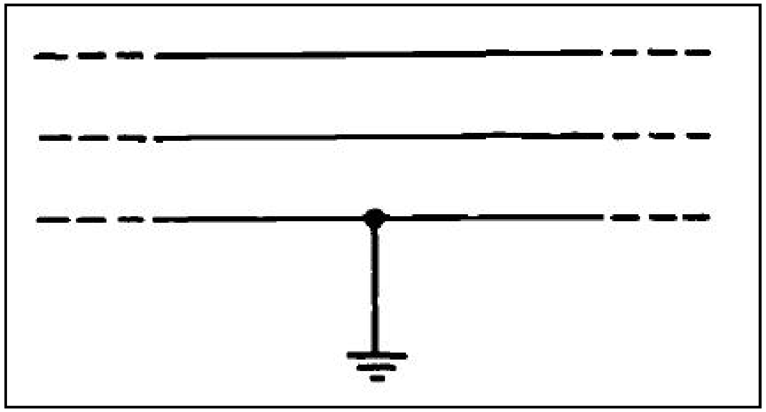
UNSYMMETRICAL FAULT



PHASE – PHASE FAULT

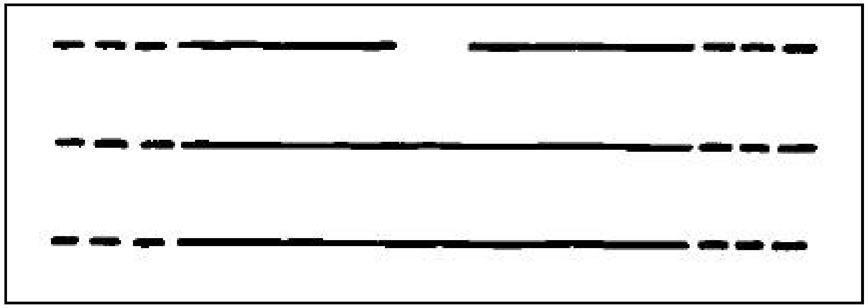


TWO PHASE – EARTH FAULT

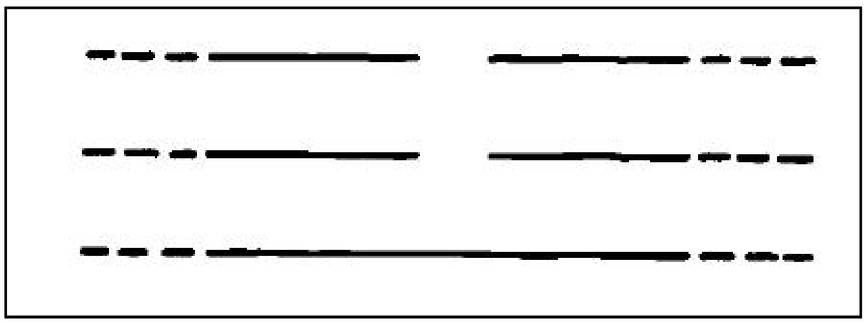


SINGLE PHASE - EARTH FAULT

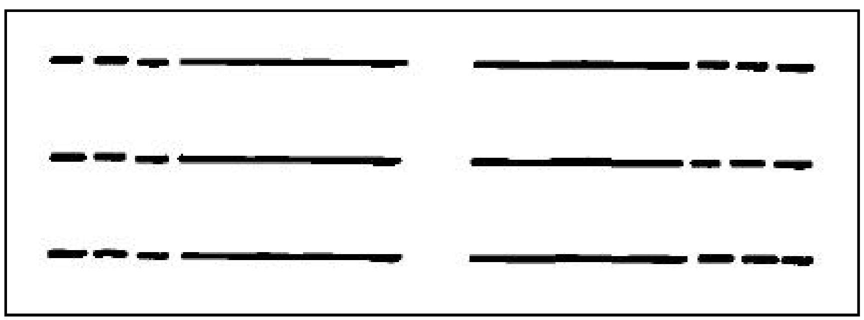
OPEN CIRCUIT FAULT



SINGLE- PHASE OPEN CIRCUIT



TWO- PHASE OPEN CIRCUIT

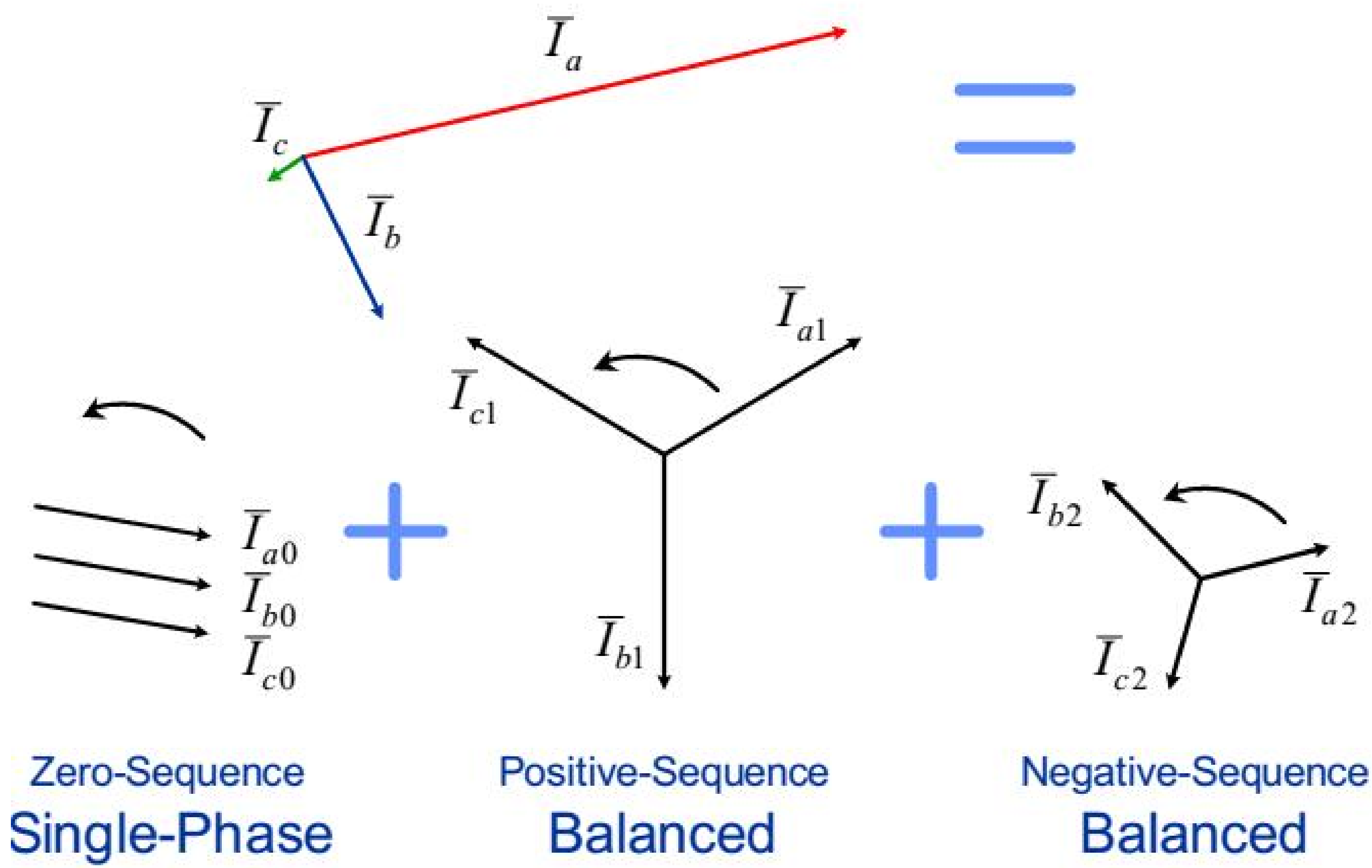


THREE- PHASE OPEN CIRCUIT

Equipments & % of total fault	Causes of Faults
Over head lines **(50%)**	•Lighting Stroke •Earthquake •Icing •Birds •Tree branches •Kite Strings •Internal Overvoltage 
Under ground Cable **(9%)** 	•Damage due to digging • Insulation failure due to temperature rise •Failure of Joints
Alternator **(7%)**	•Stator & Rotor faults

Equipments & % of total fault	Causes of Faults
Transformer (10%)	•Insulation Failure •Faults in tap changer •Overloading 
Current Transformer & Potential Transformer (12%)	•Overvoltage •Insulation Failure •Break of Conductors •Wrong Connections
Switch Gear (12%)	•Insulation failure •Leakage of air/oil/gas •Mechanical defect •Lack of Maintenance

DECOMPOSITION OF AN UNBALANCED SYSTEM



Fault Minimization

- ***Improving the quality*** of machines, equipments, installation etc., by improving the design techniques.
- ***Adequate & reliable*** protection system control
- ***Regular maintenance*** by trained professionals
- ***Effective management*** of electrical plant

Merits of Fast fault clearing

- Helps to avoid ***permanent damage to equipment & components of the apparatus***
- ***Reduces*** the chances of risks like ***fire hazards***
- Maintains the ***continuity*** of the power supply
- Brings back the power system to the ***normal state sooner***

Fault current calculation using symmetrical components

A 3φ 11 KV, 25000 KVA alternator with $x_{g0} = 0.05$ pu $x_1 = 0.15$ pu, $x_2 = 0.15$ pu is grounded through a reactance of 0.3 Ω. calculate line current for single line - ground fault

$$\text{Base current} = \frac{KVA_b}{\sqrt{3}\, KV_b} = \frac{25000}{\sqrt{3} \times 11 \times 10^3}$$

$$I_b = 1312.15 \text{ A}$$

$$I_R = \frac{3E_R}{Z_0 + Z_1 + Z_2} = \frac{3}{j0.15 + j0.15 + (Z_{g0} + 3Z_n)}$$

$$\% X_n = \frac{X_n (KVA)}{10 (KV)^2} = \frac{0.3 \times 25000}{10 (11)^2}$$

$$= 6.198 \%$$

$$= 0.06 \text{ pu}$$

$$X_0 = X_{g0} + 3X_n$$

$$= 0.05 + 3(0.06)$$

$$X_0 = 0.23 \text{ pu}$$

$$I_R = \frac{3}{j0.15 + j0.15 + j0.23} = \frac{3}{j0.53} = -j5.66 \text{ pu}$$

$$\text{Actual} = \text{pu} \times \text{Base}$$

$$= 5.66 \times 1312.15$$

$$= 7426.77 \text{ A}$$

A 30 MVA, 11 KV generator has $Z_1 = Z_2 = j0.21$ pu. $Z_0 = j0.05$ pu. If a L-L fault occurs on the terminals of generator. Find line current & line to neutral voltages under fault conditions

$$\text{Base} = \frac{KVA}{\sqrt{3} \times KV} = \frac{30 \times 10^6}{\sqrt{3} \times 11 \times 10^3} = 1574.59 \text{ A}$$

$$I_R = I_{R0} + I_{R1} + I_{R1}$$

$$I_{R1} = \frac{E_R}{Z_1 + Z_2} = \frac{1}{j0.21 + j0.21} = -j2.38 \text{ pu}$$

$$I_{R2} = -I_{R1} = j2.38 \text{ pu}$$

$$I_R = 0 - j2.38 + j2.38$$

$$I_R = 0$$

$$I_y = \frac{-j\sqrt{3}\, E_R}{Z_1 + Z_2} = -j\sqrt{3}(-j2.38)$$

$$I_y = -4.12 \text{ pu}$$

$$I_B = -I_y = 4.12 \text{ pu}$$

Actual = Base × pu

$= 1574.59 \times (-4.12)$

$I_y = -6487.3$ A

$I_B = 6487.3$ A

$$V_R = V_{R0} + V_{R1} + V_{R2}$$

$$V_{R1} = \frac{E_e Z_2}{Z_1 + Z_2} = \frac{1(j0.21)}{j0.21 + j0.21} = \frac{j0.21}{j0.42}$$

$$V_{R1} = 0.5 = V_{R2}$$

$$V_R = 0 + 0.5 + 0.5$$

$$V_R = 1$$

$$V_Y = V_{R0} + a V_{R1} + a^2 V_{R2}$$

$$= 0 + (a + a^2) V_{R1}$$

$$V_Y = (a + a^2)\, 0.5$$

$$V_Y = -0.5$$

$$V_B = V_{R0} + a^2 V_{R1} + a V_{R2}$$

$$= 0 + (a^2 + a) V_{R1}$$

$$V_Y = -0.5$$

$$E_R = \frac{11 \times 10^3}{\sqrt{3}} = 6350.85 \text{ V}$$

V_R Actual value = Base × pu

$= 6350.85 \times 1$

$= 6350.85\ V$

$V_B = 6350.85 \times -0.5$

$= -3175.43\ V$

$V_Y = 6350.85 \times -0.5$

$= -3175.43\ V$

A 30 MVA 11 KV generator has $Z_1 = Z_2 = j0.21$ pu $Z_0 = j0.05$ pu. If a double line to ground fault occurs on the terminals of the generator find line currents & phase voltages at fault.

$$\text{Base } I = \frac{30\times10^6}{\sqrt{3}\times 11\times10^3} = 1574.59 \text{ A}$$

$$I_{R0} = \frac{-E_R Z_2}{Z_1Z_2 + Z_1Z_0 + Z_0Z_2} = \frac{-1(j0.2)}{j0.21(j0.21) + (j0.2)\,j0.05 + j0.05(j0.2)}$$

$$= \frac{-j0.2}{-0.044 - 0.01 - 0.01} = j3.22 \text{ pu}.$$

$$I_{R1} = \frac{E_R}{Z_1 + \frac{Z_2 Z_0}{Z_0 + Z_2}} = \frac{1}{j0.21 + \frac{j0.21(j0.05)}{j0.21 + j0.05}} = \frac{1}{j0.21 + \frac{j^2 0.0105}{j0.26}}$$

$$= \frac{1}{j0.21 + j0.040}$$

$$= -j3.99 \text{ pu}.$$

$$I_{R2} = \frac{-E_R Z_0}{Z_1Z_2 + Z_1Z_0 + Z_0Z_2}$$

$$= \frac{-j0.05}{j0.21(j0.21) + j0.21(j0.05) + j0.05(j0.21)}$$

$$= j0.768 \text{ pu}$$

$I_R = I_{R0} + I_{R1} + I_{R2}$

$= j3.22 - j3.99 + j0.768$

$\simeq 0$

$I_Y = I_{R0} + a I_{R1} + a^2 I_{R2}$

$= j3.22 + 1\angle 120 (3.99\angle -90) + 1\angle 240 (0.768\angle 90)$

$= j3.22 + 3.99\angle 30 + 0.768\angle 330$

~~$= j3.22 + 30.26 + j82.42 +$~~

$= j3.22 + 3.455 + j1.995 + 0.665 - j0.384$

$= 4.12 + 4.831j$

$I_Y = 6.34\angle 50$ $\Rightarrow$ Actual = Base × pu

$= 1574.6 \times 6.34\angle 50$

$= 9982.96\angle 50$ A.

$I_B = I_{R0} + a^2 I_{R1} + a I_{R2}$

$= j3.22 + 1\angle 240(3.99\angle -90) + 1\angle 120 (0.768\angle 90)$

$= j3.22 + 3.99\angle +150 + 0.768\angle 210$

$= j3.22 - 3.455 + j1.995 + 0.665 - j0.384$

$= -4.12 + 4.831j$

$I_B = 6.34\angle 130$.

Actual $= 1574.6 \times 6.34\angle 130$

$I_f = I_Y + I_B$

$= 9982.96\angle 50 + 9841.25\angle 130$

$= 6416.92 + j7647.39 + 7538.83j - 6325.83$

$= 91.09 + 15186.22j$

$= 15186.49\angle 89.65$

$$V_{R1} = E_R\left[1 - \frac{Z_1}{Z_1 + \frac{Z_2 Z_0}{Z_2 + Z_0}}\right]$$

$$= \left[1 - \frac{j0.21}{j0.21 + \frac{j0.21(j0.05)}{j0.21 + j0.05}}\right]$$

$$= \left[1 - \frac{j0.21}{j0.21 - \frac{0.0105}{j0.26}}\right]$$

$$= 1 - \frac{j0.21}{j0.21 + j\,0.040}$$

$$V_{R1} = 1 - \frac{j0.21}{j0.25} = 0.16 \text{ pu}$$

Actual $V_{R1} = 0.16 \times$ ~~1024.33~~ 6350.85

$= 1016.13 \text{ V}$

$$\text{Base} = \frac{11\times 10^3}{\sqrt{3}}$$

$= 6350.85 \text{ V}$

$V_R = 3V_{R1}$

$= 3 \times 1016.13 = 3.05 \text{ kV}$

$V_Y = V_B = 0 \text{ V}$

Zones of Protection

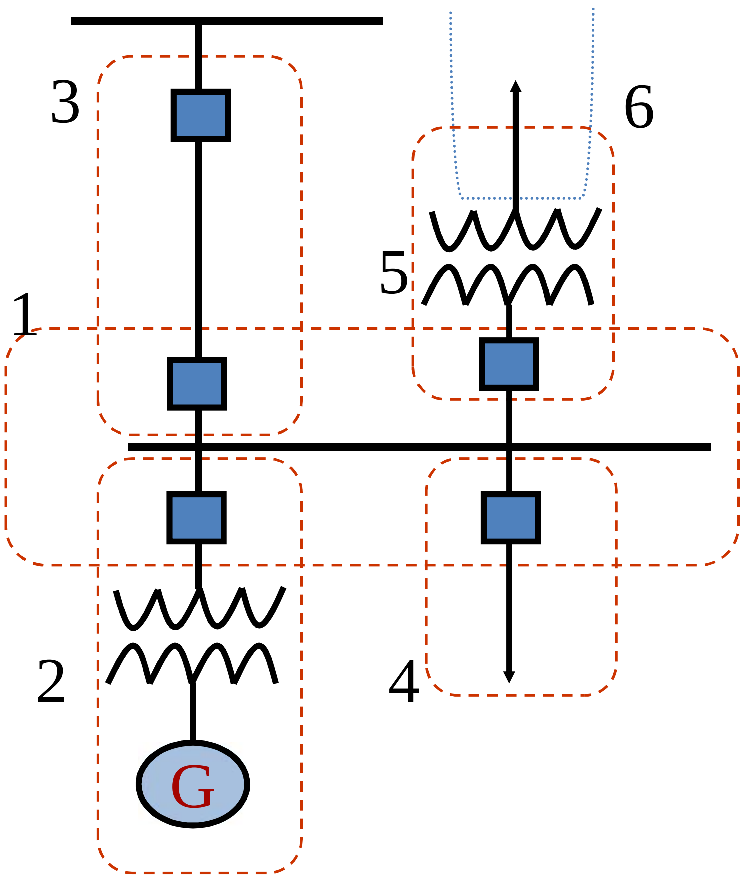
Zones of Protection

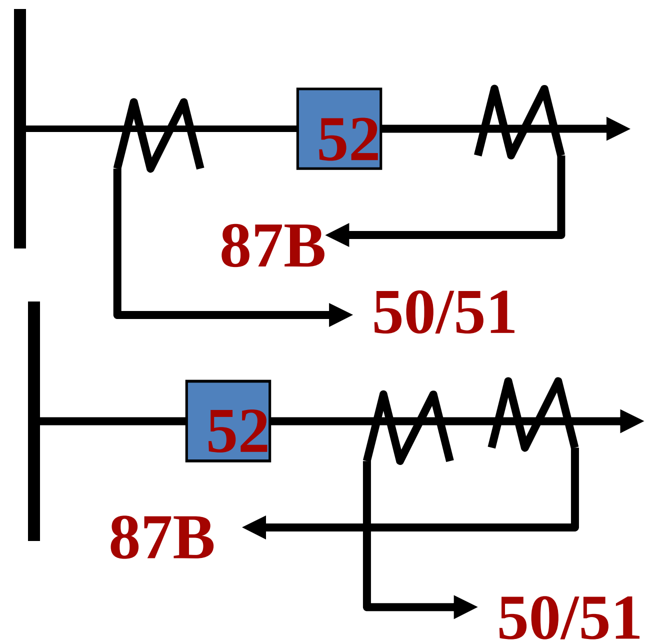
Regions (zones) of power system that can be protected adequately with fault recognition and removal resulting in isolation of a minimum amount of equipment.

Requirements: All power system elements must be encompassed by at least one zone

- Zones of protection must overlap to prevent any system element from being unprotected (no “blind spots”).

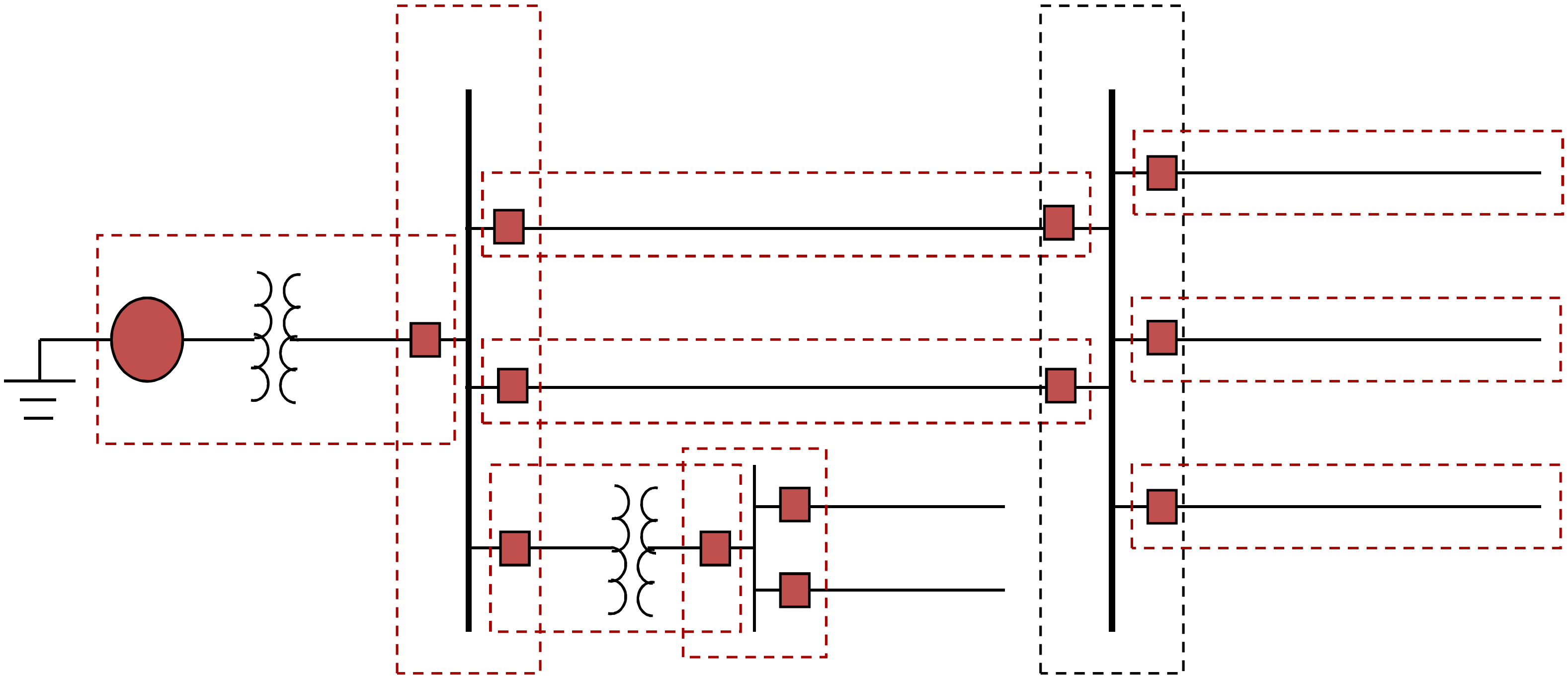
Zones of Protection





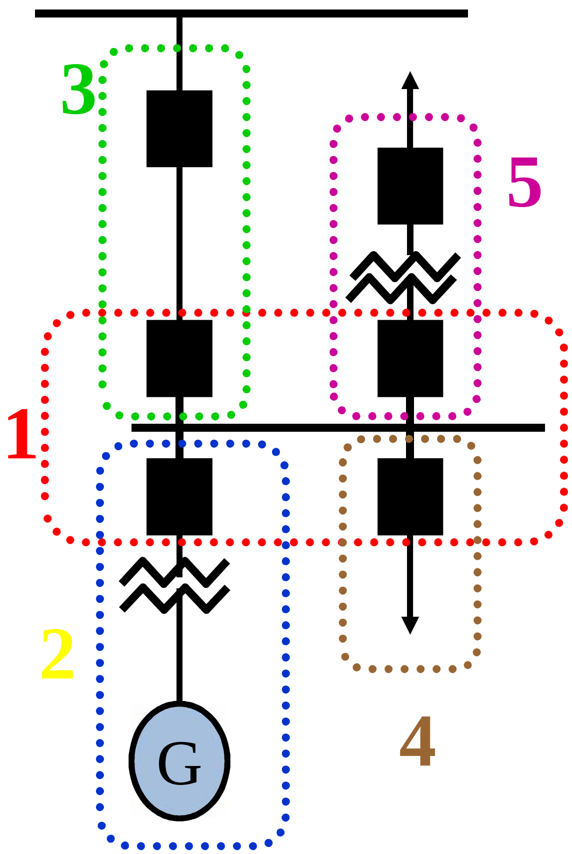
CT REQUIREMENTS FOR OVERLAPPING ZONES

Zones of Protection



Overlapping zones of protection

Zones of Protection



1 - Bus Protection

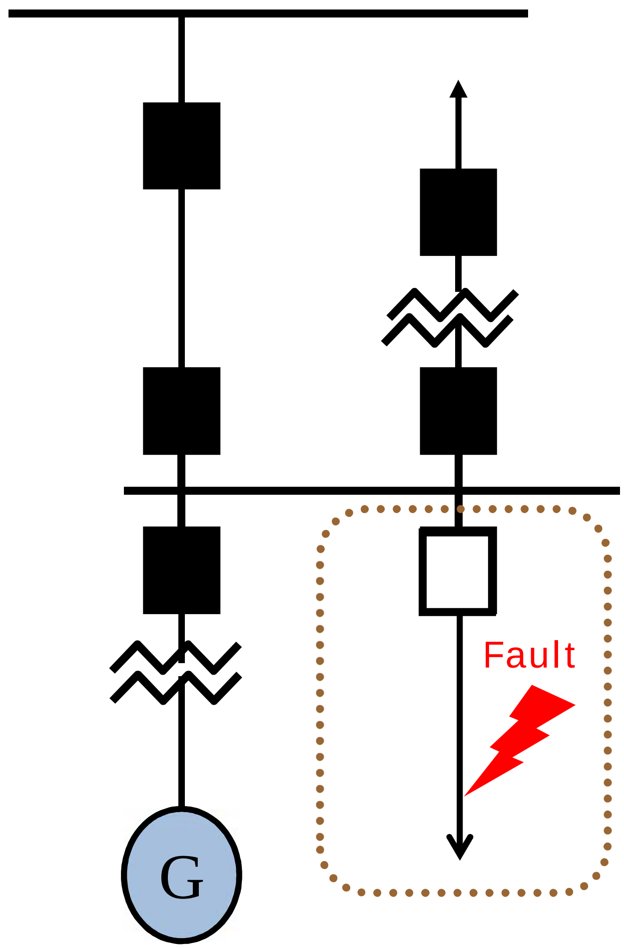
2 - Generator Protection

3 - Subtrans Line Protection

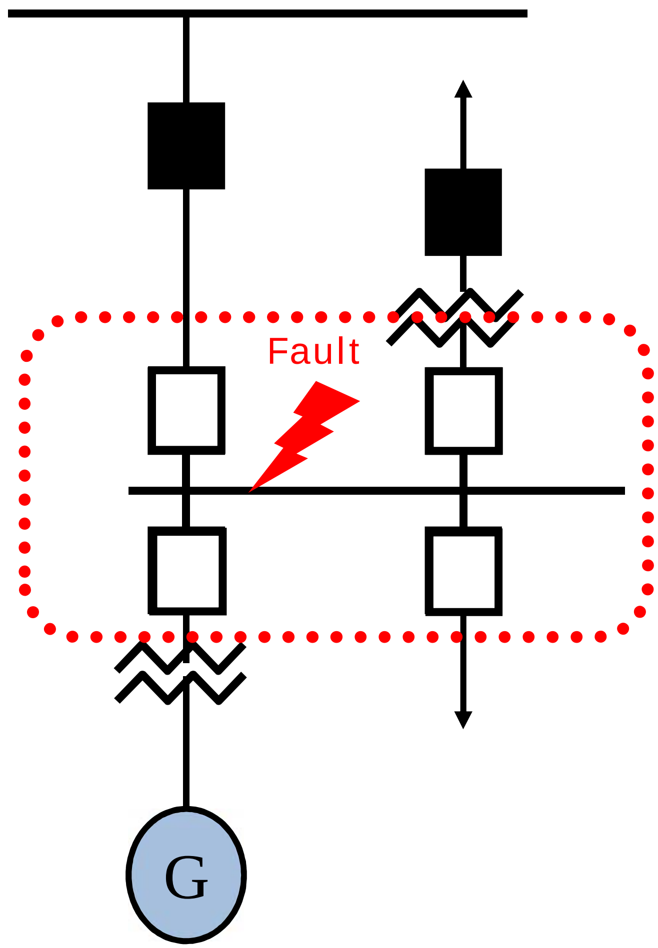
4 - Feeder Protection

5 - Transformer Protection

Feeder Protection



Bus Protection



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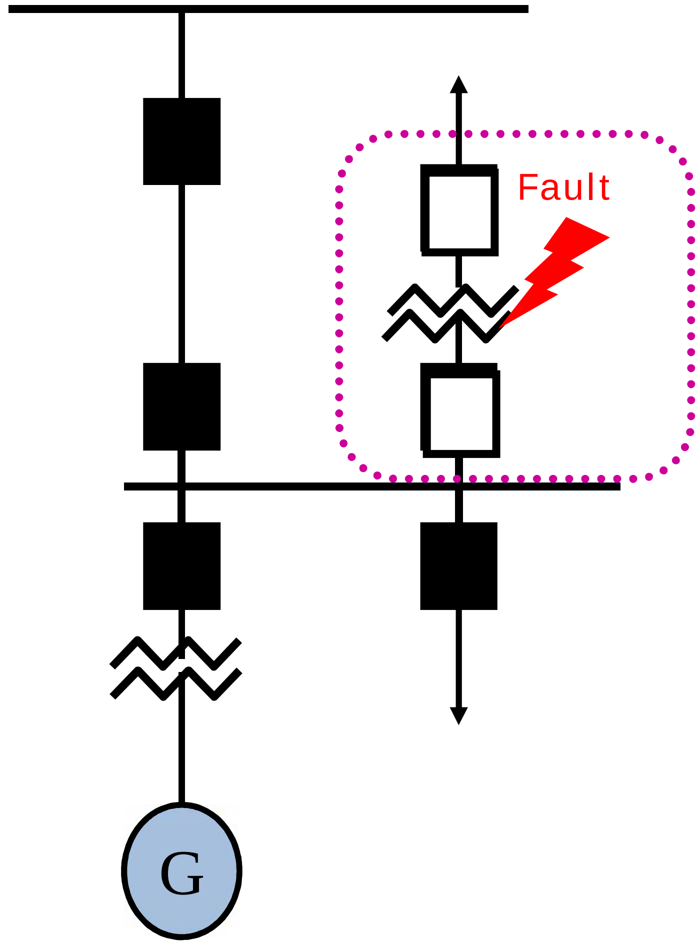
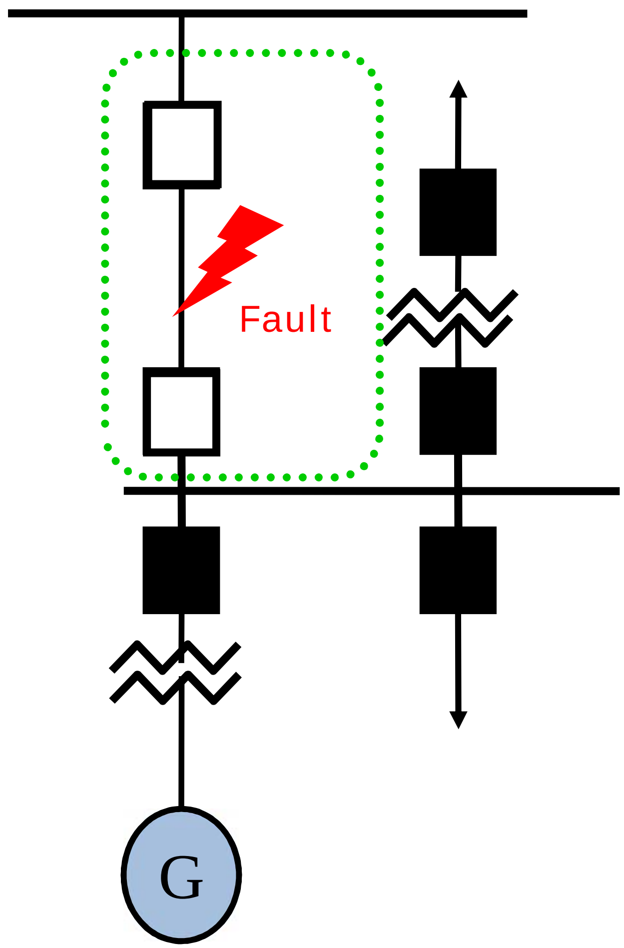
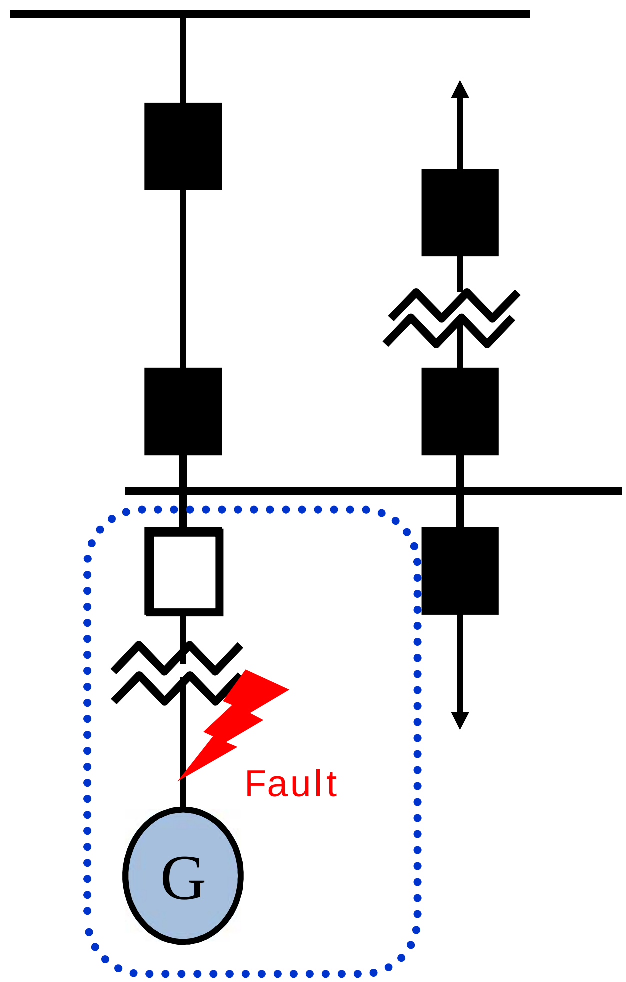
Transformer Protection



Sub transmission Line Protection



Generator Protection



Essential Qualities of protection

or

Requirement of Protective System

- Reliability
  - Dependability
  - Security
- Selectivity
- Speed
  - System stability
  - Equipment damage
  - Power quality
- Sensitivity
  - High-impedance faults
  - Dispersed generation

Reliability	• assurance that the protection will perform correctly.
Selectivity	• maximum continuity of service with minimum system disconnection.
Sensitivity	• To detect even the smallest fault, current or system abnormalities and operate correctly at its setting
Speed	• minimum fault duration and consequent equipment damage and system instability.
Simplicity	• minimum protective equipment and associated circuitry to achieve the protection objectives.

Reliability

- The level of assurance that the relay will function as intended.
- Reliability denotes:
  - Dependability - certainty of correct operation
  - Security - assurance against incorrect operation

Sensitivity

- Relaying equipment must be sufficiently sensitive so that it will operate when required
- Must discriminate normal from abnormal conditions.

Selectivity

- Performance of protective devices to select between those conditions for which prompt operation and those for which no operation, or time delay operation is required.
- Isolate faulted circuit resulting in minimum interruptions.
- Implemented through "Zone of Protection"

Speed

- Remove a fault from the power system as quickly as possible
- Classification:
  - Instantaneous - no intentional delay
  - High Speed - less than 3 cycles
  - Time-Delay - intentional time delay

Methods of Neutral grounding

(OR)

Power System Earthing

- Neutral Earthing/Grounding
- Peterson coil
- Arcing Grounds

- The process of connecting the **metallic frame** (i.e. non-current carrying part) of electrical equipment or some **electrical part** of the system to **earth** (i.e. **soil**) is called **grounding** or **earthing.**

- Grounding or earthing may be classified as :

(i) ***Equipment grounding***

(ii) ***System grounding***

Equipment Grounding

- The process of connecting non-current-carrying metal parts of the electrical equipment to earth.

System Grounding

•The process of connecting some electrical part of the power system to earth (i.e. soil) is called **system grounding.**

Neutral Earthing

Neutral Grounding

- Connecting neutral point to earth (i.e. soil) either directly or some circuit element

  (e.g. **resistance, reactance , Peterson coil** etc.) is called **neutral grounding.**

- Neutral grounding provides protection to equipment.

  (during earth fault, the current path is completed neutral)

Advantages of Neutral Grounding

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

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

(iii) Life of insulation is long.

(iv) The over voltages is reduced.

(v) It provides greater safety to personnel and equipment.

(vi) It provides improved service reliability.

(vii) Operating and maintenance expenditures are reduced.

Methods of Neutral Grounding

(i) Solid or effective grounding

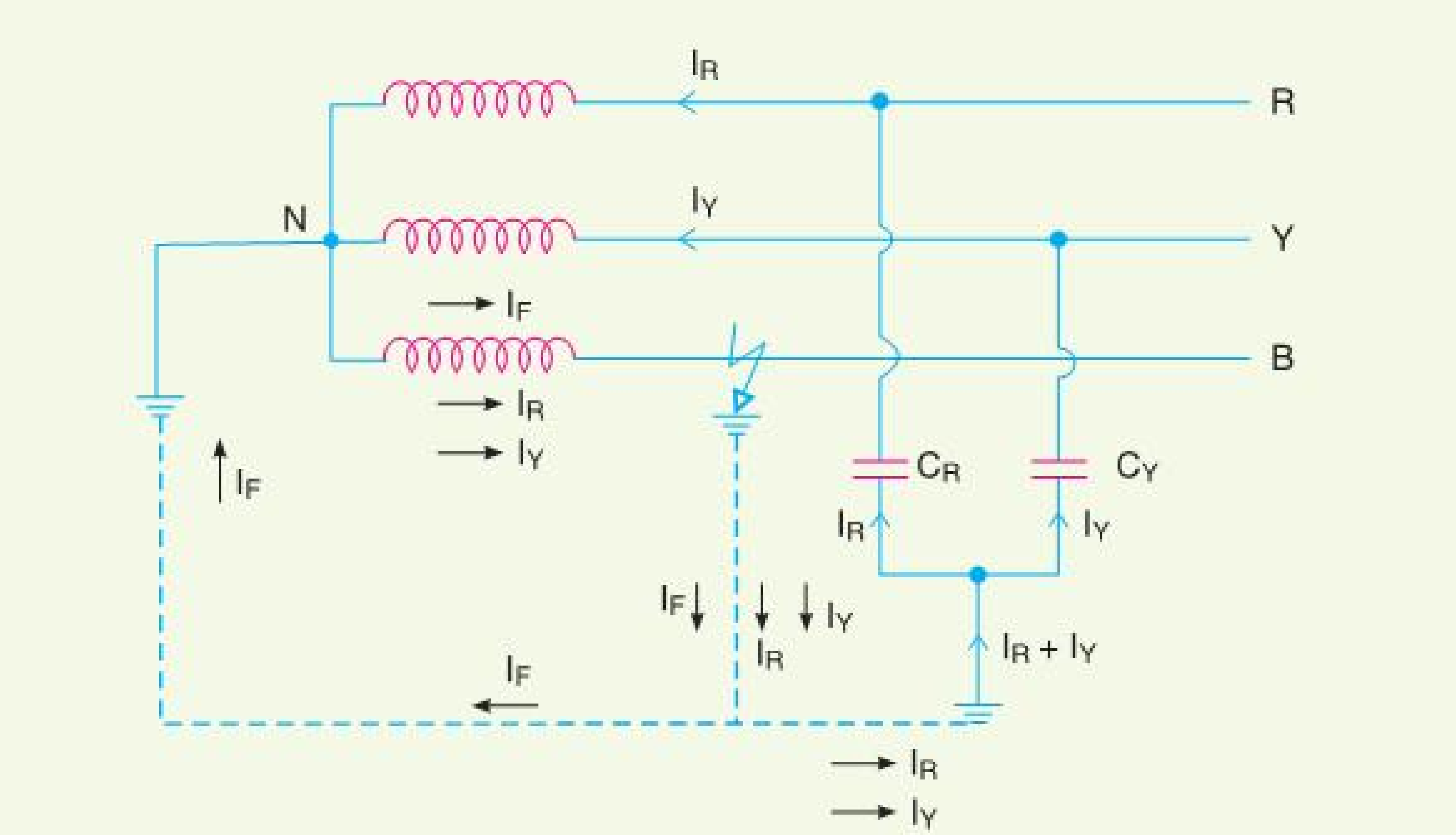
(ii) Resistance grounding

(iii) Reactance grounding

(iv) Peterson-coil grounding 

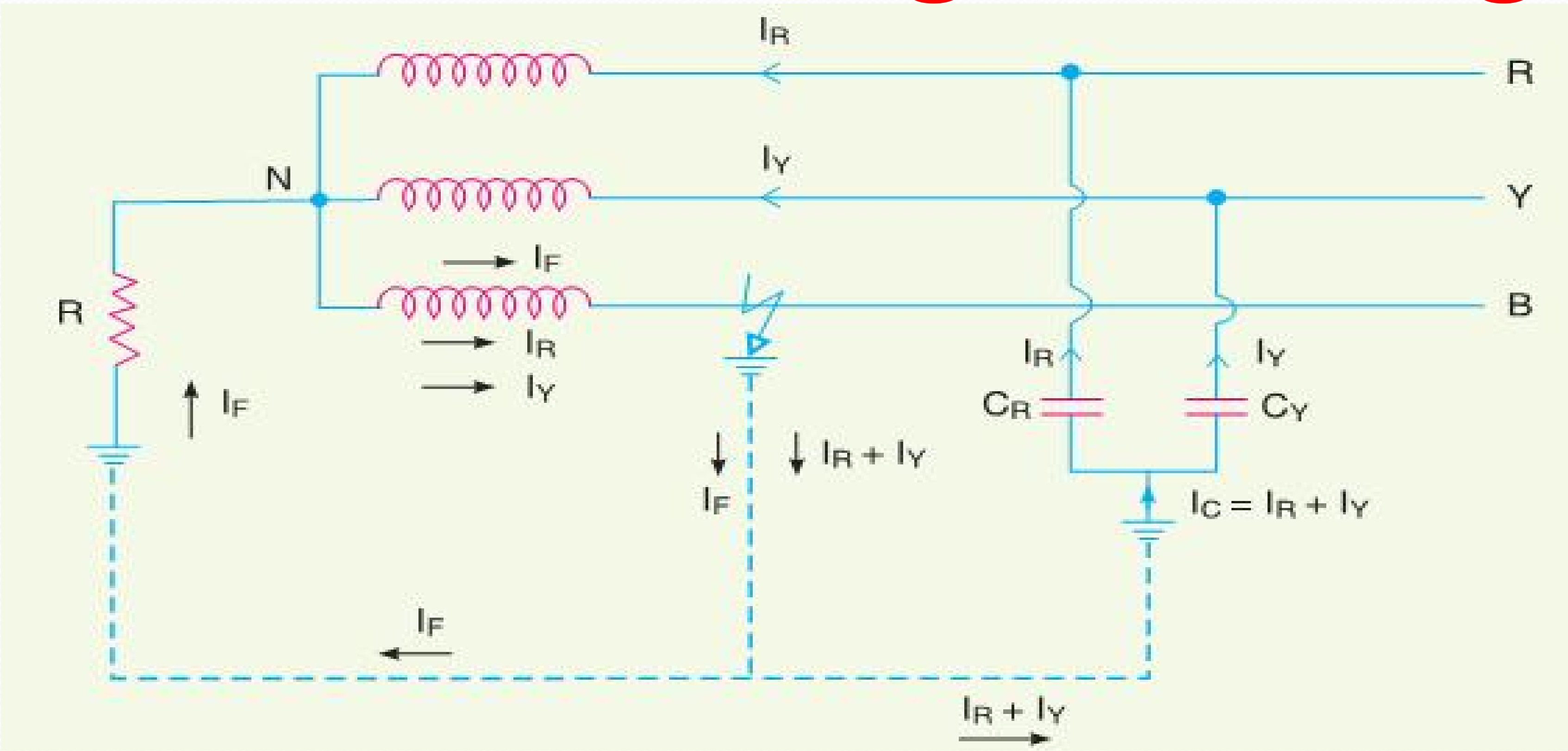
(v) Voltage transformer earthing

(i) Solid or effective grounding



- When the neutral point of a 3-phase system is directly connected to earth (i.e. soil) is called **solid grounding or effective grounding**.
- When an earth fault occurs between earth and any one phase , the voltage to earth of the faulty phase becomes zero, but the healthy phases remains at normal phase values.
- Fault current(I_F) completely nullified by capacitive current(I_C)

(ii) Resistance grounding



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

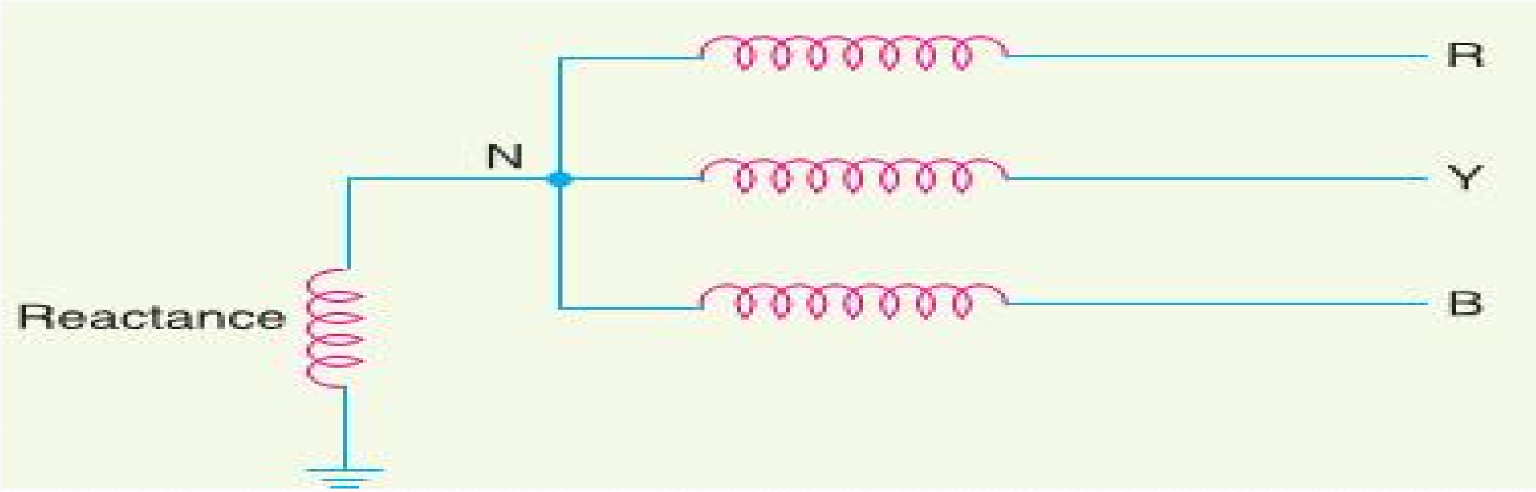
Advantages:

- By adjusting the value of R, the arcing grounds can be minimized.
- It improves the stability
- Less interference
- Minimize hazards

Disadvantages:

- By adjusting the value of R, the arcing grounds can be minimized.
- It improves the stability
- Less interference
- Minimize hazards

(iii) Reactance grounding



- In this system, a reactance is inserted between the neutral and ground
- The purpose of reactance is to limit the earth fault current.

Disadvantages :

(i) In this system, the fault current required to operate the protective device is higher than that of resistance grounding for the same fault conditions.

(ii) High transient voltages appear under fault conditions.

iv. PETERSON COIL

or

Arc Suppression Coil Grounding

or

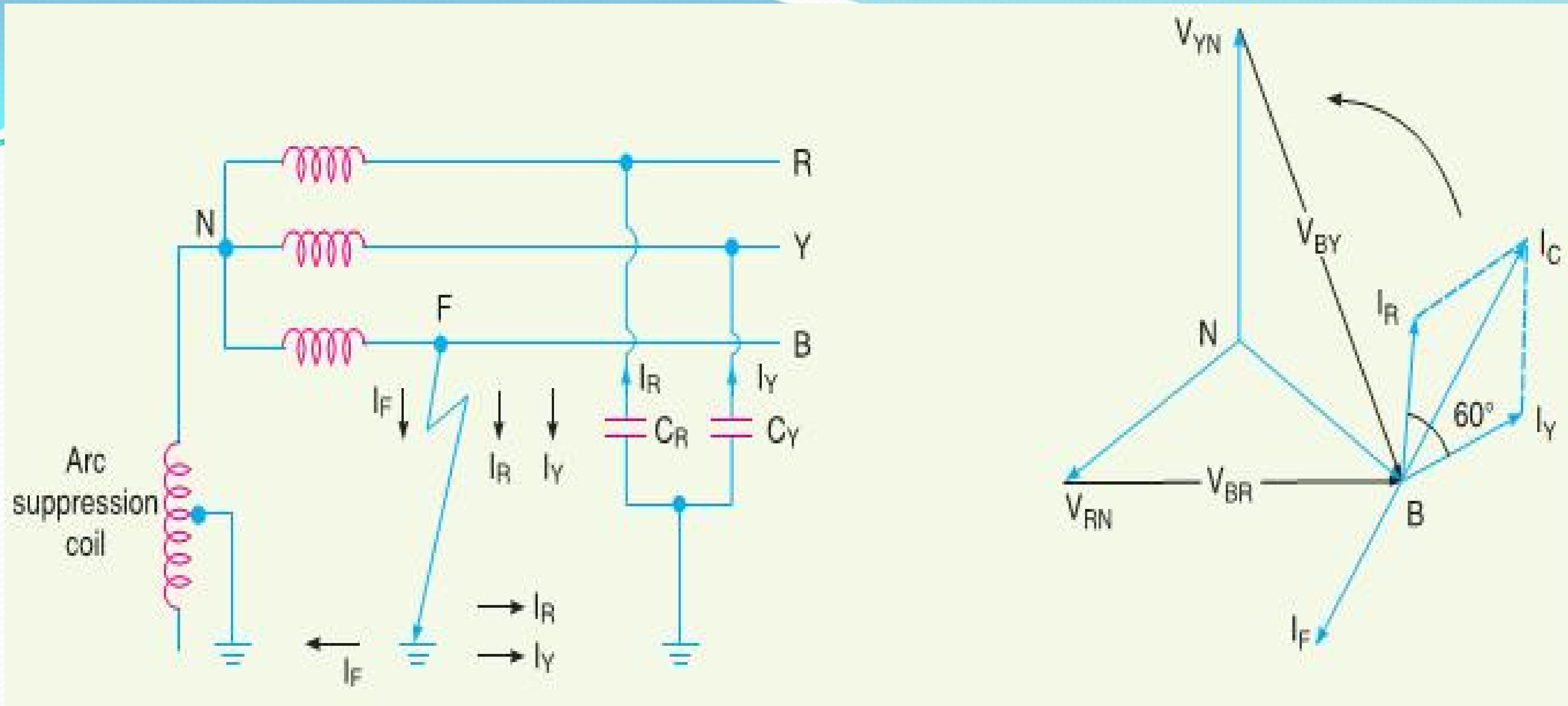
Resonant Grounding

- If inductance L of appropriate value is connected in parallel with the capacitance of the system, the fault current I_F flowing through L will be in phase opposition to the capacitive current I_C of the system. If L is so adjusted that

$$I_L = I_C$$

then resultant current in the fault will be zero. This condition is known as **Resonant Grounding**.

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



- An arc suppression coil (also called Peterson coil) is an iron-cored coil connected between the neutral and earth.
- The reactor is provided with tappings to change the inductance of the coil.
- By adjusting the tappings on the coil, the coil can be tuned with the capacitance of the system i.e. resonant grounding can be achieved.

- Suppose line to ground fault occurs in the line B at point F. The fault current I_F and capacitive currents I_R and I_Y will flow as shown in Fig
- Note that **I_F** flows through the Peterson coil (or Arc suppression coil) to neutral and back through the fault. The total capacitive current I_C is the phasor sum of **I_R & I_Y** as shown in phasor diagram in Fig.
- The voltage of the faulty phase is applied across the arc suppression coil. Therefore, fault current I_F lags the faulty phase voltage by 90°.
- The current **I_F** is in phase opposition to capacitive current **I_C** [See Fig].

By adjusting the tappings on the Peterson coil, the resultant current in the fault can be reduced. If inductance of the coil is so adjusted that **$I_L = I_C$** , then resultant current in the fault will be zero.

Value of L for resonant grounding. For resonant grounding, the system behaves as an ungrounded neutral system. Therefore, full line voltage appears across capacitors C_R and C_Y.

$$\therefore \quad I_R = I_Y = \frac{\sqrt{3}V_{ph}}{X_C}$$

$$\therefore \quad I_C = \sqrt{3}\, I_R = \sqrt{3} \times \frac{\sqrt{3}V_{ph}}{X_C} = \frac{3V_{ph}}{X_C}$$

Here, X_C is the line to ground capacitive reactance.

Fault current, $$I_F = \frac{V_{ph}}{X_L}$$

Here, X_L is the inductive reactance of the arc suppression coil.

For resonant grounding, $I_L = I_C$.

or $$\frac{V_{ph}}{X_L} = \frac{3V_{ph}}{X_C}$$

or $$X_L = \frac{X_C}{3}$$

or $$\omega L = \frac{1}{3\omega C}$$

$$\therefore \quad L = \frac{1}{3\omega^2 C} \qquad ...(i)$$

Exp. (*i*) gives the value of inductance L of the arc suppression coil for resonant grounding.

Advantages. The Peterson coil grounding has the following advantages:

(*i*) The Peterson coil is completely effective in preventing any damage by an arcing ground.

(*ii*) The Peterson coil has the advantages of ungrounded neutral system.

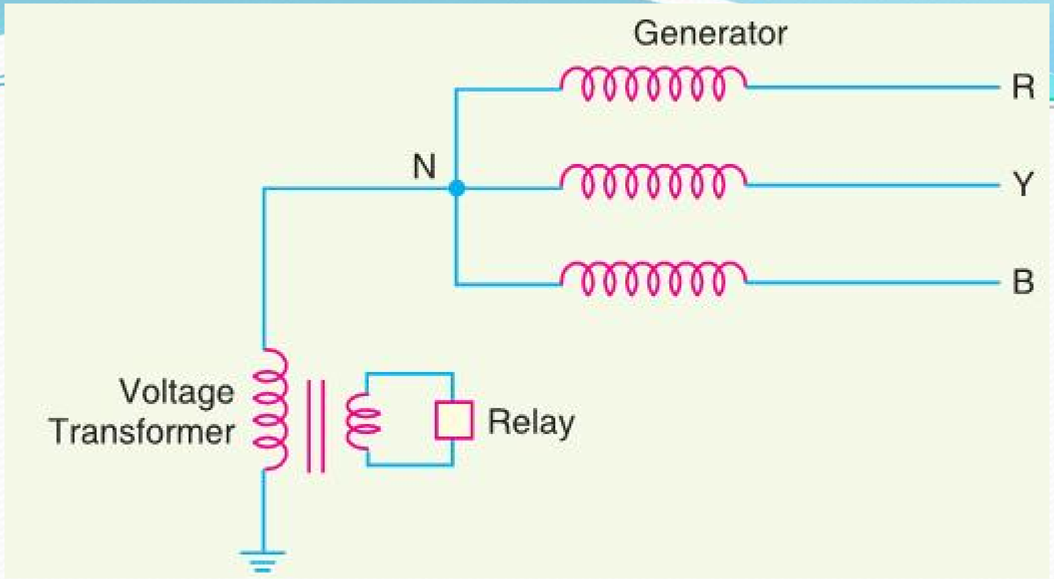
Disadvantages. The Peterson coil grounding has the following disadvantages :

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

(*ii*) The lines should be transposed.

v. Voltage Transformer Earthing

- In this method of neutral earthing , the primary of a single-phase voltage transformer is connected between the neutral and the earth as shown in Fig
- A low resistor in series with a relay is connected across the secondary of the voltage transformer. The voltage transformer provides a high reactance in the neutral earthing circuit and operates virtually as an ungrounded neutral system.



Advantages:

•Arcing grounds are reduced.
•Transient overvoltage are reduced

Protection schemes

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UNIT 2

Electromagnetic RELAY

Presented by

C.GOKUL,AP/EEE
Velalar College of Engg & Tech , Erode

UNIT 2 Syllabus - Electromagnetic relays

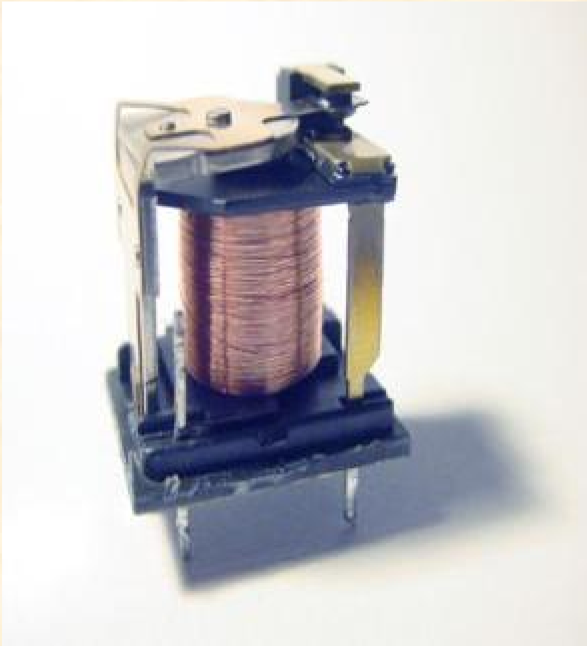
- **Operating principles of relays**
- **The Universal relay - Torque equation**
- **R-X diagram**
- **Electromagnetic Relays**
- **Overcurrent relays**
- **Directional relays**
- **Distance relays**
- **Differential relays**
- **Negative sequence relays**
- **Under frequency relays**

Relay Overview

Operating principles of relays

What are Relays?

- Relays are electrical switches that open or close another circuit under certain conditions.



What is a protective relay?

Protective relays are devices which monitor power system conditions and operate to quickly and accurately isolate faults or dangerous conditions. A well designed protective system can limit damage to equipment, as well as minimize the extent of associated service interruption.

Relay Purpose

- Isolate controlling circuit from controlled circuit.
- Control high voltage system with low voltage.
- Control high current system with low current.
- Logic Functions

Relay Types

- Electromagnetic Relays (EMRs)
- Solid-state Relays (SSRs)
  - There is no mechanical contacts to switch the circuit.
- Microprocessor Based Relays
  Commonly used in power system monitoring and protection.

Advantages/Disadvantages

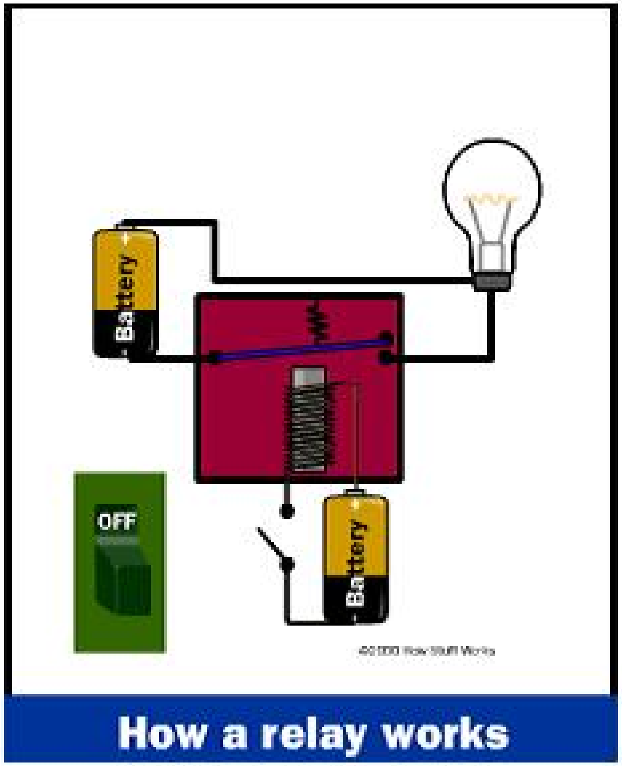
- Electromagnetic Relays (EMRs)
  - Simplicity
  - Not expensive
- Solid-state Relays (SSRs)
  - No Mechanical movements
  - Faster than EMR
- Microprocessor-based Relay
  - Much higher precision and more reliable and durable.
  - Capable of both digital and analog I/O.
  - Higher cost

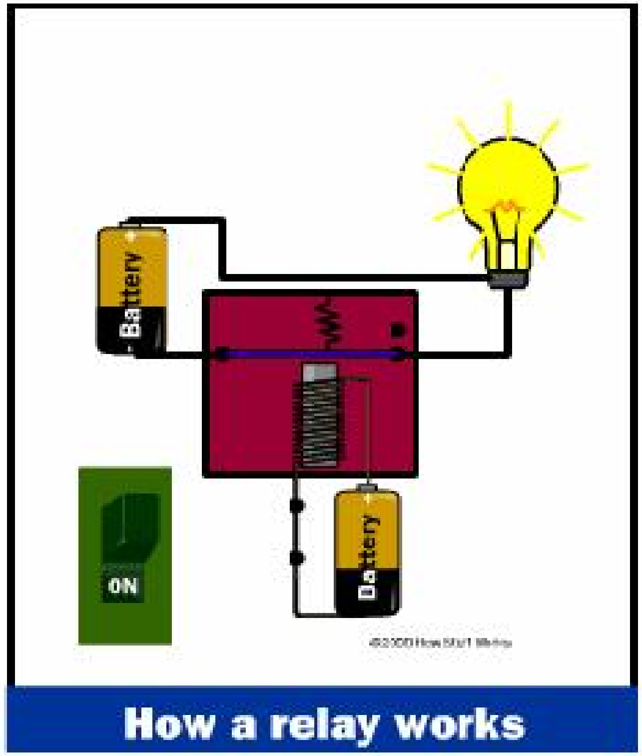
Advantages for Using Protective Relays

- Detect system failures when they occur and isolate the faulted section from the remaining of the system.

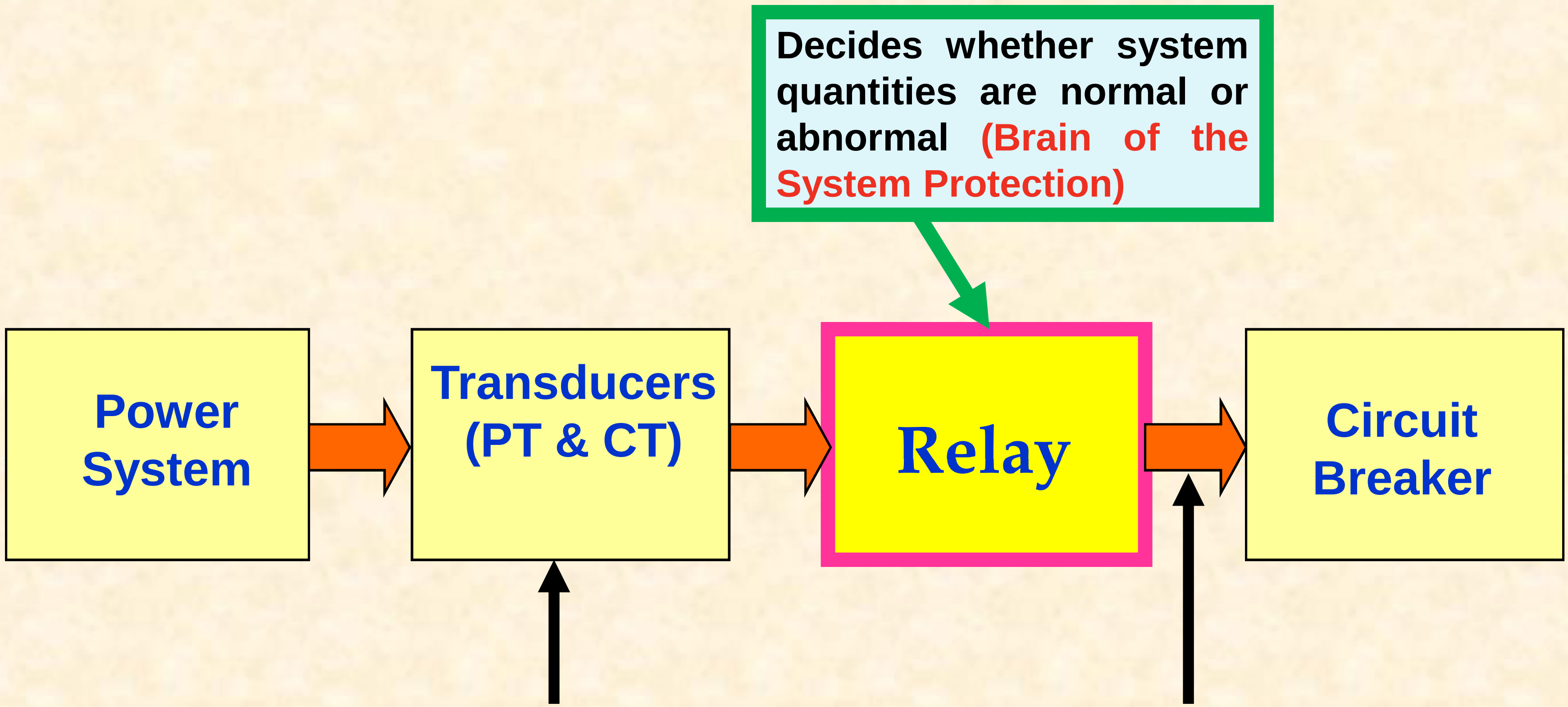
- Mitigating the effects of failures after they occur. Minimize risk of fire, danger to personal and other high voltage systems.

How a Relay Works





Components of Power System Protection



These devices change electrical quantities to level relays can use, i.e., 5 amperes, 115 volts

* If quantities are normal, no signal is sent to breaker
* If quantities are abnormal, signal is sent to breaker to trip

Relay-definitions

- **Primary Relay**: relay connected **directly** in the circuit
- **Secondary Relay**: relay connected to the **protected circuit** through CT & VT.
- **Auxiliary Relay**: relay operate in response to opening or closing of another relay.
- **Measuring Relay**: It performs the measurement of normal & abnormal conditions in the power system.
- **Electro Magnetic Relay**: It operates on the principle of Electromagnetic induction.
- **Static Relay(Solid-state relay)**: They use diodes , transistors , SCRs , Logic gates etc.

  (Static circuit is the measuring circuit & no moving parts)
- **Microprocessor Based Relay**: All functions of a relay can done by using microprocessor . Relays are programmable.

  μP can compare , compute and send trip signals.

- **Thermal Relay**: It operates on the principle of Electro-thermal effect.
- **Distance Relay**: relay measures the impedance or reactance or admittance.
- **Impedance Relay**: relay measures the impedance of the transmission line.
- **Reactance Relay**: relay measures the reactance of the transmission line.
- **Over-current Relay**: relay operates when the current exceeds a pre-set value.
- **Under-voltage Relay**: relay operates when the voltage falls a pre-set value.
- **Directional Relay**: relay able to sense whether fault lies in forward or reverse direction.
- **Polarized Relay**: relay depends on the direction of the current.

- **Differential Relay**: it measures the difference b/w 2 actual quantities.
- **Earth fault Relay**: It is used for protection of element of a power system against **Earth** faults.
- **Phase fault Relay**: It is used for protection of element of a power system against **phase** faults.
- **Negative Sequence Relay**: relay uses negative sequence current as its actuating quantity.
- **Zero Sequence Relay**: relay uses zero sequence current as its actuating quantity.

UNIVERSAL RELAY

REFER BOOK

Electromagnetic Relay

They work on the following two main operating principles :

(i) Electromagnetic attraction

(ii) Electromagnetic induction

Electromagnetic Attraction Relays

(i) Attracted armature type relay

(ii) Solenoid type relay

(iii) Balanced beam type relay

Induction Relays / Electromagnetic induction

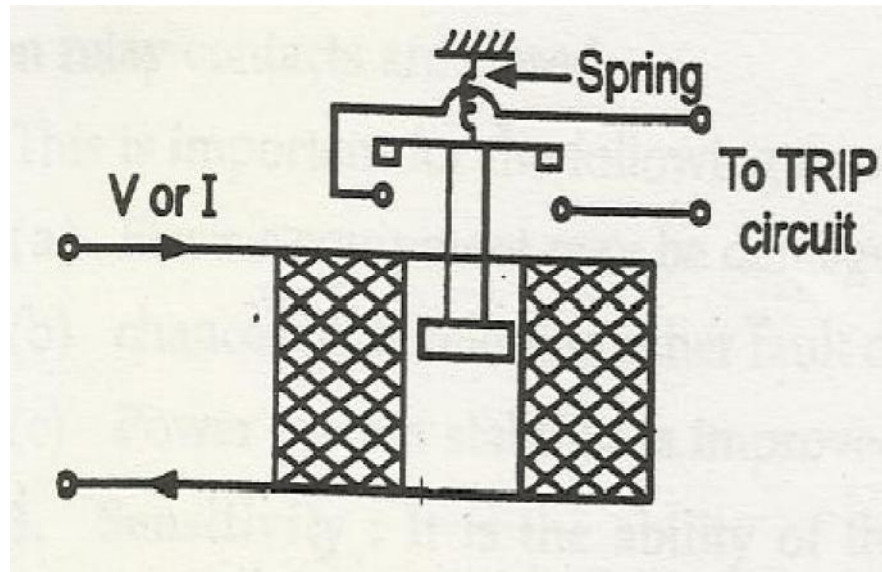
(i) Induction type overcurrent Relay (**Non Directional Relay**)

(ii) Induction Cup Relay (**Directional Relay**)

1. Attracted Armature Type Relays

These have a coil or electromagnet energized by a coil .The coil is energized by operating quantity like V or I.

Under normal conditions the coil cannot attract the plunger due to spring force. Under fault condition the fault current increases so armature or plunger gets attracted to close the contacts .



Operating Principle : The electromagnetic force developed on moving element is proportional to square of the flux in air gap. If saturation is neglected force will be proportional to I^2.

$$\boxed{F = K_1 I^2 - K_2}$$

F = Net force

K_1 = Constant

K_2 = Restraing force including friction

I = Current in the relay coil

When relay is on the verge of operation.

$$K_1 I^2 = K_2$$

$$\therefore \quad I = \sqrt{\frac{K_2}{K_1}} \text{ ...... constant}$$

Advantages :

1. Relay responses to both A.C. and D.C. ($\because$ Torque $\propto I^2$).
2. Light moving parts, small length of travel of armature or plunger in air gap. Therefore, relays are fast in operation.
3. These relays are instantaneous but operating time varies with current (see characteristics). **The operating time and resetting time can be adjusted by adjusting the air gap so relays can be made slow operating relay.**

Attracted Armature Type Relays

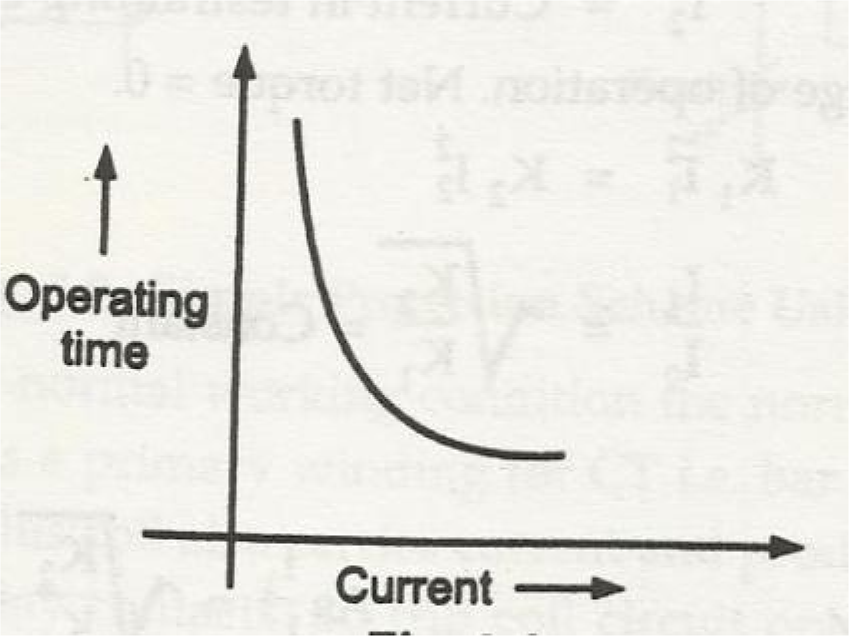
Applications

1.For over current protection

2.Differential Protection

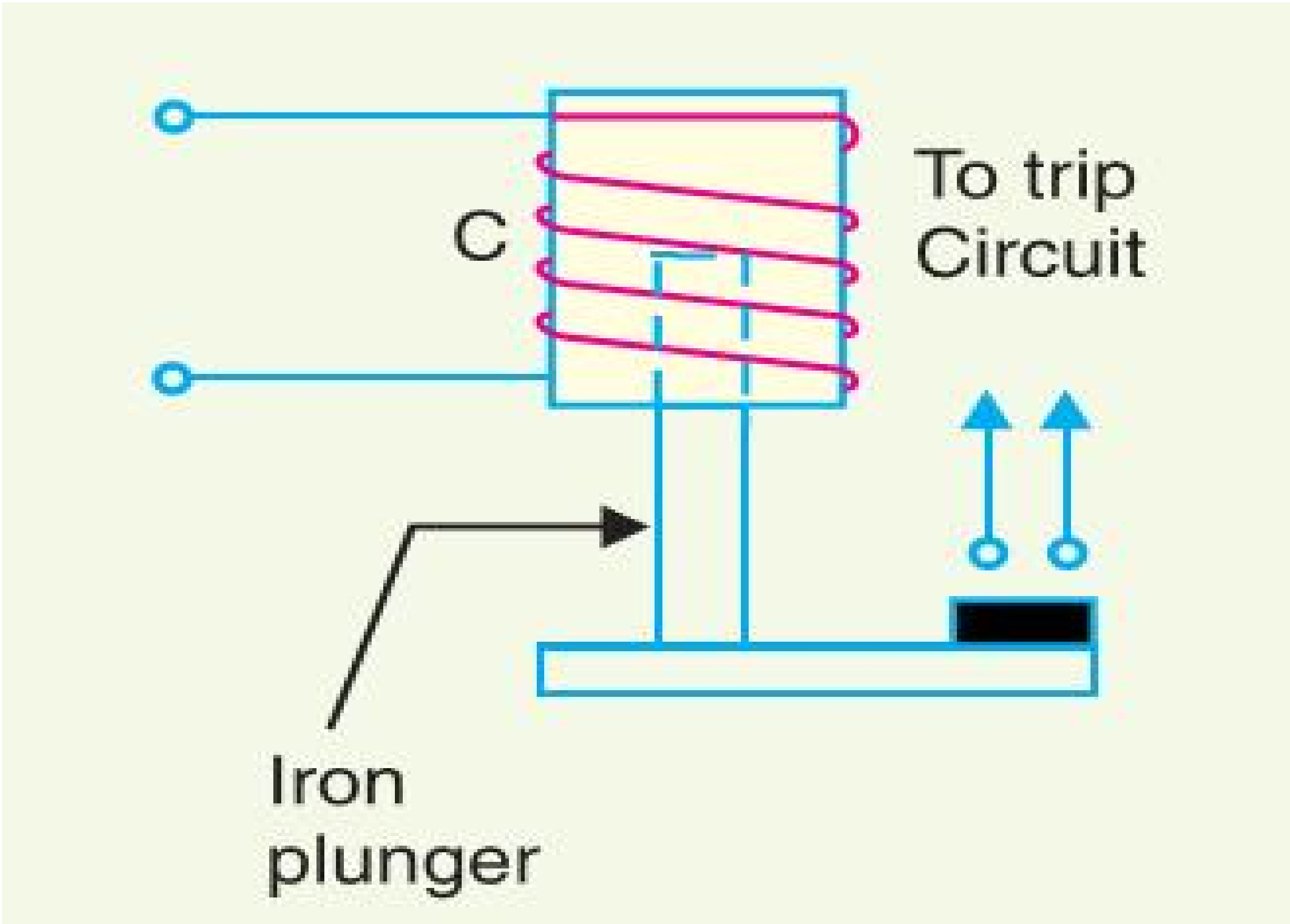
3.Auxiliary Relays

4.Definite time lag over current and earth fault protection



(ii) Solenoid type relay

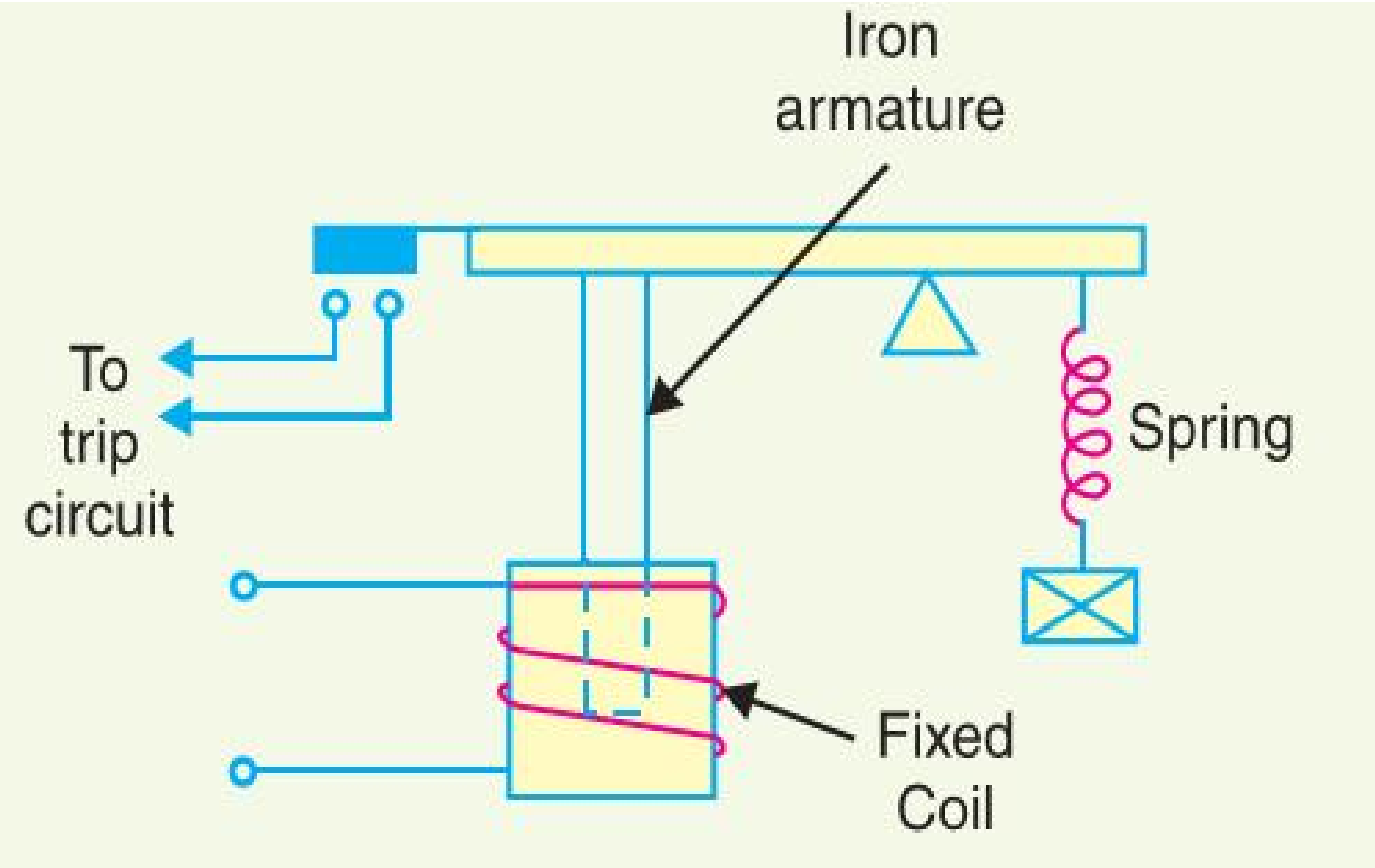
- It consists of a solenoid and movable iron plunger arranged as shown.
- Under normal operating conditions, the current through the relay coil C is such that it holds the plunger by gravity or spring in the position shown.
- However, on the occurrence of a fault, the current through the relay coil becomes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



Solenoid type relay

(iii) Balanced beam type relay

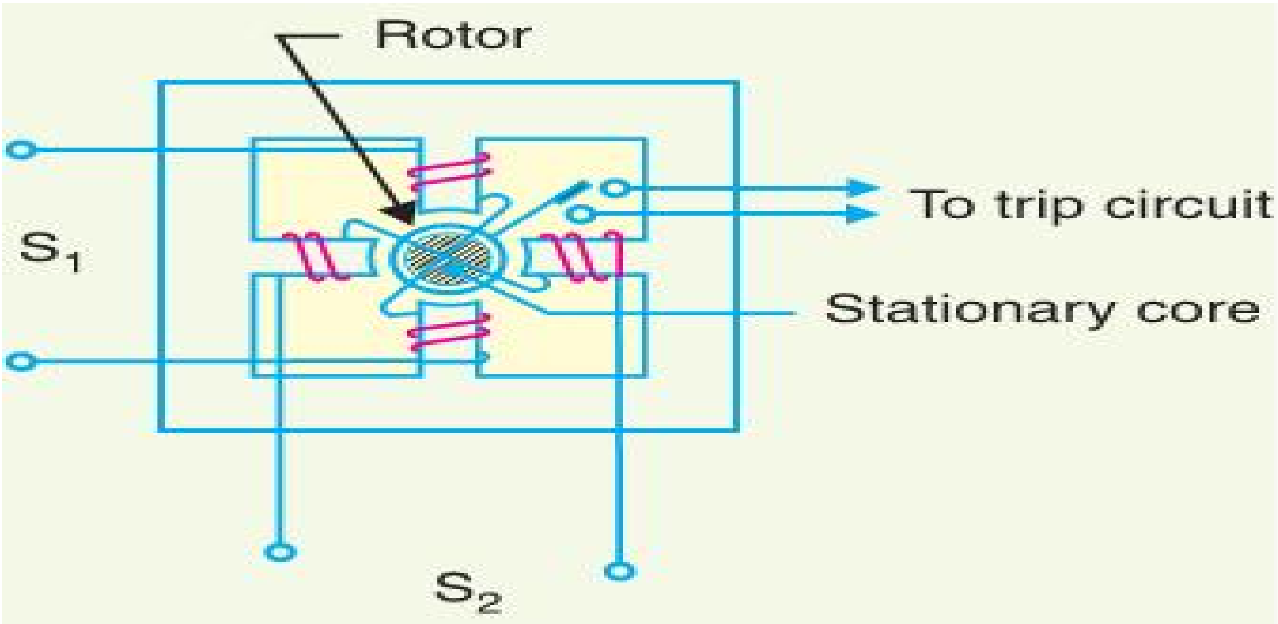
- It consists of an iron armature fastened to a balance beam. Under normal operating conditions , the current through the relay coil is such that the beam is held in the horizontal position by the spring.
- When a fault occurs, the current through the relay coil becomes greater than the pickup value and the beam is attracted to close the trip circuit. This causes the opening of the circuit breaker to isolate the faulty circuit.



Balanced beam type relay

Induction cup structure

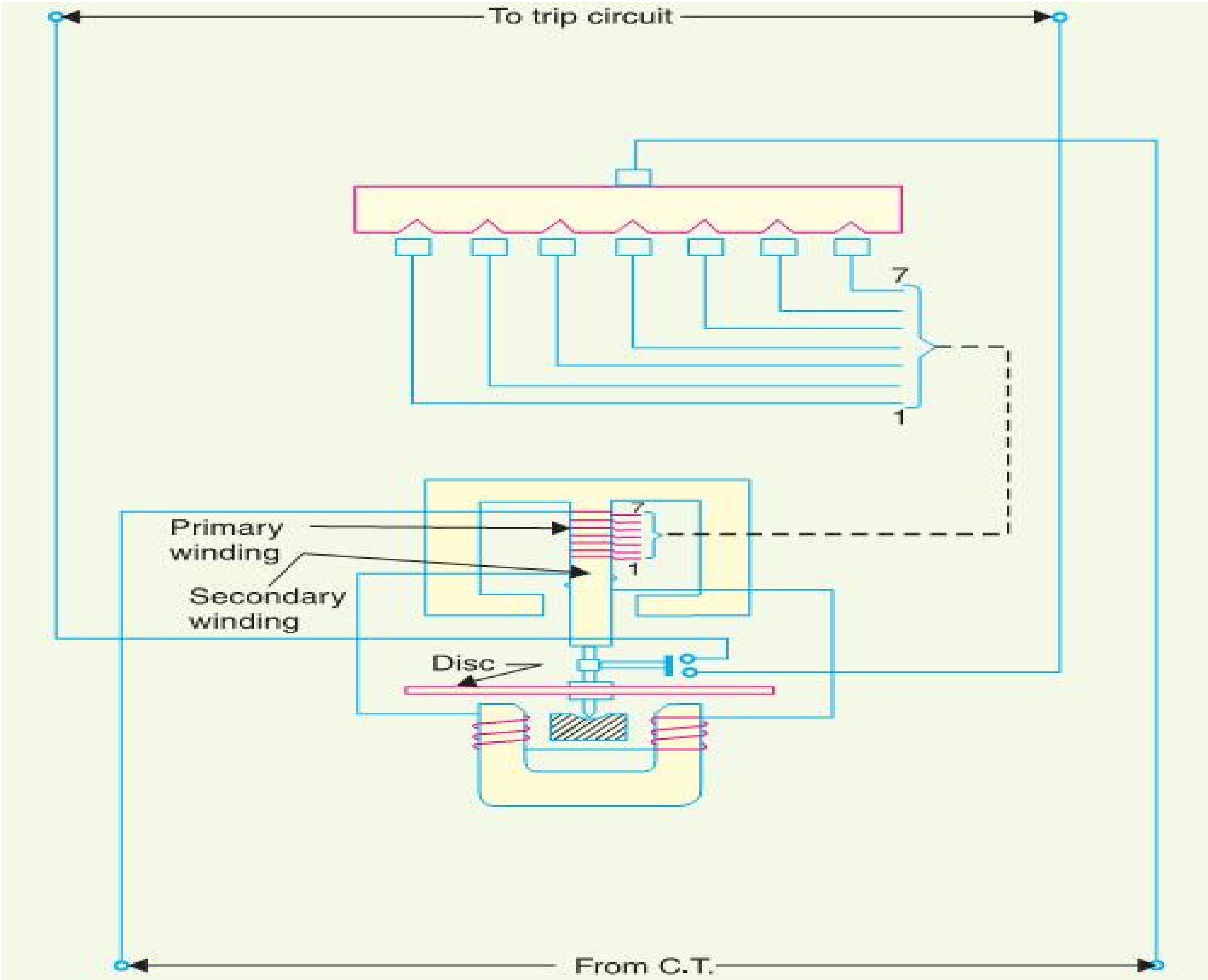
- It most closely resembles an induction motor, except that the rotor iron is stationary, only the rotor conductor portion being free to rotate.
- The moving element is a hollow cylindrical rotor which turns on its axis. The rotating field is produced by two pairs of coils wound on four poles as shown.
- The rotating field induces currents in the cup to provide the necessary driving torque.



- If **φ1** and **φ2** represent the fluxes produced by the respective pairs of poles, then torque produced is proportional to **φ1 Φ2 sin α** .
- where α is the phase difference between the two fluxes. A control spring and the back stop for closing of the contacts carried on an arm are attached to the spindle of the cup to prevent the continuous rotation.
- Induction cup structures are more efficient torque producers than either the shaded-pole or the watthour meter structures. Therefore, this type of relay has very high speed and may have an operating time less then 0.1 second.

Induction type overcurrent Relay (**Non Directional Relay**)

- This type of relay works on the induction principle and initiates corrective measures when current in the circuit exceeds the predetermined value.
- The actuating source is a current in the circuit supplied to the relay from a current transformer. These relays are used on a.c. circuits only and can operate for fault current flow in either direction.



To trip circuit
7
1
7
1
Primary winding
Secondary winding
Disc
From C.T.

Constructional details

It consists of a metallic (aluminium) disc which is free to rotate in between the poles of two electromagnets. The upper electromagnet has a primary and a secondary winding. The primary is connected to the secondary of a C.T. in the line to be protected and is tapped at intervals. The tappings are connected to a plug-setting bridge by which the number of active turns on the relay operating coil can be varied, thereby giving the desired current setting.

The secondary winding is energized by induction from primary and is connected in series with the winding on the lower magnet. The controlling torque is provided by a spiral spring.

The spindle of the disc carries a moving contact which bridges two fixed contacts (connected to trip circuit) when the disc rotates through a pre-set angle. This angle can be adjusted to any value between 0° and 360° . By adjusting this angle, the travel of the moving contact can be adjusted and hence the relay can be given any desired time setting.

Operation

The driving torque on the aluminium disc is set up due to the induction principle. This torque is opposed by the restraining torque provided by the spring.

Under normal operating conditions, restraining torque is greater than the driving torque produced by the relay coil current. Therefore, the aluminium disc remains stationary.

If the current in the protected circuit exceeds the pre-set value, the driving torque becomes greater than the restraining torque. Consequently, the disc rotates and the moving contact bridges the fixed contacts when the disc has rotated through a pre-set angle. The trip circuit operates the circuit breaker which isolates the faulty section.

DIRECTIONAL RELAY

induction relays are two types

non directional relays

directional relays

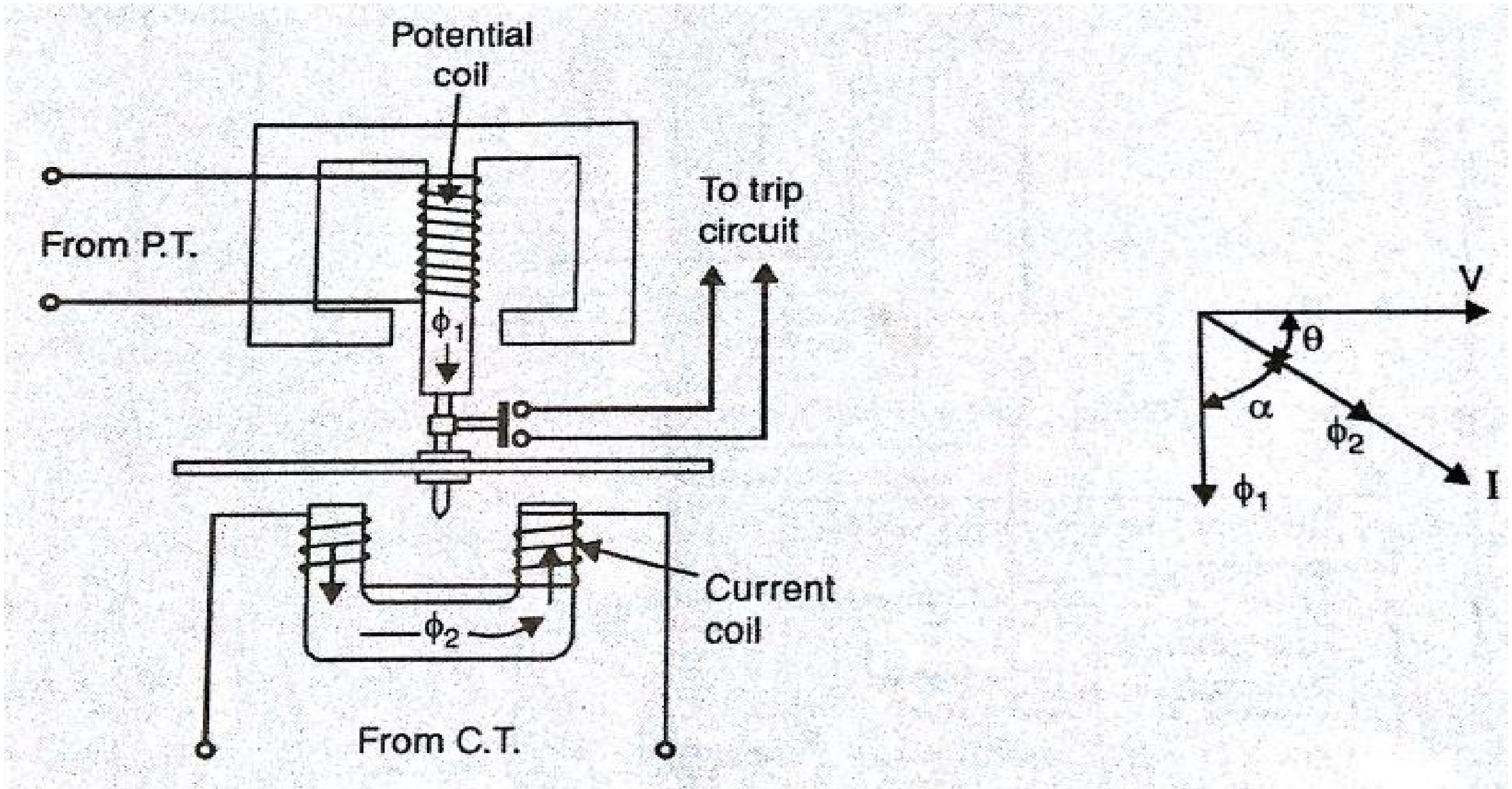
Difference between the two:………..?

- non directional relays are activated by only **current flowing in the circuit to be protected**.

- directional relays are activated by power flowing in the specific direction. Hence it requires both current and voltage of the circuit to be protected.

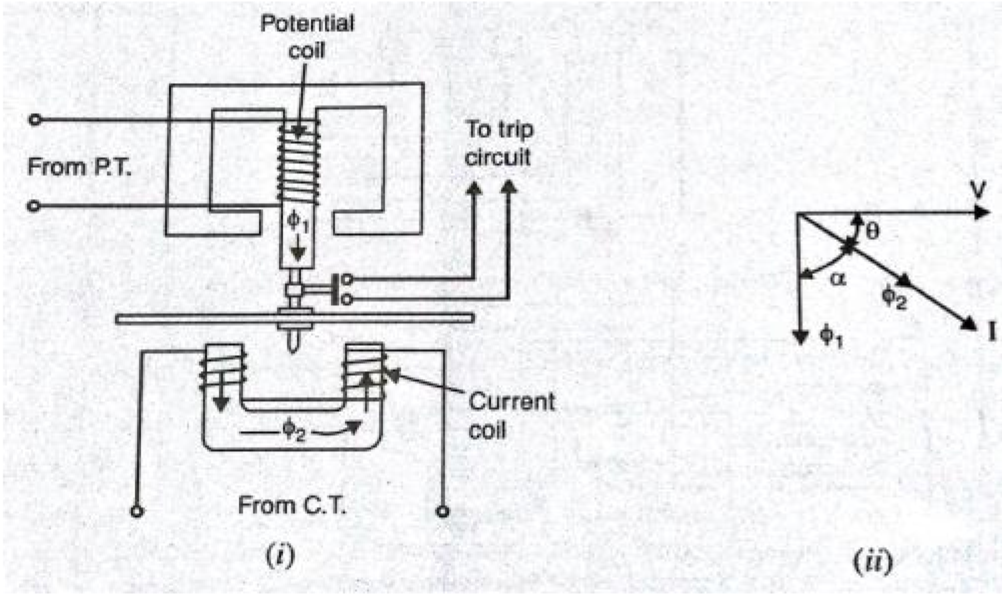
* it requires specific direction of current flow*

DIRECTIONAL POWER RELAY



(i)

(ii)



<u>Constructional details:</u>

It consits of two electro magnets

1) upper magnet which is E- shaped
2) lower magnet which is U- shaped.

- The upper maget consits of primary winding on the central limb which is energised by voltage from secondary of P.T

- lower magnet houses secondary winding which is energised by current of the circuit from secondary of C.T. Further lower magnet is connected to PSM as previous case (not shown)

- In between this two electro magnets we have aluminium disc pivoted as shown

- This alumunium disc carries a moving contact which can bridge fixed contact by rotating though a pre set angle.

- The time of operation depends upon the pre set angle

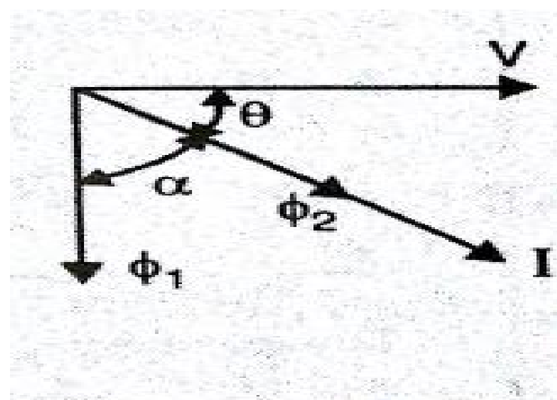
- Restraining torque is provide by spring which twists in reverse direction.

Operation:

from the diagram we can conclude that we have two flux quantaties: φ_1 & φ_2 .

always φ_1 laggs V by 90^0

φ_2 inphase with current I



Due to phase difference between two flux quantaties i.e., $\alpha = 90-\theta$

$\Phi_1 \ \alpha \ V$ & $\varphi_2 \ \alpha \ I$

Hence $T = \varphi_1 \ \varphi_2 \ \sin \alpha$

$= \varphi_1 \ \varphi_2 \ \sin(90-\theta)$

$= VI \ COS \ \theta$

= POWER

- Hence the relay activated only when there is a specific direction of power flow
- when power flows in normal direction both driving torque and restraining torque twists in same direction and relay does not operates.
- when the power flow is in reverse direction, driving torque and restraining torque acts in opposite direction and relay operates.therefore CB operates and disconnects faulty section.

DIRECTIONAL OVER CURRENT RELAY:

From the previous discussion

$$T = V I \cos \theta$$

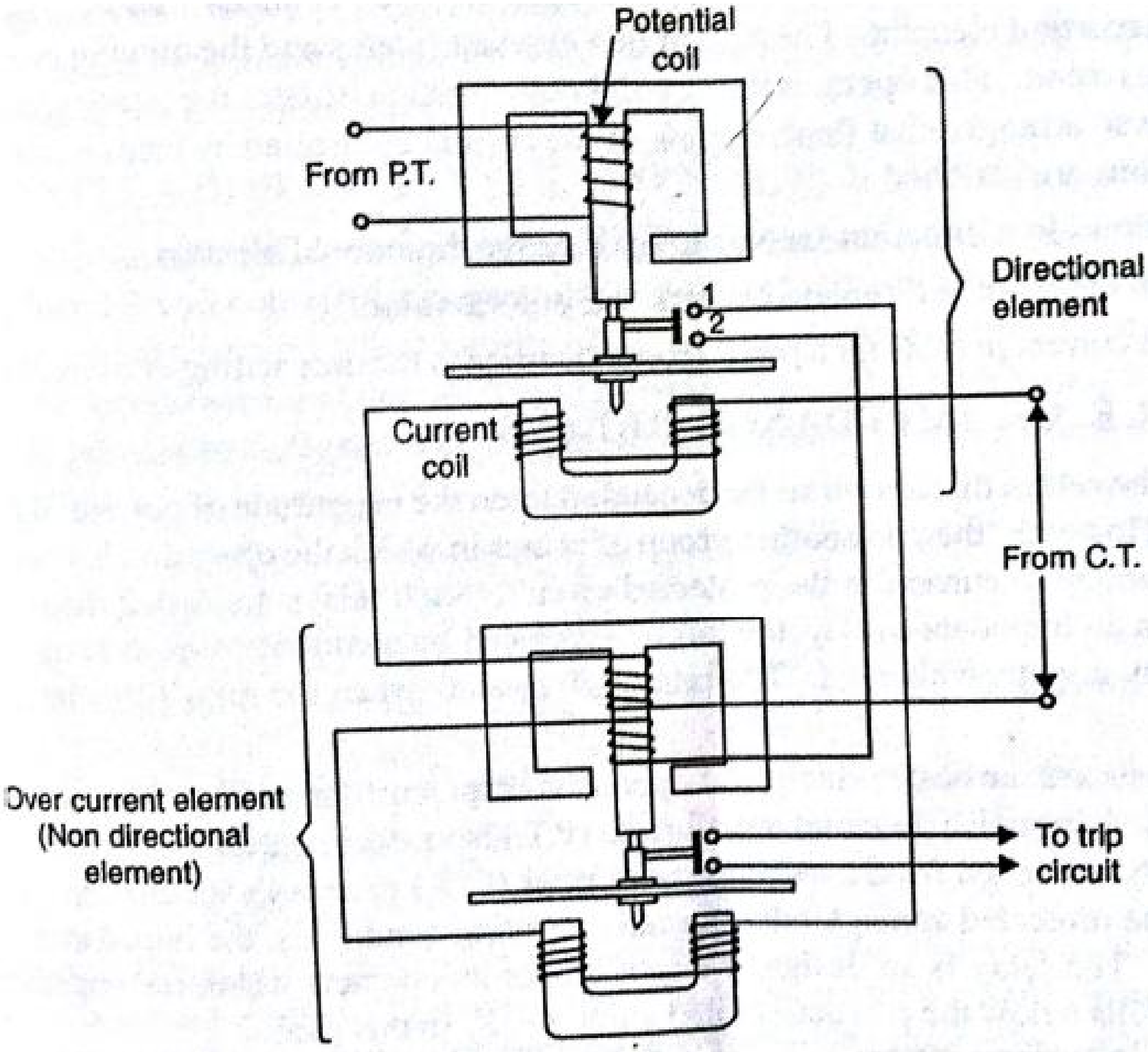
Under abnormal condition

under abnormal conditions voltage in the circuit is too low. Therefore the driving torque becomes abnormally too small .Hence the relay does not operate.

ie., the directional power relay is not suitable for short circuit conditions.

This problem can be overcome by directional over current relay.

Directional overcurrent relay:



Directional overcurrent relay makes use of two relays

i) directional power relay (directional element)
ii) Non directional current relay (non-directional element)

Construction:

1) **Directional element :**

It is similar in construction to directional power relay.

- it consists of upper magnet which is E-shaped and carries primary winding which is excited by voltage of the circuit to be protected through secondary of PT.

- The lower magnet is U-shaped carries secondary winding which is excited by current of the circuit to be protected through secondary of CT.
- The secondary winding is extended to lower magnet primary winding as shown.
- The trip contacts 1 & 2 are connected in series with secondary winding of lower magnet.

therefore for the relay to operate, at first directional element should be activated first.

2) Non directional element:

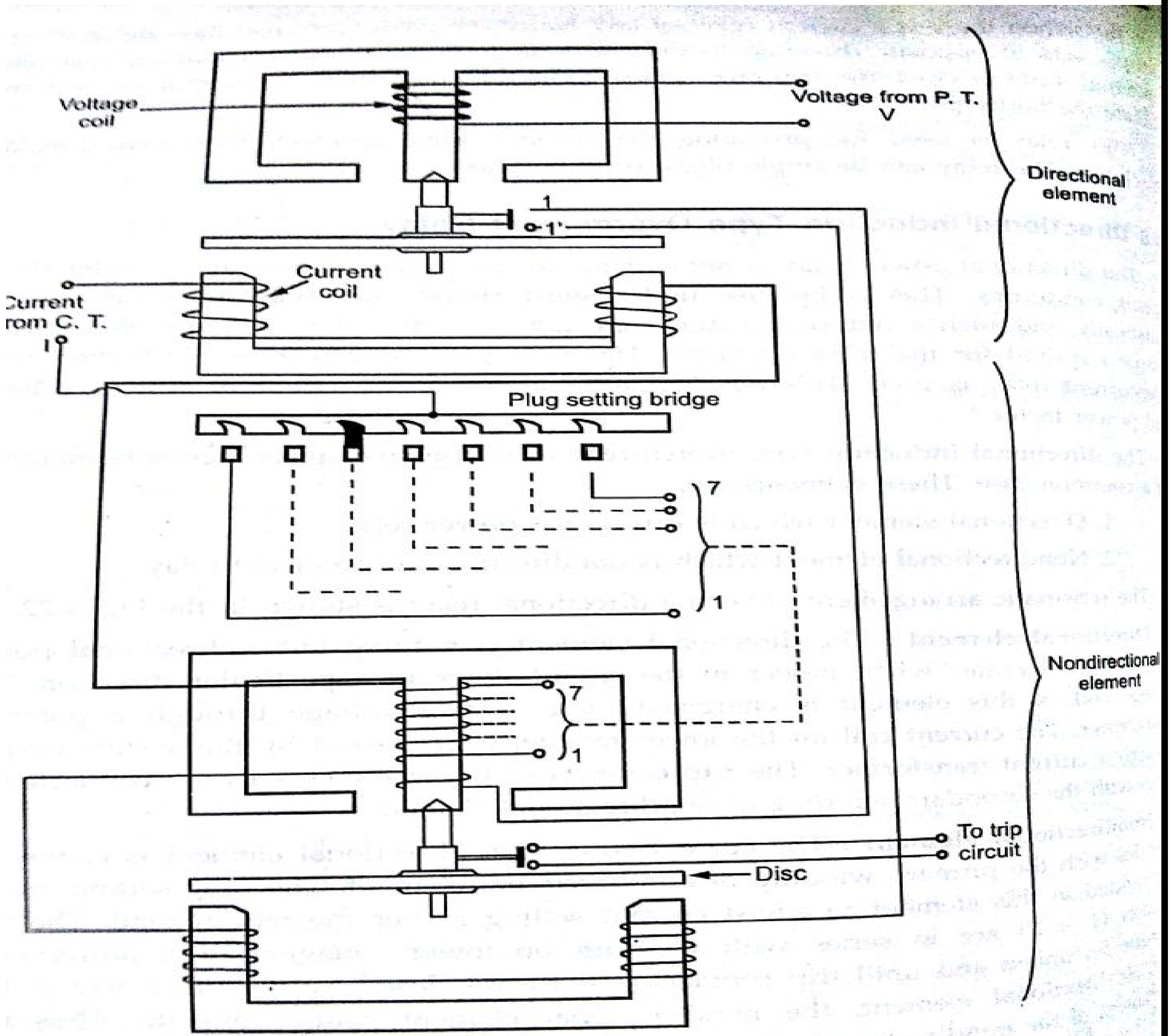
*** It is activated only by current flowing in the circuit***

- it is similar in construction to non-directional over current relay. For this element to operate ,at first directional element should be activated first.
- the secondary winding is further connected to PSM(not shown), for current setting.

Operation :

- When short circuit occurs current tend to be reversed .Hence directional element starts operating and closes the trip contact.

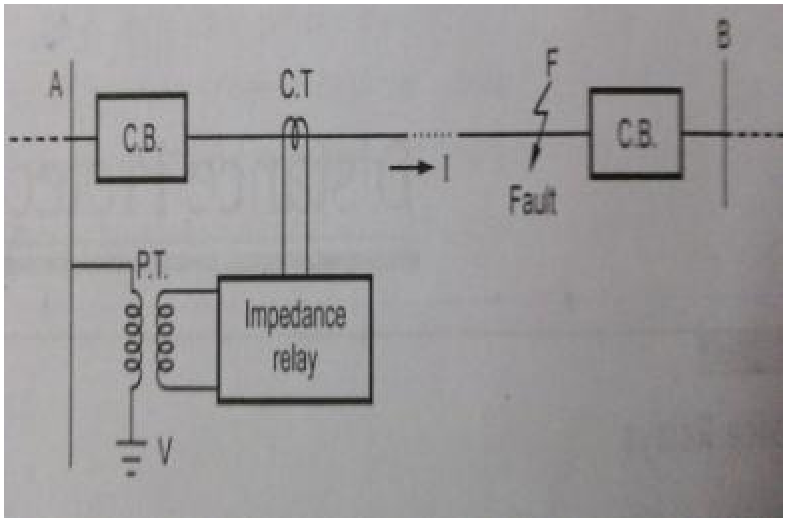
- with closing of trip contact, the secondary winding of non directional element is complete and disc starts rotating. When moving contact bridges fixed contact the circuit breaker operates and separates the faulty section.



Voltage coil
Voltage from P. T.
V
Directional element
1
1'
Current coil
Current from C. T.
I
Plug setting bridge
7
1
Nondirectional element
7
1
To trip circuit
Disc

Distance Relay
(mho relay)

DISTANCE RELAY :-



1.IMPEDANCE RELAY

- +ve (operative)Torque by current element
- -ve(restraining)Torque by voltage element

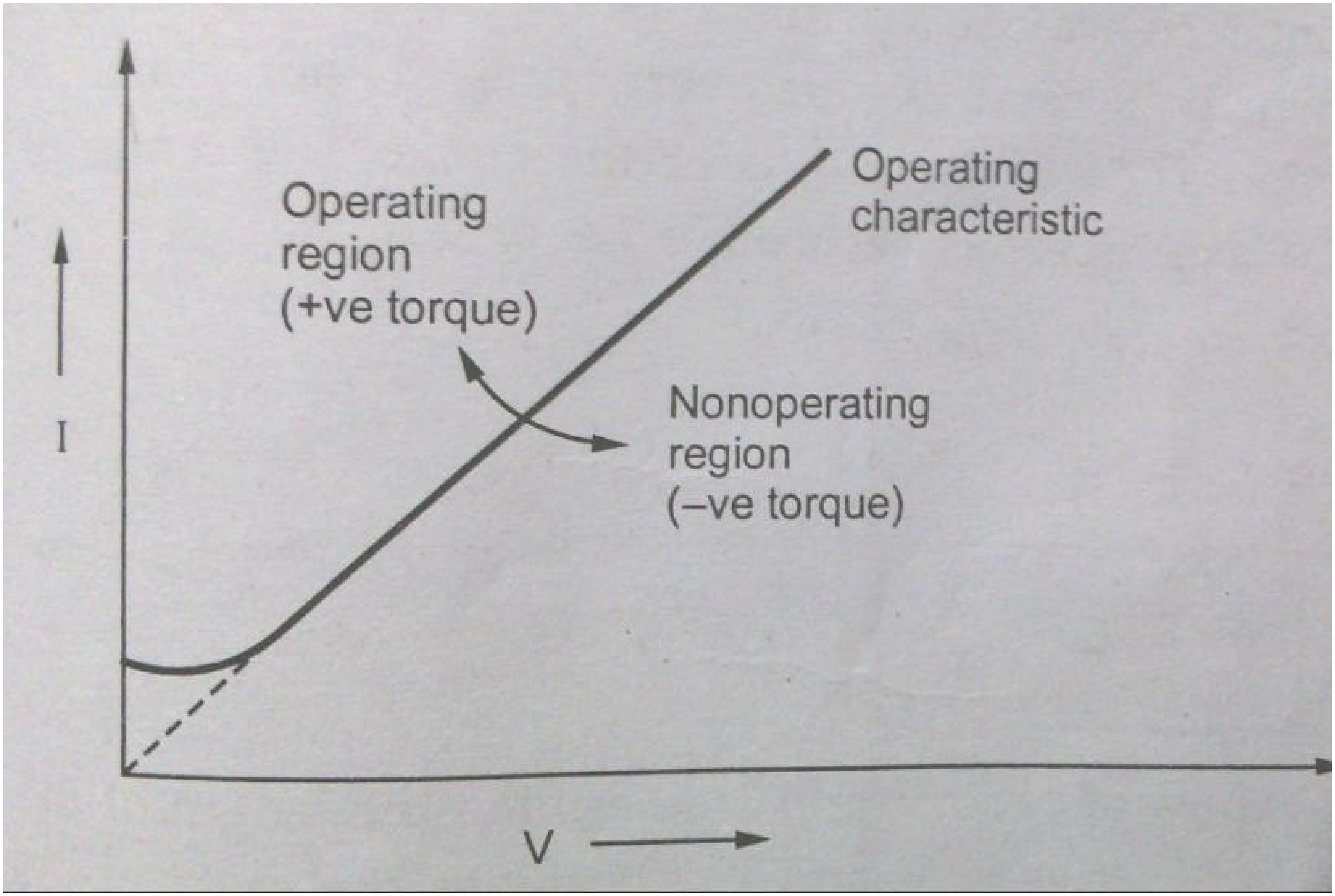
✓At normal condition

operative torque = restraining torque

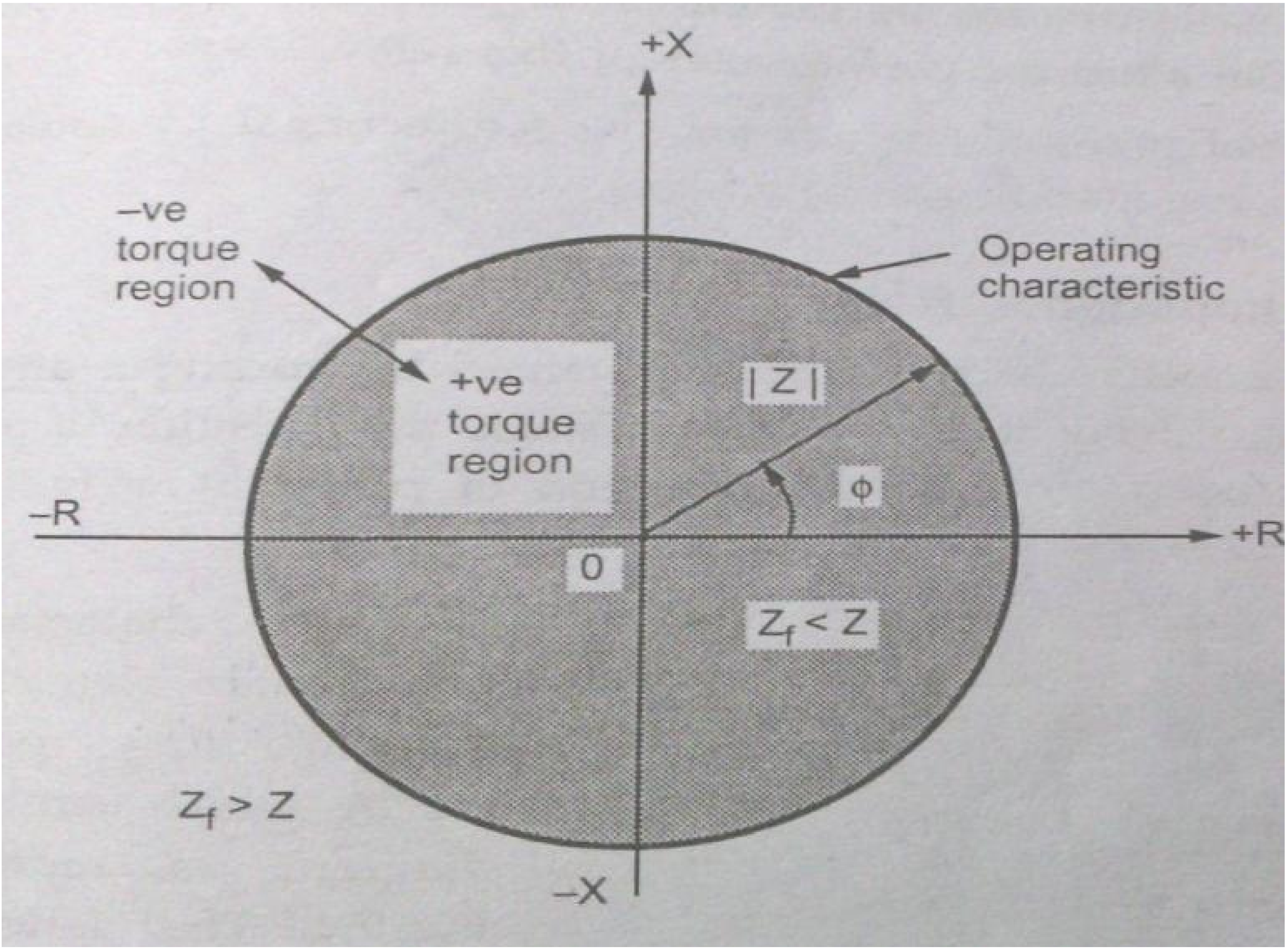
✓At fault

operative torque > restraining torque

➢Also called voltage restrained over current relay.

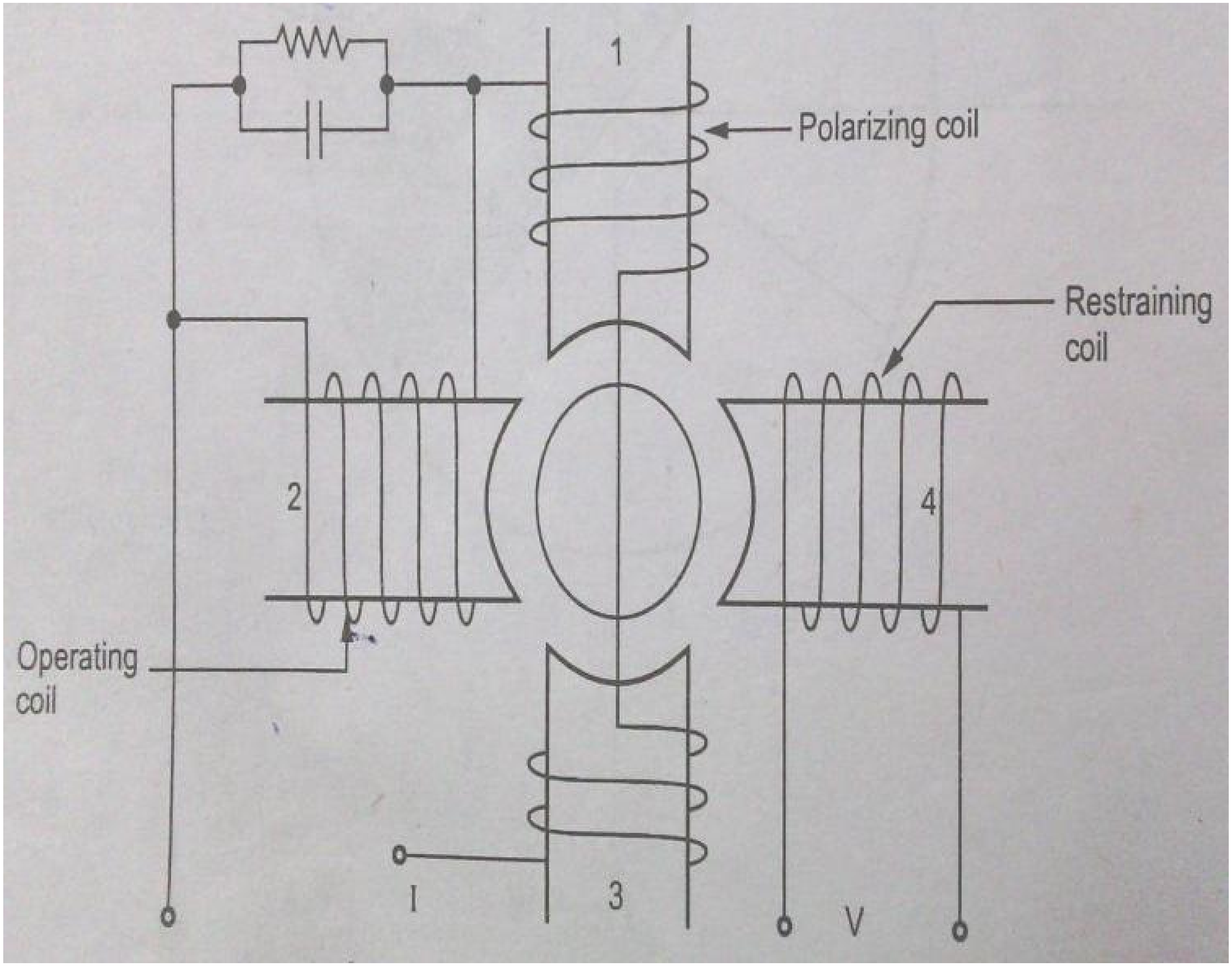


Operating region (+ve torque)
Operating characteristic
Nonoperating region (–ve torque)
I
V

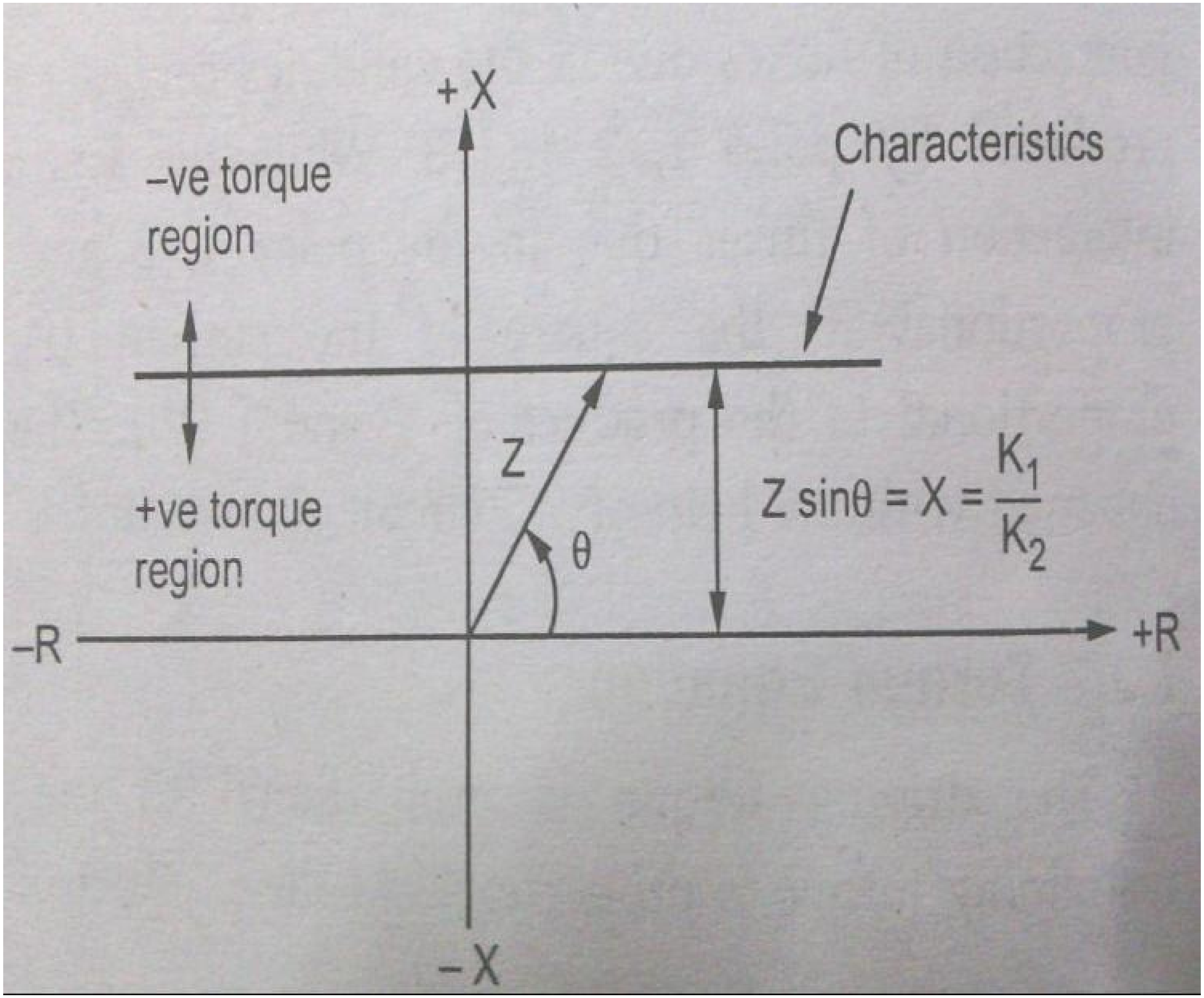

+X
–ve
torque
region
Operating
characteristic
+ve
torque
region
| Z |
ϕ
–R
+R
0
Z_f < Z
Z_f > Z
–X

2.REACTANCE RELAY :-

- o Operative Torque by current
- o Restraining Torque by Current-Voltage Directional relay
- ❖ +ve torque by over current element
- ❖ -ve torque by directional unit
- ✓Directional element designed for maxi. Torque angle = 90 degree



1
Polarizing coil
Restraining
coil
2
4
Operating
coil
I
3
V


+X
Characteristics
–ve torque
region
Z
$Z \sin\theta = X = \frac{K_1}{K_2}$
+ve torque
region
θ
–R
+R
–X

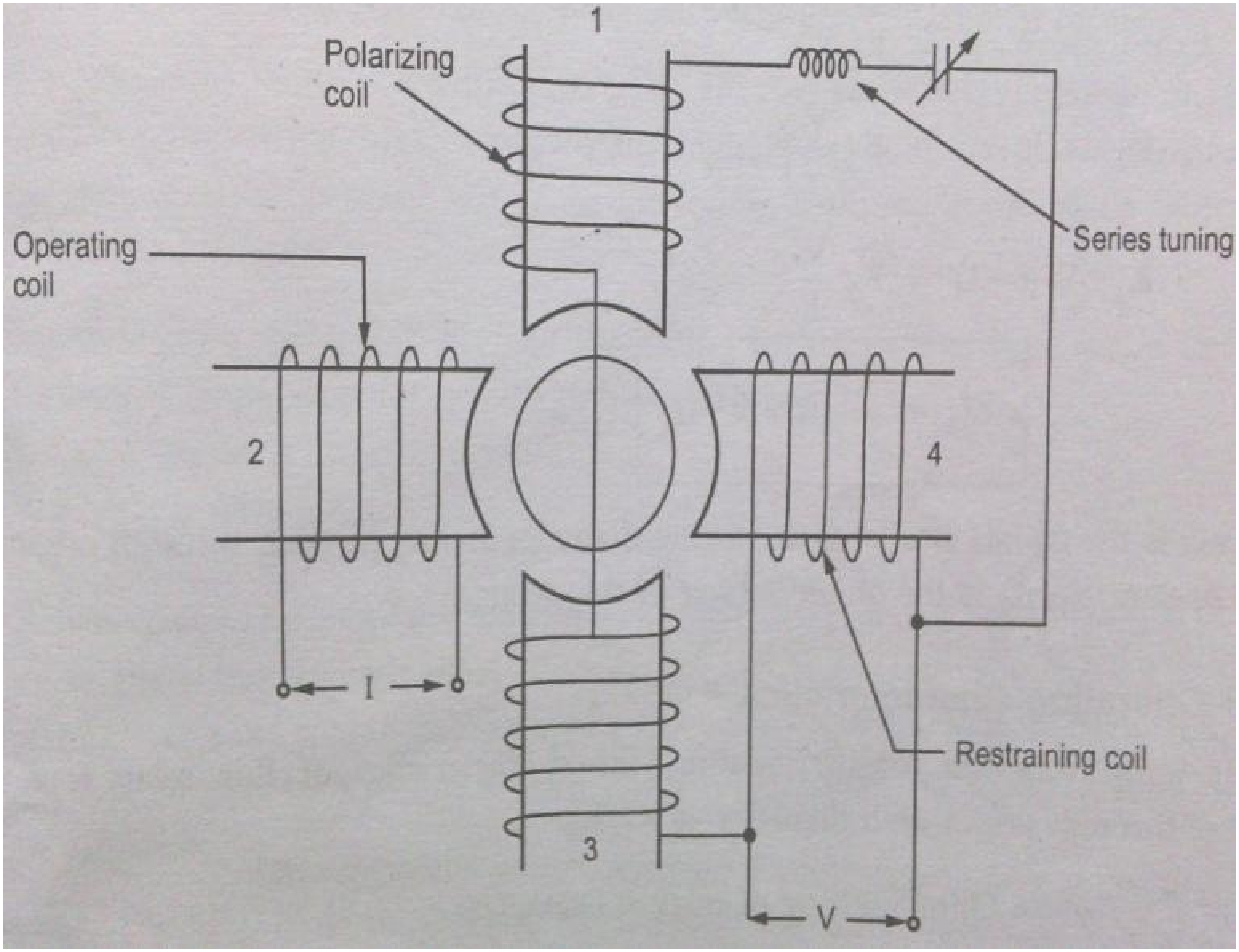
3.MHO RELAY :-

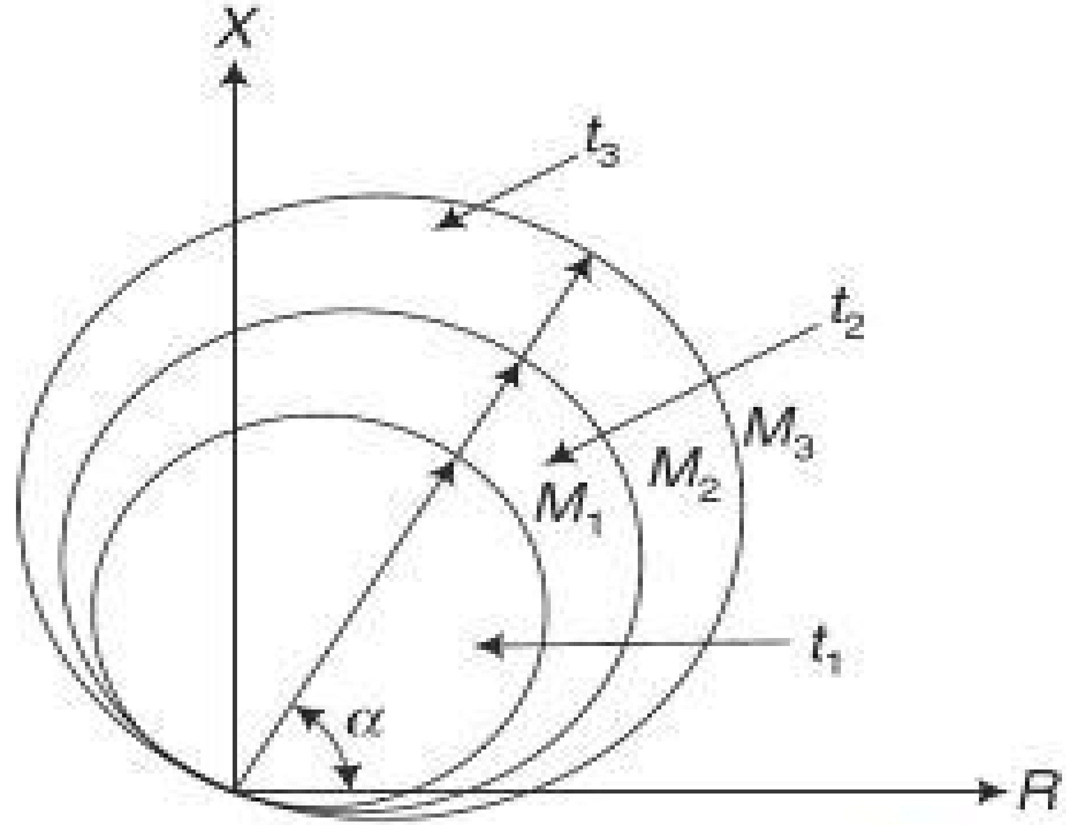
- Induction cup type structure.

- Operative Torque produced by V & I element.

- Restraining Torque by Voltage element.

- Also called ***Admittance relay.***


1
Polarizing
coil
Series tuning
Operating
coil
2
4
I
Restraining coil
3
V



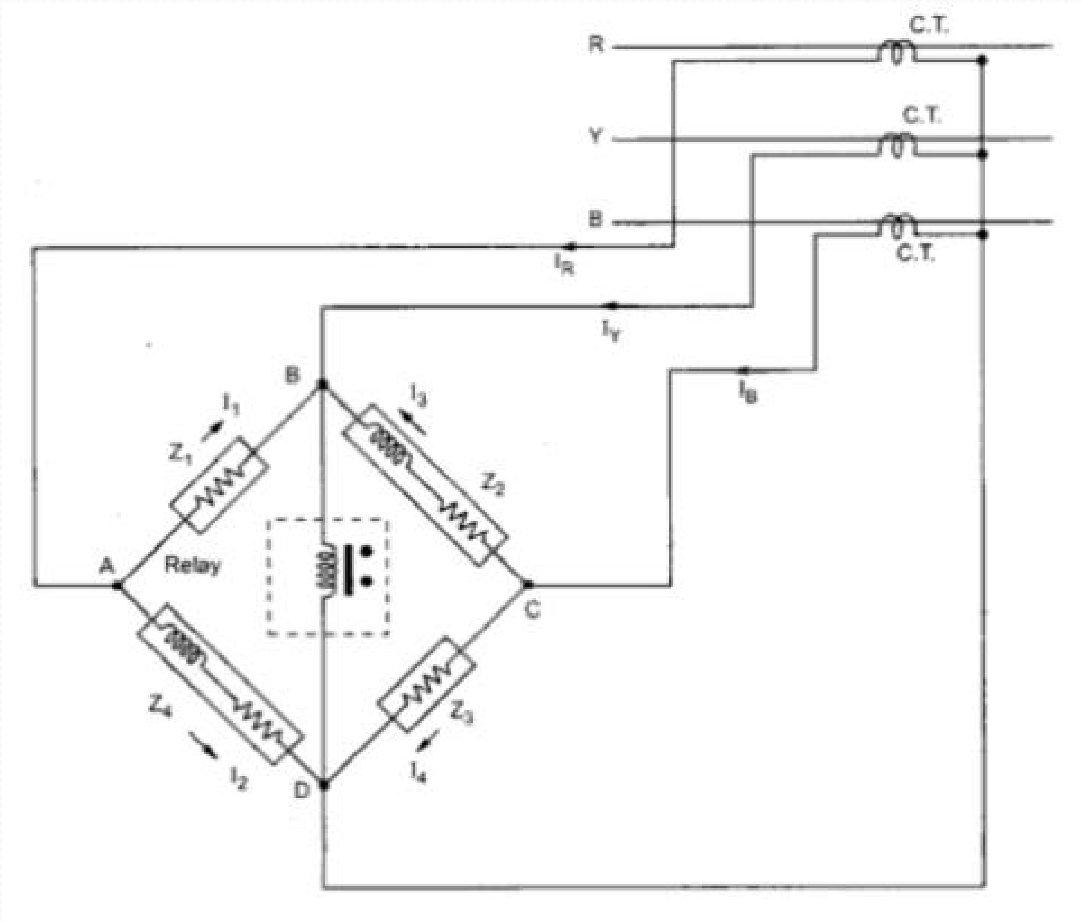
X
t_3
t_2
M_3
M_2
M_1
t_1
α
R

NEGATIVE SEQUENCE RELAYS

NEGATIVE SEQUENCE RELAY

- The negative relays are also called phase unbalance relays because these relays provide protection against negative sequence component of unbalanced currents existing due to unbalanced loads or phase-phase faults.
- The unbalanced currents are dangerous from generators and motors point of view as these currents can cause overheating. Negative sequence relays are generally used to give protection to generators and motors against unbalanced currents.

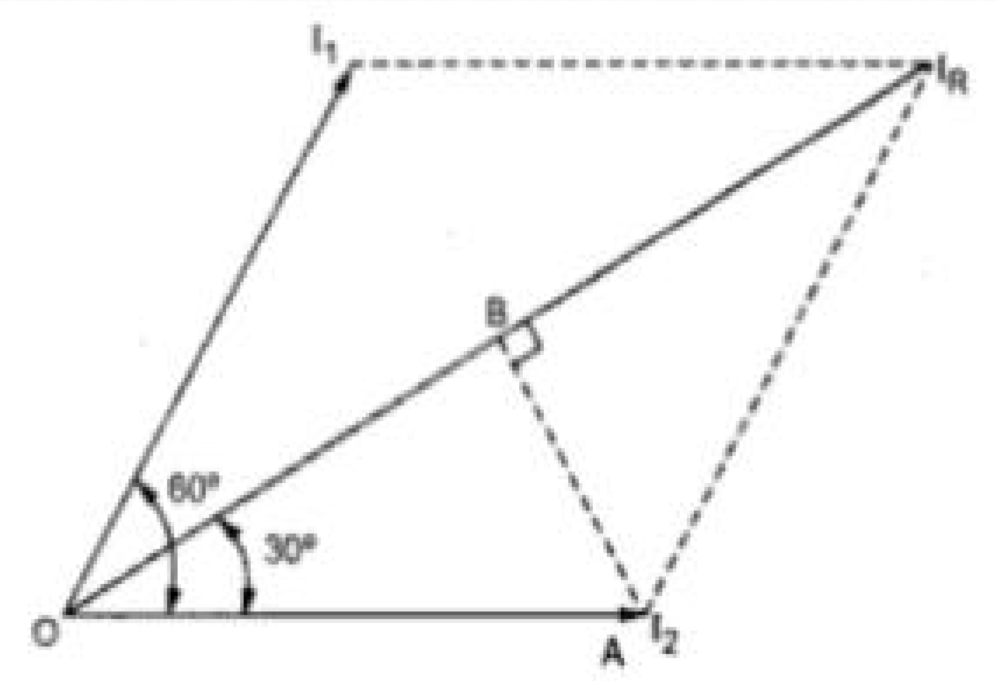
DIAGRAM:



CONSTRUCTION:

- It consists of a resistance bridge network.
- The magnitudes of the impedances of all the branches of the network are equal.
- The impedances Z_1 and Z_3 are purely resistive while the impedances Z_2 and Z_4 are the combinations of resistance and reactance.
- The currents in the branches Z_2 and Z_4 lag by 60^o from the currents in the branches Z_1 and Z_3.
- The vertical branch B-D consists of inverse time characteristics relay. The relay has negligible impedance.

PHASOR DIAGRAM:



The current I_R gets divided into two equal parts I_1 and I_2. And I_2 lags I_1 by 60^o.

$$\bar{I}_1 + \bar{I}_2 = \bar{I}_{rs}$$

Let $$I_1 = I_2 = I$$

The perpendicular is drawn from point A on the diagonal meeting it at point B. This bisects the diagonal.

$\therefore$ $$OB = I_R / 2$$

Now in triangle OAB,

$$\cos 30 = OB/OA$$

$\therefore$ $$\sqrt{3}/2 = (I_R/2)/I$$

$\therefore$ $$I = I_R/\sqrt{3} = I_1 = I_2 \qquad \text{...........(1)}$$

Now I_1 leads I_R by 30° while I_2 lags I_R by 30°.

Similarly the current I_B gets divided into two equal parts I_3 and I_4. The current I_3 lags I_4 by 60°. From equation (1) we can write,

$$I_B / \sqrt{3} = I_3 = I_4 \qquad \text{...............(2)}$$

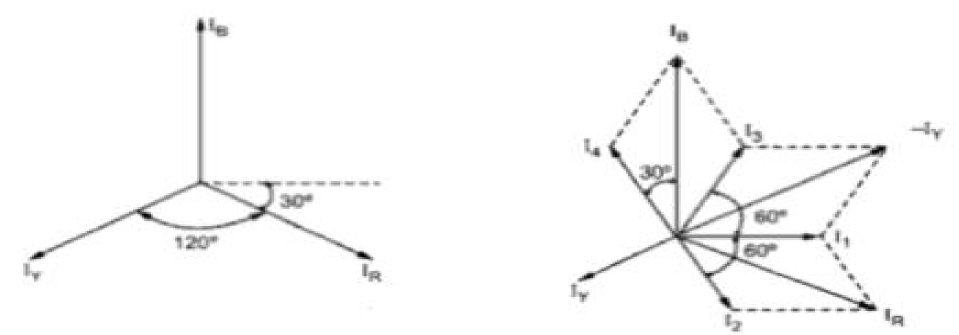
The current I_4 leads by I_B while current I_3 lags I_B by 30°.

The current entering the relay at the junction point B in the Fig. 1 is the vector sum of , and .

$$I_{relay} = \bar{I}_1 + \bar{I}_3 + \bar{I}_Y$$

$$= I_Y + (I_R/\sqrt{3}) \text{ (leads } I_R \text{ by } 30°) + I_B/\sqrt{3} \text{(lags } I_B \text{ by} 30°)$$

- **when the load is balanced and no negative sequence currents exist.**



(a) C. T. secondary currents (b) Vector sum

$$\bar{I}_1 + \bar{I}_3 = -\bar{I}_Y$$

$$\therefore \quad \bar{I}_1 + \bar{I}_3 + \bar{I}_Y = 0$$

Thus the current entering the relay at point B is zero. Similarly the resultant current at junction D is also zero. Thus the relay is inoperative for a balanced system.

UNDER FAULTY CONDITION:

Now consider that there is unbalanced load on generator or motor due to which negative sequence currents exist.

The component I_1 and I_3 are equal and opposite to each other at the junction point B. Hence I_1 and I_3 cancel each other. Now the relay coil carries the current I_Y and when this current is more than a predetermined value, the relay trips closing the contacts of trip circuit which opens the circuit breaker.

ZERO SEQUENCE CURRENT:

- Under zero sequence currents the total current of twice the zero sequence current flows through the relay. Hence the relay operates to open the circuit breaker.
- To make the relay sensitive to only negative sequence currents by making it inoperative under the influence of zero sequence currents is possible by connecting the current transformers in delta .Under delta connection of current transformers, no zero sequence current can flow in the network.

DIFFERENTIAL RELAYS

Definition

- A two-winding relay that operates when the difference between the currents in the two windings reaches a predetermined value is called differential relays.

- A two-winding relay that operates when the difference between the currents in the two windings reaches a predetermined value.

- In case of electrical quantities exceed a predetermined value, a current differential relay is one that compares the current entering a section of the system with current leaving the section.
- Under normal operating conditions, the two currents are equal but as soon as fault occurs, this condition no longer applies. The difference between the incoming and outgoing currents is arranged to flow through relay operating coil. If this difference is equal to or greater than the pick up value the relay will operate and open the circuit breaker and isolate the faulty section.
- Any type of relay when connected in a particular way can be made to operate as a differential relay. It is not the relay construction but the way in which relay is connected in a circuit makes it a differential relay.

There are three fundamental systems of differential or balanced protection:

I. current differential relay
II. voltage differential relay
III. Biased beam relay or percentage differential relay

(i) Current balance protection

Fig 16 a shows an arrangement of an over current relay connected to operate as a differential relay. A pair of identical current transfonners is fitted on either end of the section to be protected (alternator winding in this case). The secondaries of CT's are connected in series in such a way that they carry the induced currents in the same direction. The operating coil of over current relay is connected across the CT secondary circuit. This differential relay compares the current at the two ends of the alternator winding.

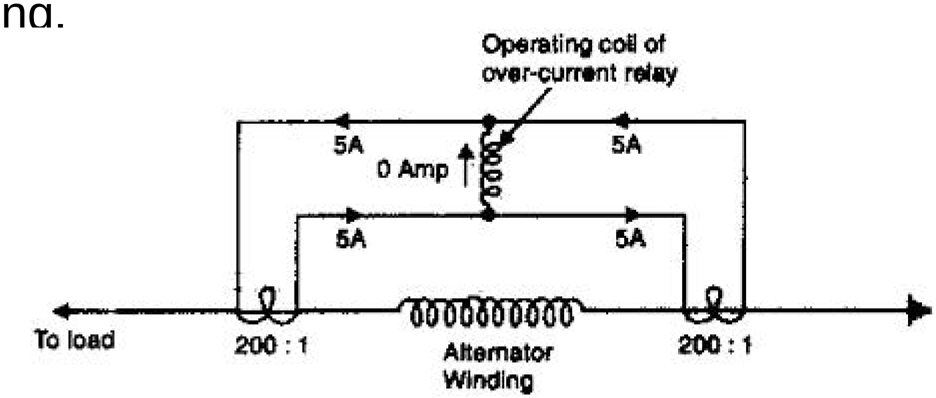


fig 16 a

Under normal operating conditions, suppose the alternator winding carries a normal current of 1000 A. Then the current in the two secondaries of CT's are equal as in figure. These currents will merely circulate between the two CT's and no current will flow through the differential relay as shown in the diagram fig 16 a. Therefore, the relay remains inoperative.

If a ground fault occurs on the alternator winding as shown in fig 16 b. the two secondary currents will not be equal and the current flows through the operating coil of the relay, causing the relay to operate. The amount of current flow through the ng fed.

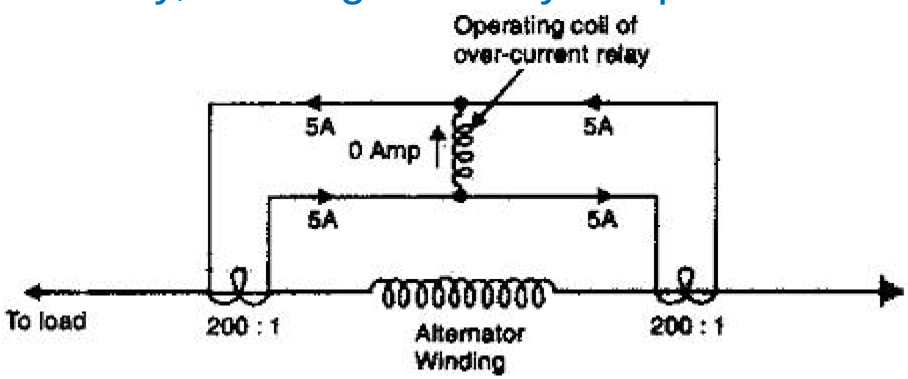


fig 16 a

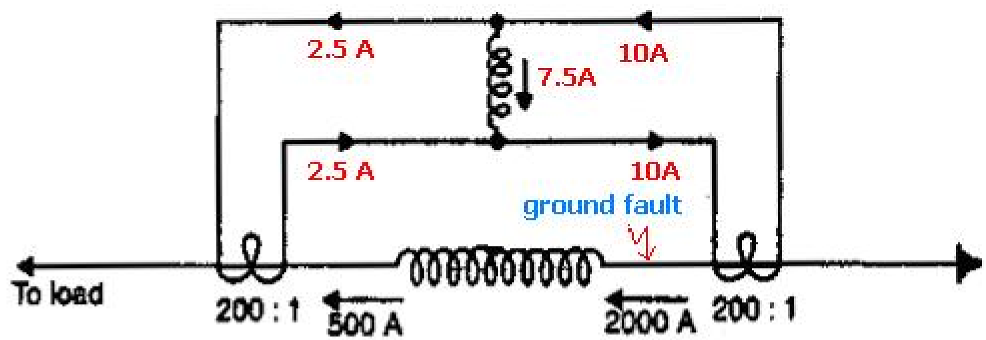


fig 16 b

Disadvantages

- The impedance of the pilot cables generally causes a slight difference between the currents at the two ends of the section to be protected, then the small differential current flowing through the relay may cause it to operate even under no fault conditions.

- Pilot cable capacitance causes incorrect operation of the relay when a large current flows

- Accurate matching of current transformers cannot be achieved due to pilot circuit impedance

(ii) voltage differential relay

❖Fig. 18 shows the arrangement of voltage balance protection.

❖In this scheme of protection, two similar current transformers are connected at either end of the element to be protected (e.g. an alternator winding) by means of pilot of wires.

❖The secondaries of current transformers are connected in series with a relay in such a way that under normal conditions, their induced e.m.f's are in opposition

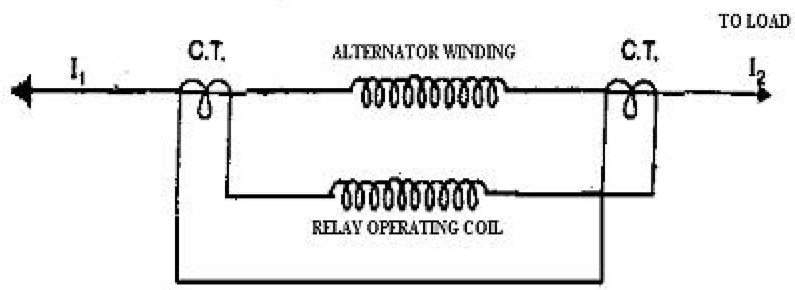


fig 18

❖Under healthy conditions, equal currents will flow in both primary windings. Therefore, the secondary voltages of the two transformers are balanced against each other and no current will flow through the relay-operating coil.

❖When a fault occurs in the protected zone, the currents in the two primaries will differ from one another and their secondary voltages will no longer be in balance.

❖This voltage difference will cause a current to flow through the operating coil of the relay, which closes the trip circuit.

Disadvantages

The voltage balance system suffers from the following drawbacks

- A multi-gap transformer construction is required to achieve the accurate balance between current transformer pairs.

- The system is suitable for protection of cables of relatively short, lengths due to the capacitance of pilot wires.

III. Biased beam relay or percentage differential relay

➢The biased beam relay also called percentage differential relay is designed to respond to the differential current in terms of its fractional relation to the current flowing through the protected section.

➢It's called percentage differential relay because the ratio of differential operating current to average restraining current is a fixed percentage.

➢It's called bias relay because restraining known as biased coil produces the bias force. Fig 17 a, shows the schematic arrangements of biased beam relay. It is essentially an over current balanced beam type relay with an additional restraining coil. The restraining coil produces a bias force in the opposite direction to the operating force.

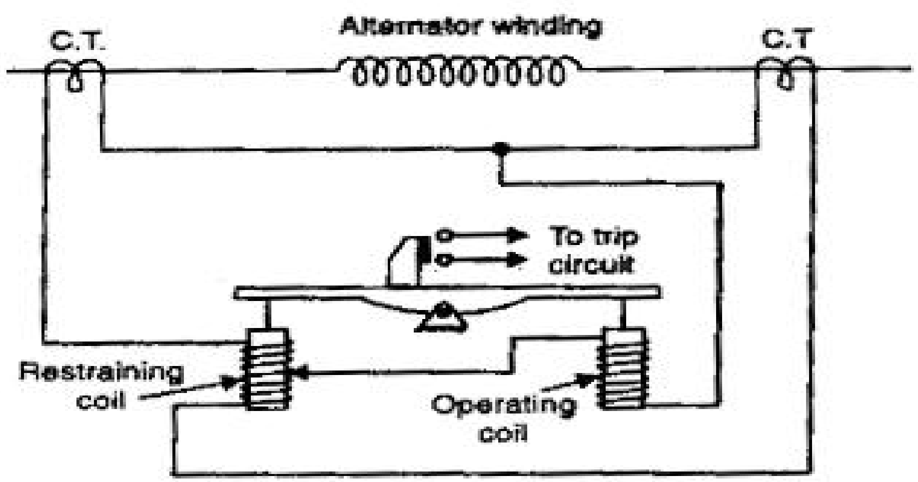


fig 17 a

Under normal and through load conditions, the bias force due to restraining coil is greater than operating force. Therefore, the relay remains inoperative.

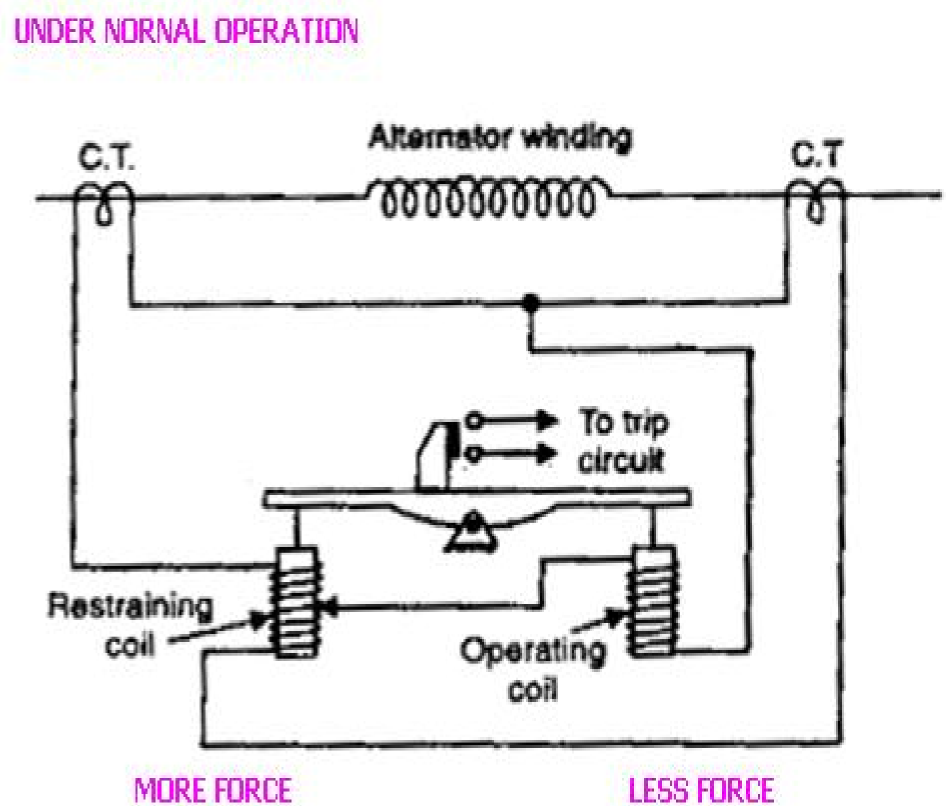


fig 17 a

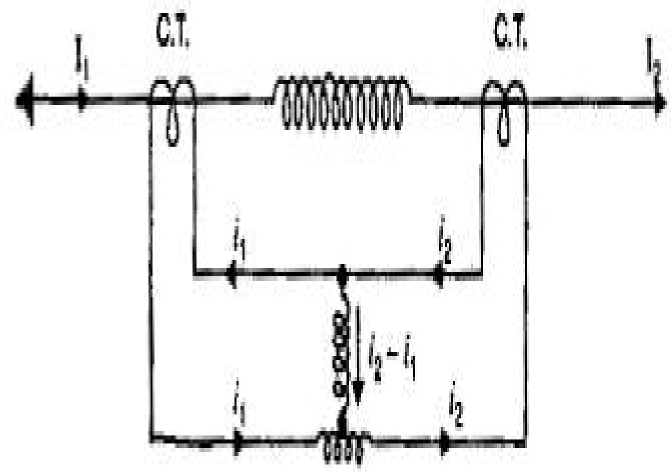
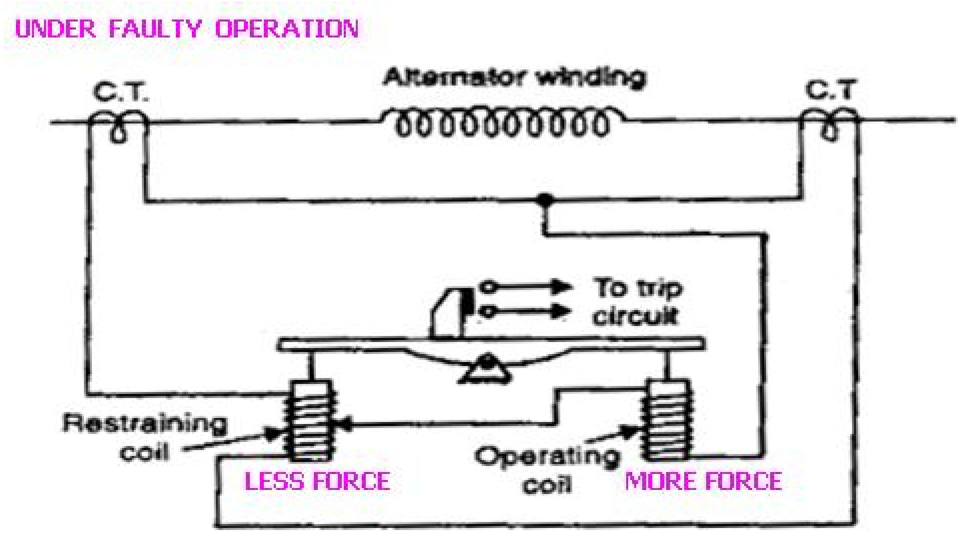


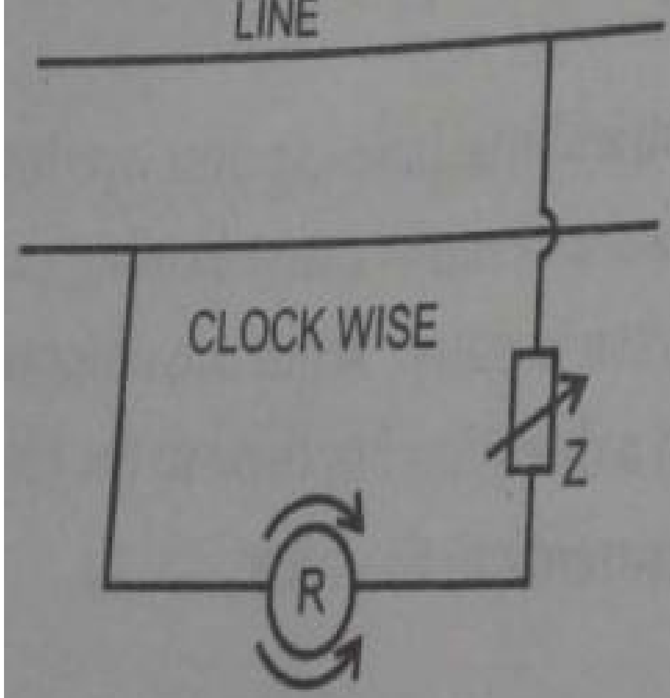
fig 17 b

➢When an internal fault occurs, the operating force exceeds the bias force. Consequently the trip contacts are closed to open the circuit breaker.

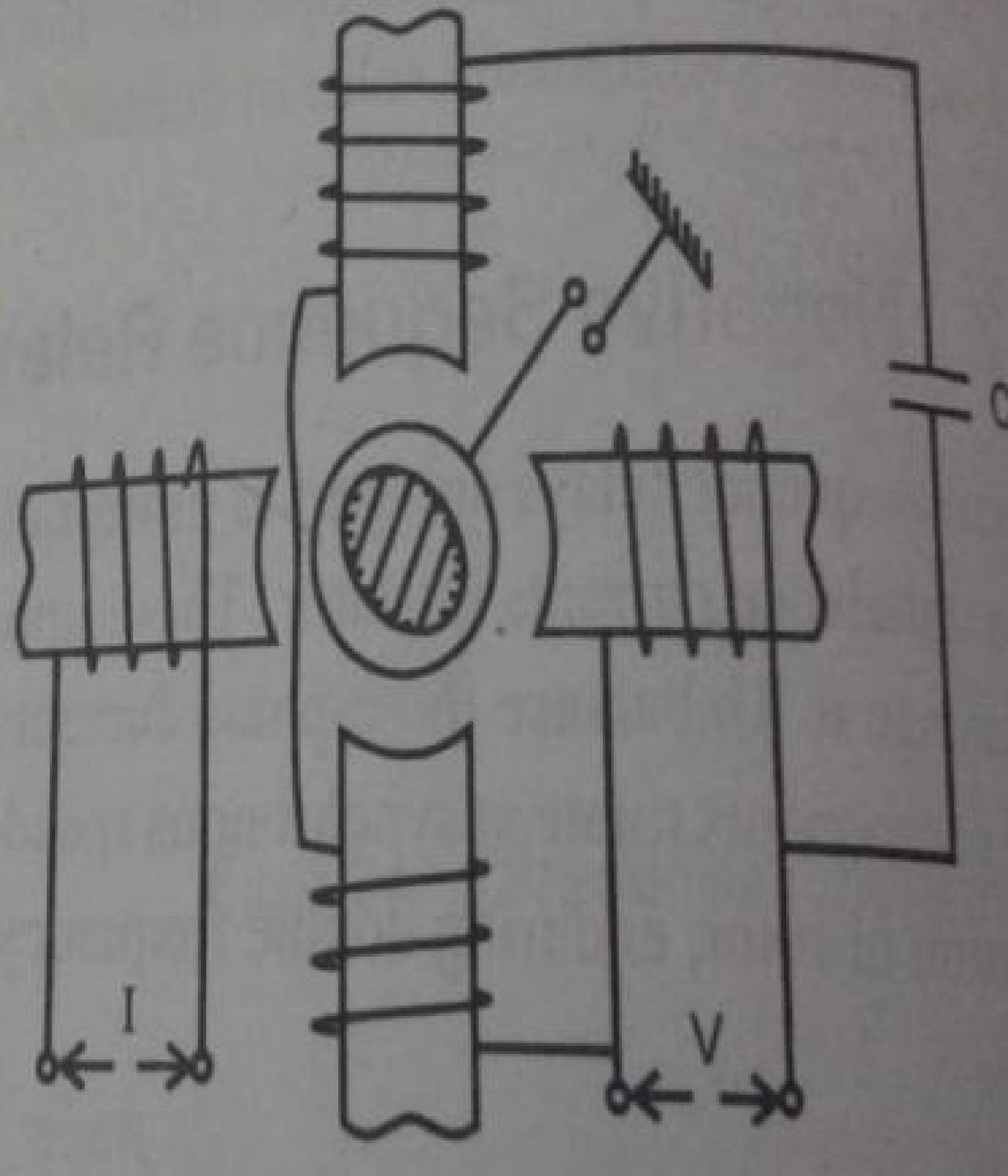
➢The bias force can be adjusted by varying the number of turns on the restraining coil.



Under frequency relays



(a) Anticlockwise



(b) Cup rotor relay(R)

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

The frequency relay is connected to the secondary of the V.T. The relay monitors the frequency continuously. It has two pairs of coils and are connected in parallel to the supply voltage through the impedance 'Z'. The impedance will vary with frequency. Under normal conditions, the impedance is so tuned, that no torque is applied on the cup-rotor. Under fault conditions, a torque is applied on the cup rotor due to change in impedance either in the clock-wise direction or in the anti-clockwise direction, depending on the frequency is higher or lower than the desired frequency. The frequency setting varied by the sliding resistor and the pickup can be varied by the restraining spring.

UNIT 3

Apparatus Protection

Presented by
C.GOKUL,AP/EEE
Velalar College of Engg & Tech , Erode

UNIT 3 Syllabus

- Protection of transformer.
- Protection of generator.
- Protection of motor.
- Protection of busbars.
- Protection of transmission line.

MAIN CONSIDERATIONS IN APPARATUS PROTECTION

Introduction

The two major items of equipment in a power system are the generators and transformers. They have very high chance of fault occurrence and usually takes much time and money to repair the damage.

Fault and Abnormal Conditions

- **Generator :** Over Current, Over Voltage, Under Voltage, Under Frequency, Unbalanced Current, Loss of Excitation, Reverse Power, Winding Inter turn Fault, Winding Earth Fault etc.

- **Transformer :** Over Current, Winding Inter turn fault, Excessive Temperature Rise, Unbalance Current, Over fluxing etc.

- **Motors** : Over Current, Under Voltage, Unbalance Current, Winding Short Circuit, Stator Earth Fault, etc.

- **Transmission Line** : Single Phase to ground fault, Phase to Phase Fault, three phase to ground fault, Over Current etc.

Transformer Protection

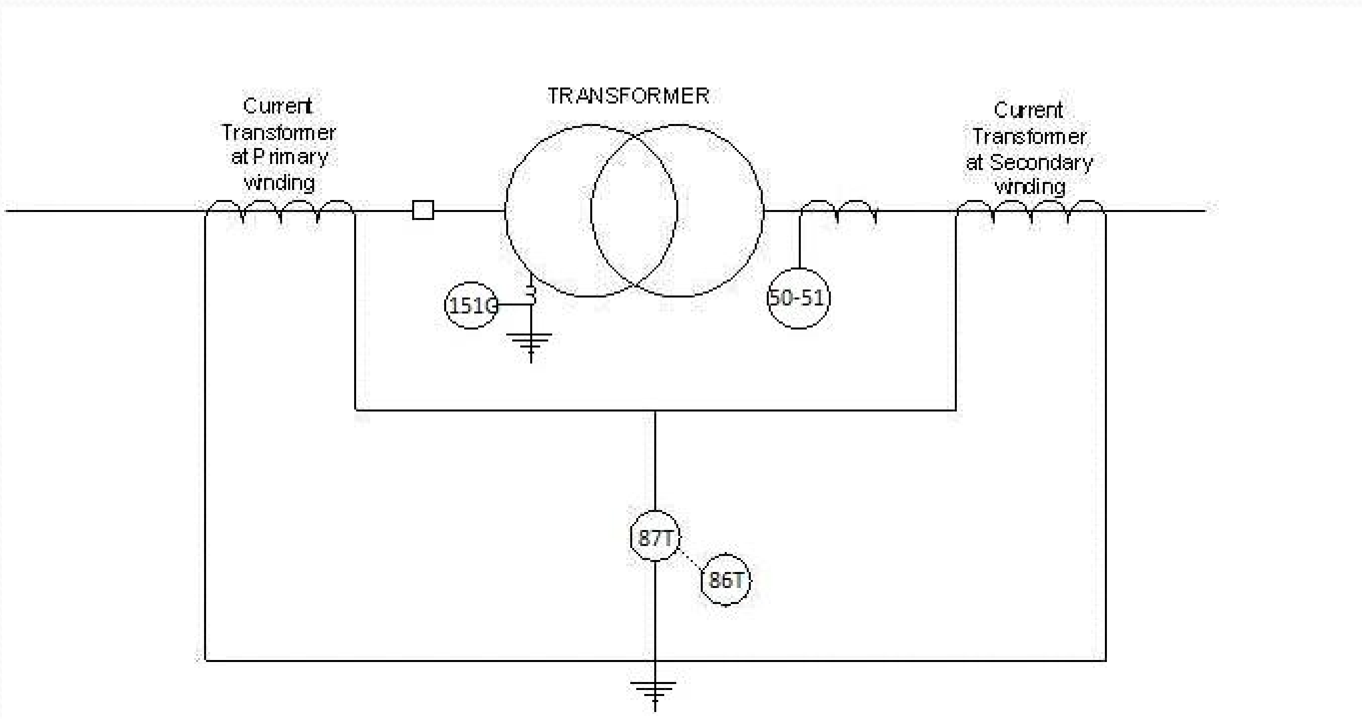
Faults occurring in Transformers

- Open-Circuit faults
- Earth faults
- Phase-to-Phase faults
- Inter-Turn faults
- Overheating

Factors in choosing Protective Gear for a Transformer

- Type of Transformer
- Size of the Transformer
- Type of Cooling
- System where used
- Importance of service for which it is required

Transformer Relaying Scheme



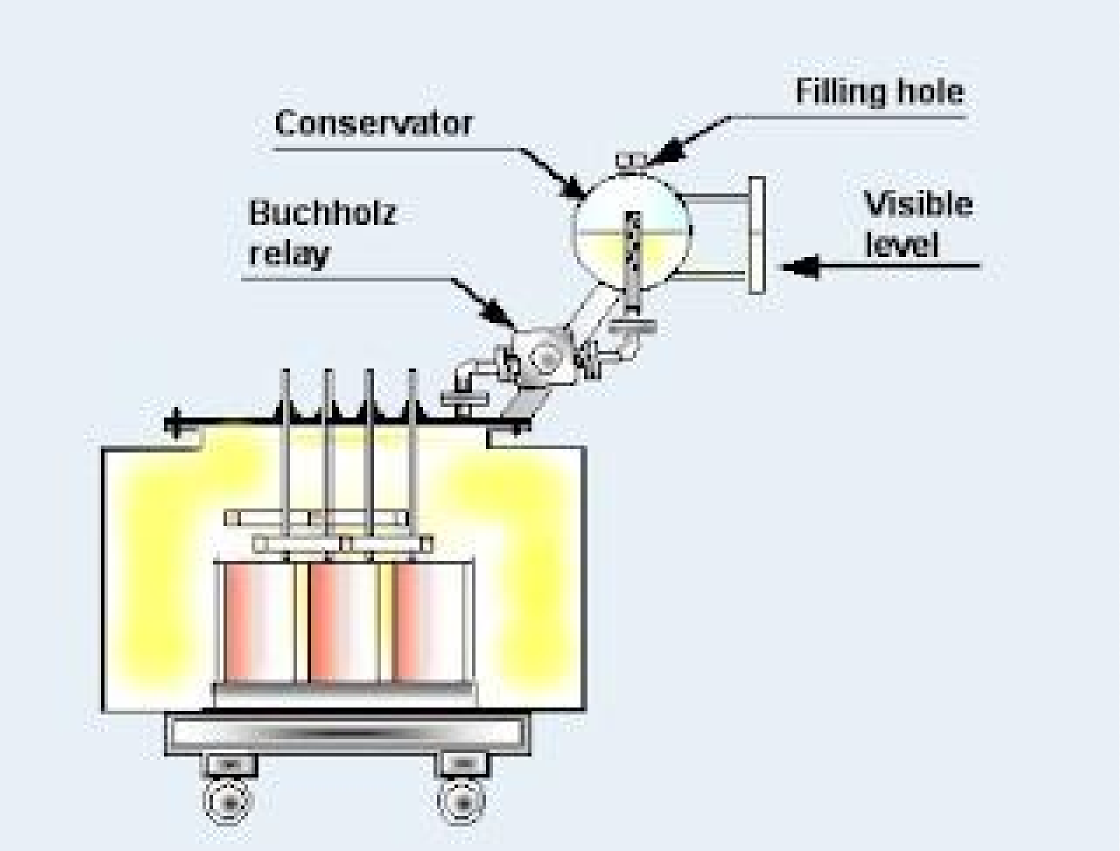
Buchholz Protection

Also known as gas accumulator relay, commonly used on all oil-immersed transformer provided with conservator.

Working Principle:

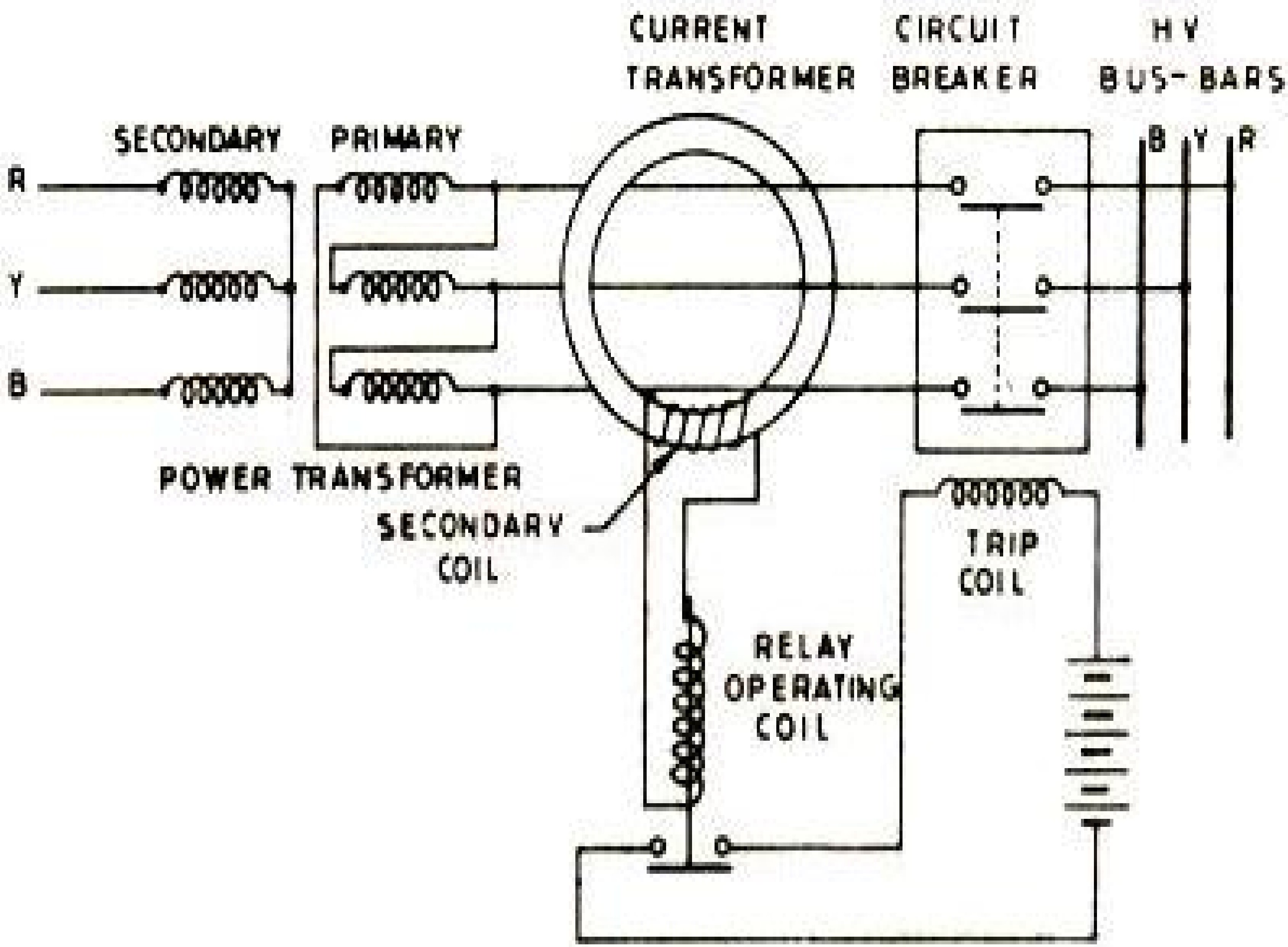
Whenever a fault occur inside the transformer, the oil of the tank gets overheated and gases are generated. The heat generated by the high local current causes the transformer oil to decompose and produce gas which can be used to detect the winding faults

Buchholz Protection



Core-Balance Leakage Protection

This system is used to provide protection against earth faults on high voltage winding. When earth fault occurs, the sum of the three currents is no longer zero and a current is induced in the secondary of the CT causing the trip relay to operate and isolate the transformer from the bus-bars.

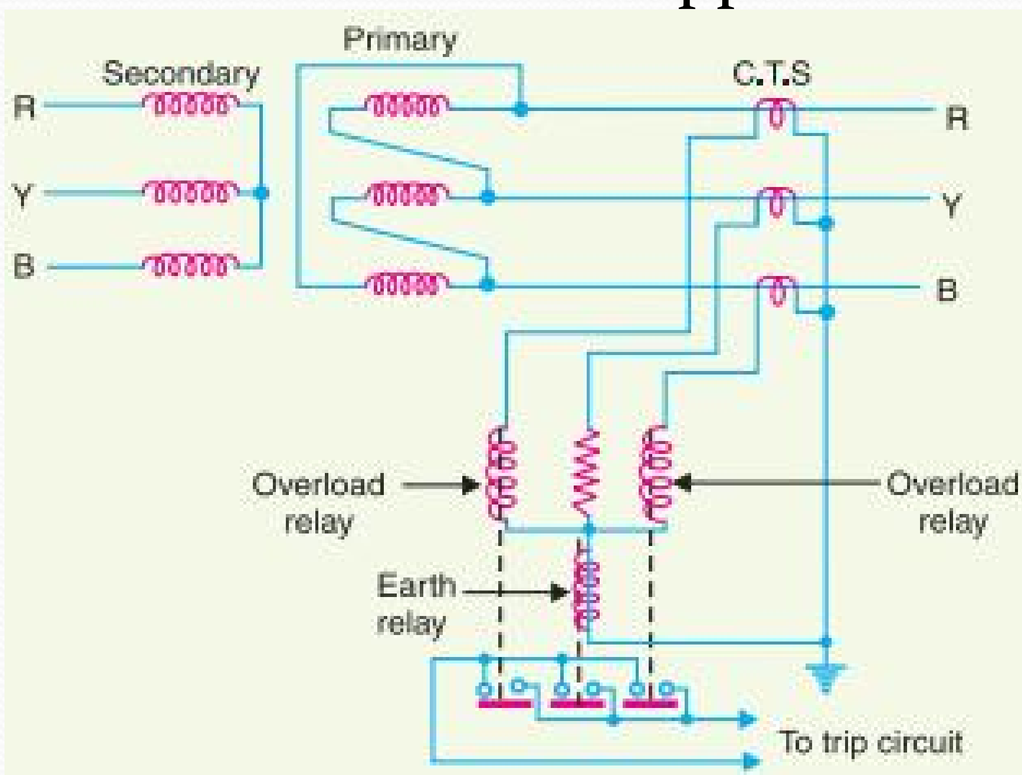


CURRENT TRANSFORMER
CIRCUIT BREAKER
H V BUS-BARS
SECONDARY
PRIMARY
R
Y
B
B
Y
R
POWER TRANSFORMER
SECONDARY COIL
TRIP COIL
RELAY OPERATING COIL

Combined Leakage and Overload Protection

The core-balance protection cannot provide protection against overload. It is usual practice to provide combined leakage and overload protection for transformer. The earth relay has ***low current setting*** and operates under earth faults only. The overload relays have ***high current setting*** and are arrange to operate against faults between the phases

- In this system, two overload relay and one earth relay are connected. 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 the energizing of either one of them, the circuit breaker will tripped.



Transformer Protection

- Overheating

  Normal maximum working temp. = 95 °C

  8-10 °C rise will halve the life of the transformer.

- Overcurrent

  Fuses for distribution transformer

  Overcurrent relaying for 5MVA and above

  Characteristics:

  – Must be below the damage curve

  – Must be above magnetizing inrush

Conclusion

- Open-circuit faults, earth faults, phase-to-phase faults, inter-turn faults and overheating are the fault that are likely occur in a transformer
- Relays control output circuits of a much higher power.
- Safety is increased
- Protective relays are essential for keeping faults in the system isolated and keep equipment from being damaged.

Generator Protection

Introduction

- Generator is the electrical end of a turbo-generator set. Without Generator, turbine/boiler/any Power Plant Equipment is meaningless. Generator is the most precious/valuable equipment in PP which actually converts the mechanical energy of turbine into electricity. So, Generator should be protected from faults occurring within generator and also from external faults/abnormal operating condition in the GRID which affected the generator.
- Various relays/devices are used to detect the abnormalities in operations and whenever fault conditions appear, they can give warning alarms to the operators or trip the unit automatically.
- Generally automatic tripping are provided if the time for operator to take corrective action is less or the fault is likely to cause serious damage to the unit.

FAULT IN THE GENERATOR

- Stator
  - Phase to Phase fault.
  - Inter – turn fault
  - Earth fault (80% & 100%)
- Rotor
  - Rotor E/F – Two stage relay: a) Alarm b) Trip
  - Over voltage in the rotor.

ABNORMAL OPERATING CONDITIONS:

Which affects the generator

- Negative Phase sequence
- Loss of Excitation
- Over fluxing protection
- Reverse power
- Over-speeding
- Pole slipping/ Out of Step

PROTECTION CATEGORY

- Complete Generator protection is divided into two category i.e.
- Class – A Protection
- Class – B Protection
- **CLASS – A: Protection where electrical isolation is an emergency.(Insulation failure, ,S.C. etc.). Trip the GCB/Turbine/Boiler without time delay or Generator automatic trips.**
- .Class – A follows;
- Gen. Differential Prot.
- Gen. 100% E/F
- Gen. SB E/F
- Gen. NVD
- Gen. O/C
- Rotor 2nd stage E/F
- Gen. Brg. Temp. high

CLASS - B

- **CLASS – B: Protection where external abnormalities come into picture, such as temp. rise. Generator trips through LFP relay.**
- **Class – B** follows;
- Reverse power
- Voltage restrained O/C
- Thermal O/C
- Negative Phase sequence
- U/V and O/V 2nd stage
- Over fluxing/ Field failure
- Gen. over/under frequency.

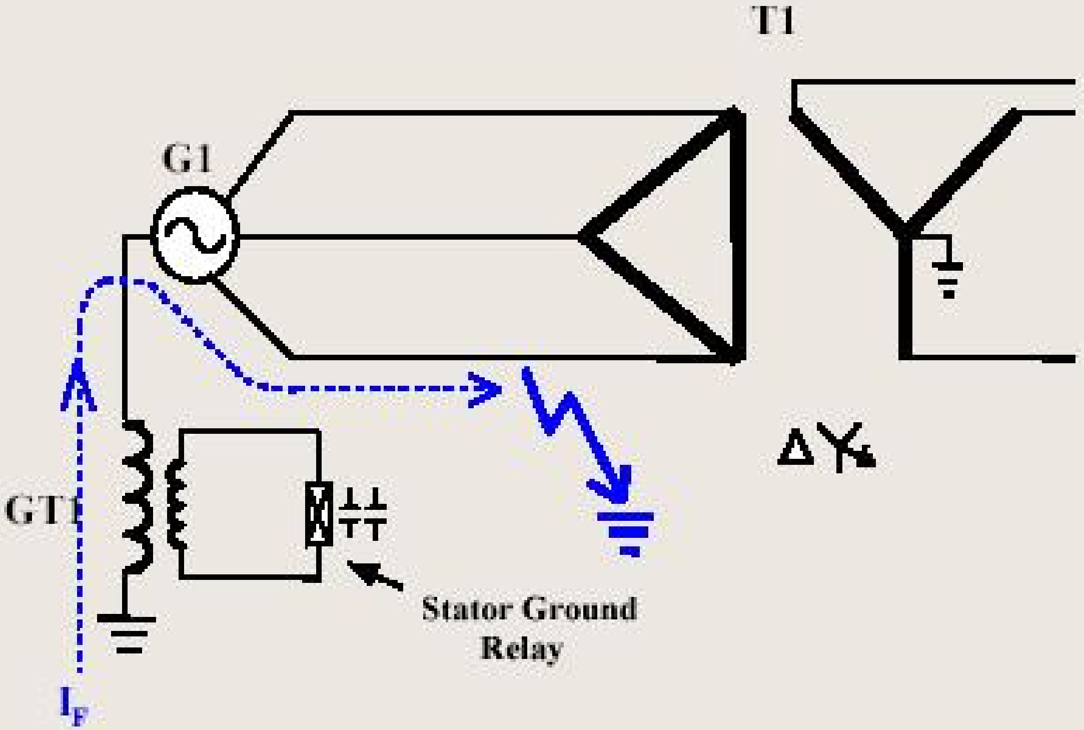
EARTH FAULT:

- When fault current flows through earth return path, the fault is called Earth Fault.
- Possible causes are ;(a) Insulation failure, (b) due to over heating (Failure of water/air circulation through stator conductor).
- Earth fault may occur between any phase conductor and core.
- It is usually practice to limit the earth fault current to avoid extensive damage to the stator core.

STAND BY EARTH FAULT:

- **This protection is practically protects 95% of generator winding. Therefore a current setting of 5% of in to be set.**
- E/F current is generally limited to about 15/20Amps.
- Earth fault current of even 100A for few seconds can cause external damage. So the earth fault is restricted to 100Amps. By providing NGR of 63.5 ohms at 11KV Voltage Level.
- This is a Back-Up protection.

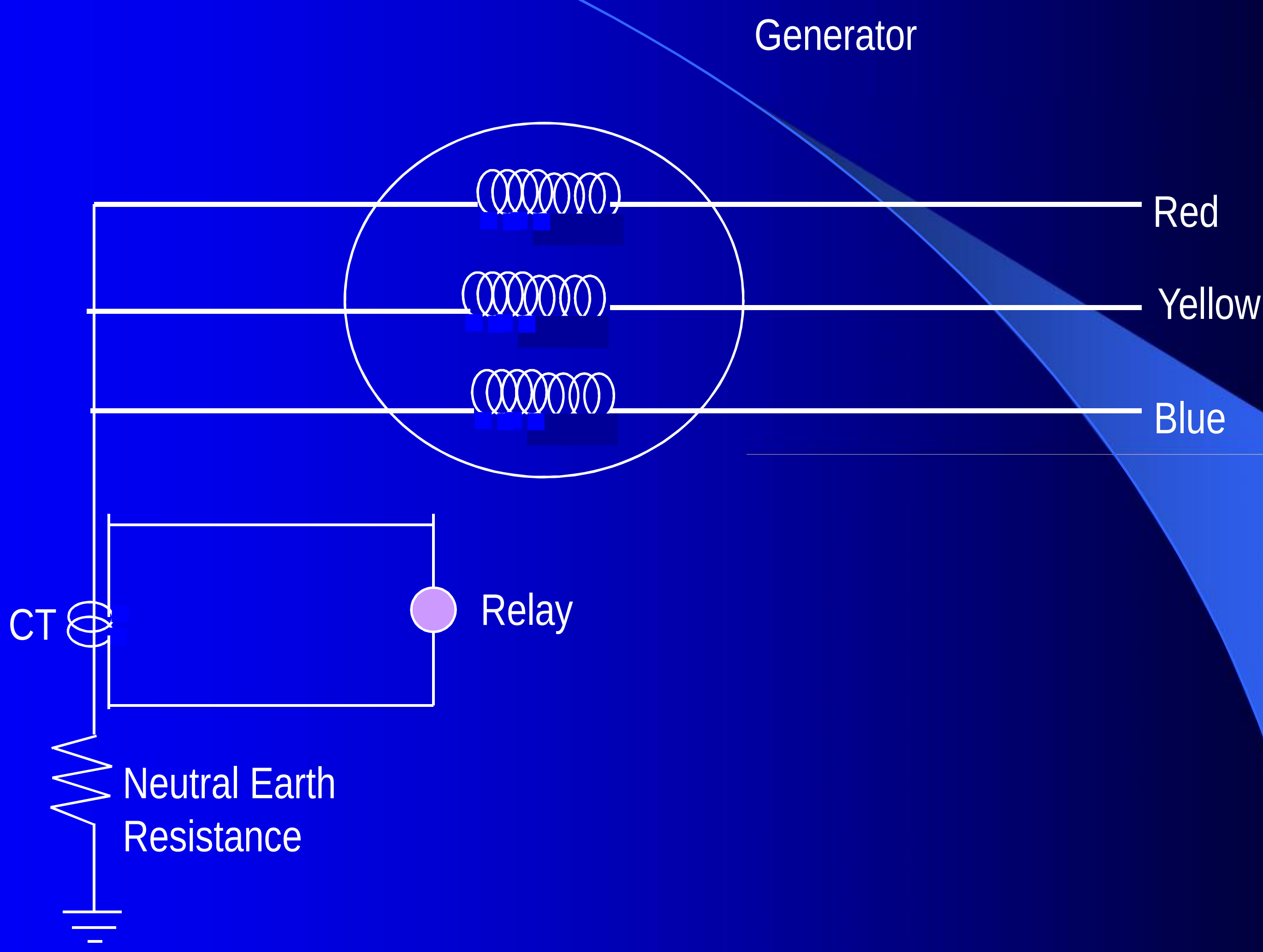
Ground Fault Protection



100% STATOR EARTH FAULT:

- In this protection, where neutral voltage measurement is made at generator terminals, (By Broken Delta), the third harmonic voltage element is used.
- First earth fault very near to neutral produces negligible current as driving voltage is nearly zero. But if a 2nd earth fault occurs at machine terminal, line to ground fault is not limited by NGR. The resulting fault current can be high. Hence, the 1st E/F very near to neutral has to be detected early and isolated.
- All generators produce continuous current of 3rd harmonic voltage. Under normal condition, 3rd harmonic voltage is present. If there is a fault near neutral, the amount of 3rd harmonic voltage comes down and this is used for detection.

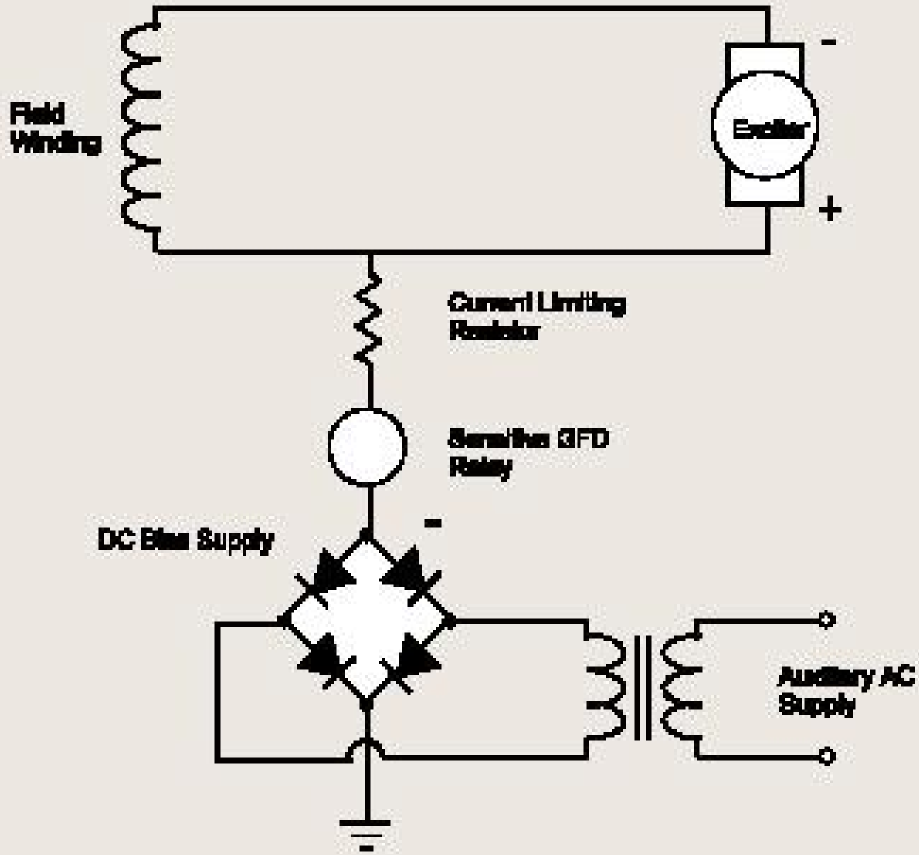
STATOR EARTH FAULT PROTECTION



ROTOR EARTH FAULT:

- **Since rotor** circuits operate ungrounded, a single earth fault is caused by insulation failure due to moisture, ageing of insulation or vibration of rotor etc. But existence of single ground fault increases the chance of a second ground fault. The occurrence of second earth fault can cause fault current flows. This results unsymmetrical flux distribution. The air gap flux is badly distorted. The rotor is displaced enough to rub stator leading to severe vibrations and can damage the bearing.
- **Although a machine can continuously run on a single earth fault but second rotor earth fault, if allowed to occur, should be detected immediately and generator should be tripped.**

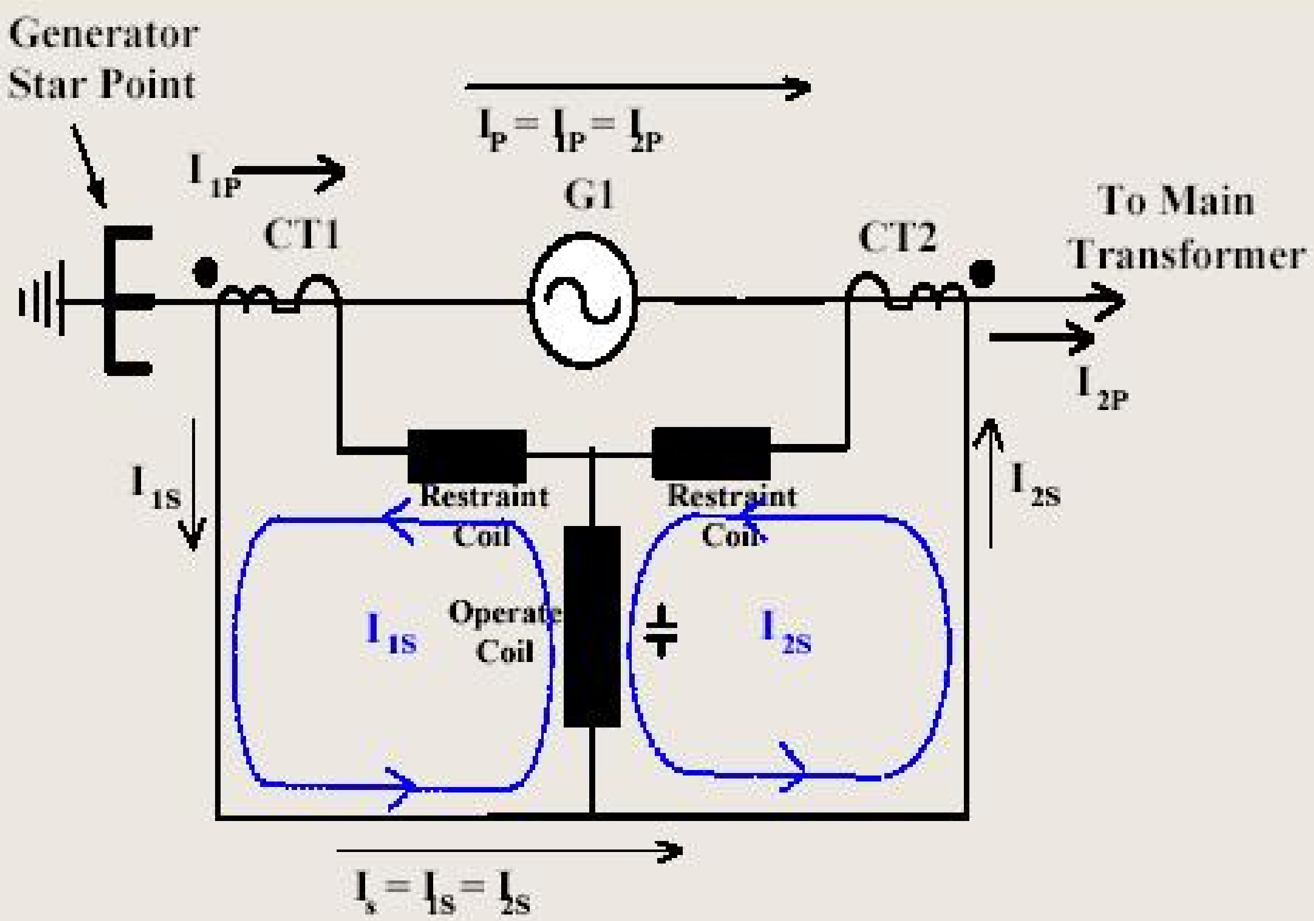
Rotor Ground Fault



DIFFERENTIAL PROTECTION

- Differential protection is very reliable method for stator winding phase to phase fault. In this, currents on both sides of the generator are compared.
- Under normal condition or for a fault outside of the protected zone, current i1s is equal to current i2s. Therefore, the currents in the CTs secondaries are also equal, i1s=i2s and no current flows through the current relays.
- If a fault develops inside of the protected zone, current i1s and i2s are no longer equal, therefore i1s and i2s are not equal and therefore a current flowing in the current relay.

Differential



Negative Phase Sequence Protection:

- When the generator is connected to a balanced load, the phase currents are equal in magnitude and displaced electrically by 120°. The ATs wave produced by the stator currents rotate synchronously with the rotor and no eddy currents are induced in the rotor parts.
- If there is an unbalanced loading of the generator, and then the stator currents have a –ve sequence component. The stator field due to these –ve sequence currents rotates at synchronous speed but in a direction opposite to the direction of the field structure on the rotor. Thus, the –ve sequence stator armature mmf rotates at a speed –Ns, while the rotor field speed is +Ns. There is a relative velocity of 2Ns between the two.
- These causes double frequency currents, of large amplitude to be induced in the rotor conductors and iron part. So both the eddy currents as well as the hystersis losses increase due to these double frequencies induced currents in the rotor.
- Unbalanced loading affects ;(a) Rotor heating (b) Severe vibration & heating of stator.

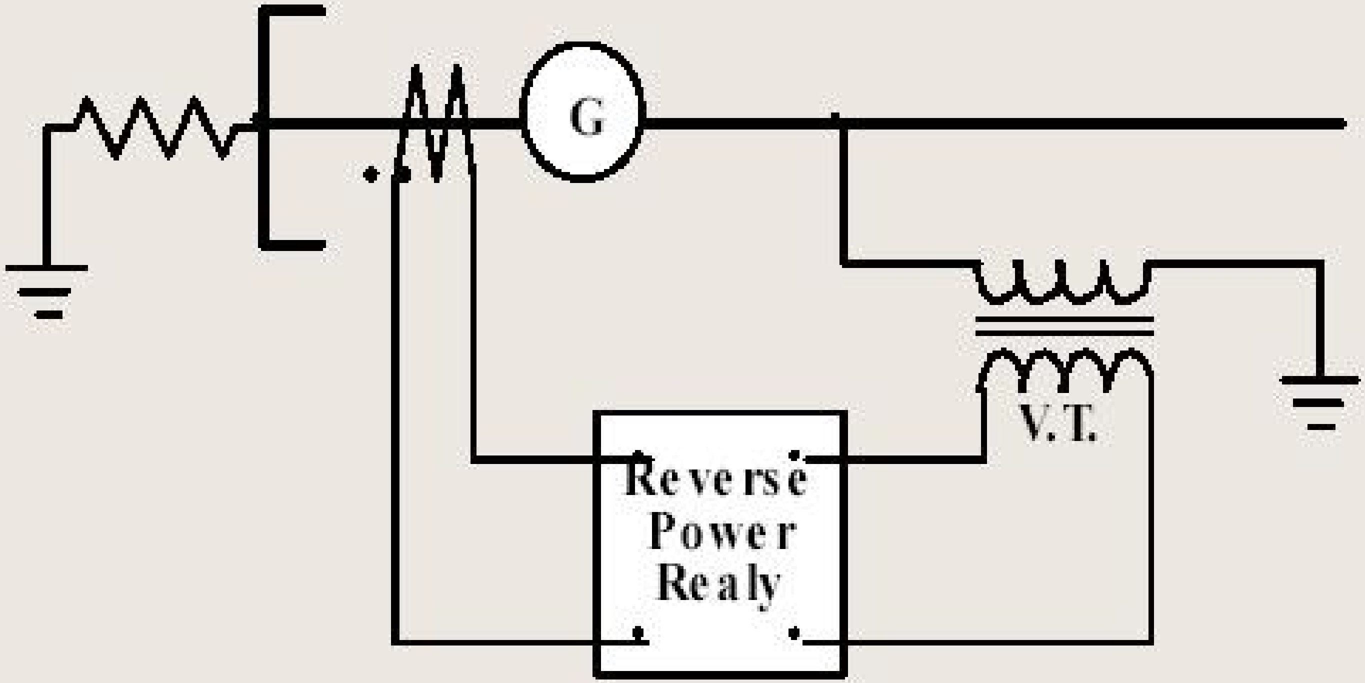
FIELD FAILURE PROTECTION:

- Acts as an Induction Generator.
- Possible Causes;
  - AVR Fault
  - Tripping of Field C.B.
  - Open circuit or Short circuit occurring in the D.C. circuit.
  - PMG failure
- In normal condition, generator when running shares the reactive demand of the system. If excitation fails, synchronous generator runs at a super-synchronous speed, draws reactive power from the power system instead of supplying the Qe. In case, the other generators can't meet the requirement of reactive power, this shall result in large voltage drop which may ultimately result in instability.
- In this case, slip becomes –Ve result in slip frequency currents. Rotor gets heated up due to induced currents in the rotor winding, core or damage the winding if this condition is sustained. Stator heats up due to high stator currents due to increase in reactive current from the system.
- By monitor (i) Field current, If
- (ii) Phase current & voltage.

REVERSE POWER PROTECTION:

- This protection is provided to protect against motoring.
- A generator is expected to supply active power to the connected system in normal operation. If the generator primover fails, a generator that is connected in parallel with another source of electrical supply will to begin to motor. This reversal of power flow due to loss of prime mover can be detected by reverse power element.
- Possible Causes:
- When immediately after Synchronising control valves are not operated which may happen due to some fault in the system or some delay by the operating personnel.
- In case of sudden closure of stop valves or control valves when the generator unit is still connected to the grid.
- Reverse power operation is harmful to the turbine since without steam flow in the turbine. If the turbine continues to rotate, it will result in heating of turbine blades due to churning action. However, the period for the turbine to overheat may vary from a few seconds to minutes depending upon the turbine & operating conditions.

Reverse Power



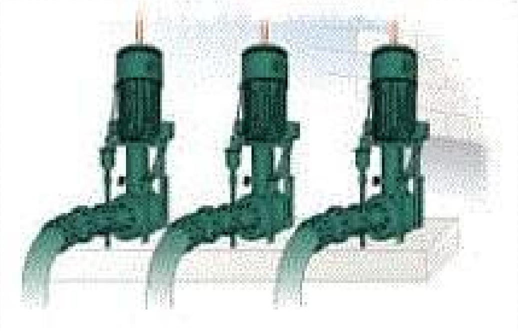
OVER FLUXING PROTECTION:

- Fundamental Voltage- Flux relation:
- $V = 4.44 * N * f * ø$
- $V/f = 4.44 * N * ø$
- $= K * ø = K * B/A$
- V/f is a measure of flux in machine. That means, over fluxing can occur if the ratio of voltage to frequency exceeds certain limits. High voltage or low frequency, causing a rise in the V/f ratio, will produce high flux densities in the magnetic core of the generator.This could cause the core of the machine to saturate & stray flux to be induced in the unlamilated components that have not designed to carry flux. The resulting eddy currents in the solid components e.g. core bolts & clamps and end of core laminations can cause rapid overheating and damage.
- POSSIBLE CAUSES:
- AVR failure
- Load rejection under manual AVR control
- Excessive excitation with Generator Offline.
- Decreasing Speed with operator tries to maintain rated stator voltage.
- AUTO to Manual transfer of AVR.

Motor Protection

Various Industry Motor Applications

- Fan, Blower
- Pump, Compressor
- Conveyor
- Mixer
- Cranes



Types of Fault in Motors

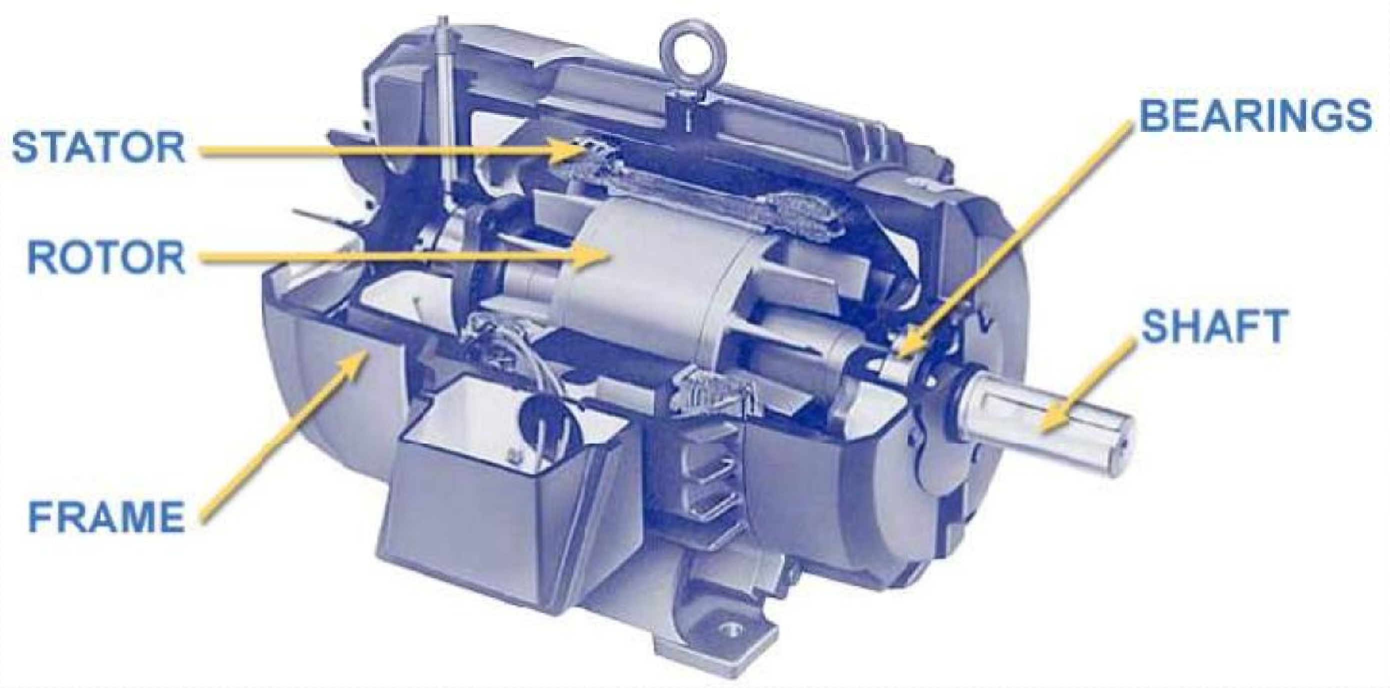
External Fault	Internal Fault
Mechanical Load	Bearing Failure
Unbalance Supply Voltage	Winding phase and earth fault
Single Phasing	
Phase Reversal	

Motor Protection Summary

- THERMAL OVERLOAD
- SHORT CIRCUIT
- EARTH FAULT
- UNBALANCE
- BLOCKED ROTOR/STALLING PROTECTION

Thermal Stress Causes Motor Failure

- Most of the motor failure contributors and failed motor components are related to motor overheating.
- Thermal stress potentially can cause the failure of all the major motor parts: Stator, Rotor, Bearings, Shaft and Frame.

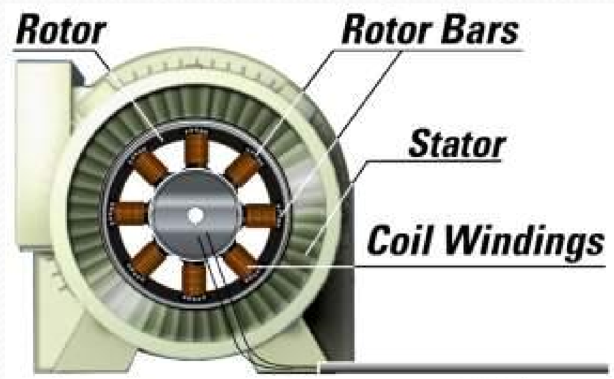


Thermal Overload

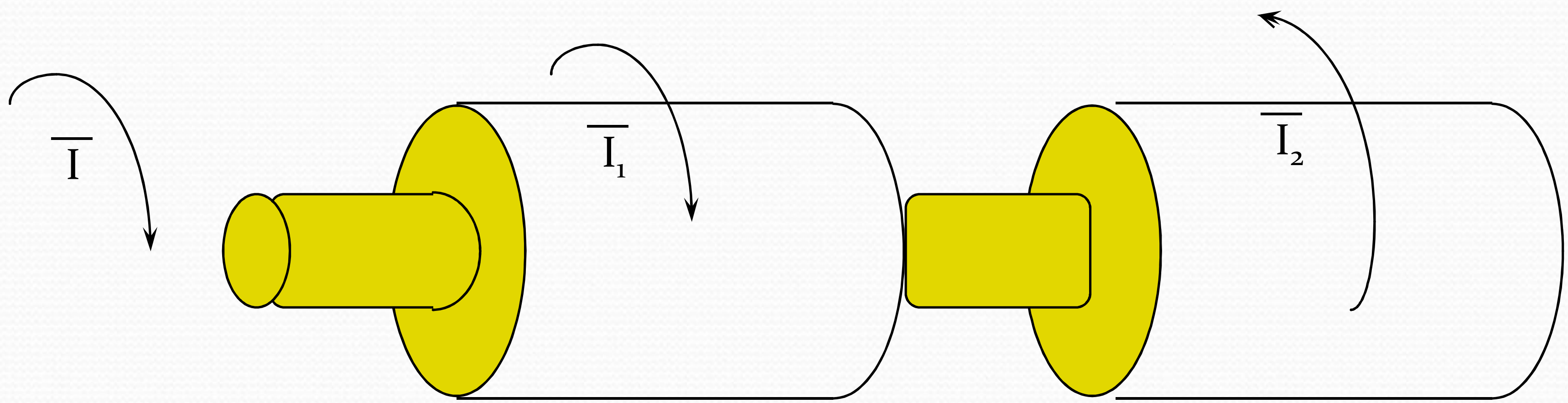
- Consider a motor is as homogenous body
- Developing heat at constant rate.
- Dissipating heat at constant rate.

Heat disspation is proportional to temperature rise

$T = KI_R^2 (1-e^{-t/\tau})$



Rotor I^2t Protection



$I = I_1$ (positive sequence) + $k * I_2$ (negative sequence)

(Overload protection includes additional heating effect of negative sequence curre

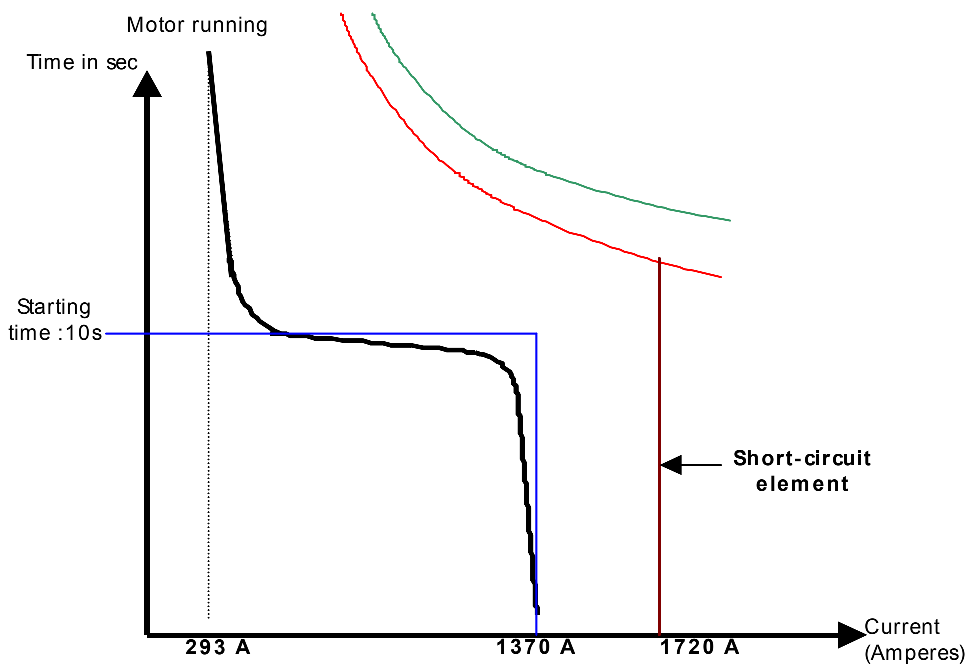
$$I_{eq} = \sqrt{\left(I_1^2 + KI_2^2\right)}$$

Overload Protection - Thermal Model

- Main Factors and Elements Comprising the Thermal Model are:
  - Overload Pickup Level
  - Overload Curve
  - Cooling Time Constants
  - Hot/Cold Stall Time Ratio

THERMAL OVERLOAD cont……

SETTING CRITERIA : Thermal Element



HOT & COLD CURVES OF THE RELAY ARE TO BE MATCHED WITH THAT OF THE MOTOR

$$\text{PICKUP} = \frac{\text{FULL LOAD CURRENT X CT SECONDARY}}{\text{CT PRIMARY X 1.05}}$$

THERMAL ALARM (PRETRIP)

MONITORS THERMAL CONTENT & GIVES AN ALARM WHEN CONTENT REACHES 75% OF HOT TRIP TIME

LED INDICATION

THERMAL LOCKOUT

LOCKOUT RELAY PICKSUP WHEN THERMAL CONTENT EXCEEDS TRIP LEVEL & INDICATES

SHORT CIRCUIT PROTECTION

- What is:-Motor short-circuit protection - provided to cater for major stator winding faults and terminal flashovers.
- Settings - Definite time over current relay element, set to about 130% of motor starting current and time delay set at 100ms.

SHORT CIRCUIT ELEMENT

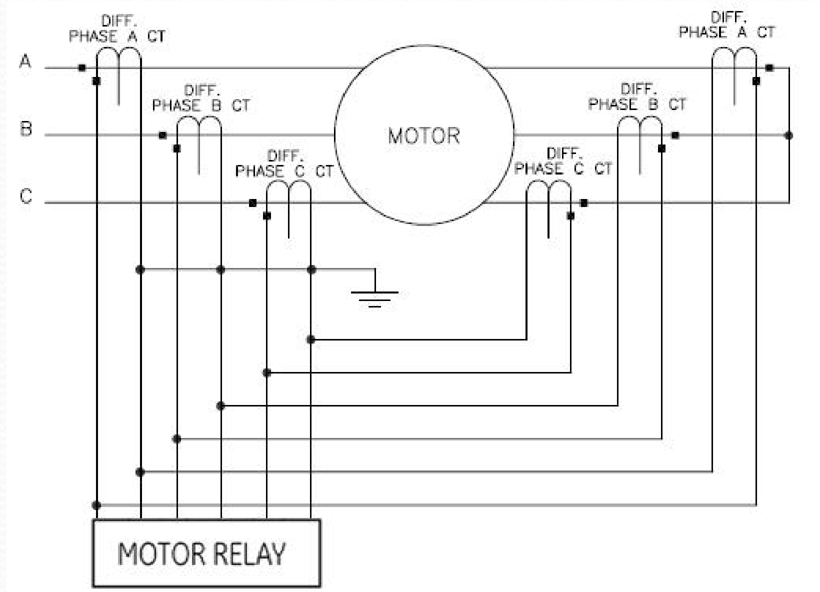
$$\text{SETTING} = \frac{1.3 \text{ X STARTING CURRENT X CT SEC.}}{\text{CT PRIMARY}}$$

Differential Protection

- Differential protection may be considered the first line of protection for internal phase-to-phase or phase-to-ground faults.

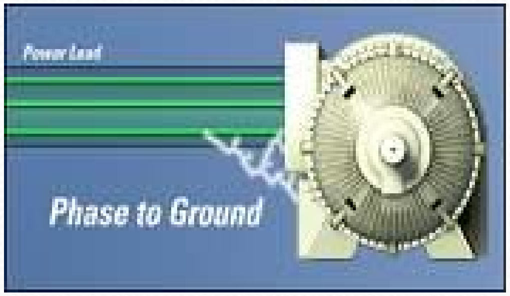
<u>Summation method with six CTs:</u>

- If six CTs are used in a summing configuration, during motor starting, the values from the two CTs on each phase may not be equal as the CTs are not perfectly identical and asymmetrical currents may cause the CTs on each phase to have different outputs.
- The running differential delay can then be fine tuned to an application such that it responds very fast and is sensitive to low differential current levels.



Ground Fault Protection

- **What is:-**A ground fault is a fault that creates a path for current to flow from one of the phases directly to the neutral through the earth bypassing the load

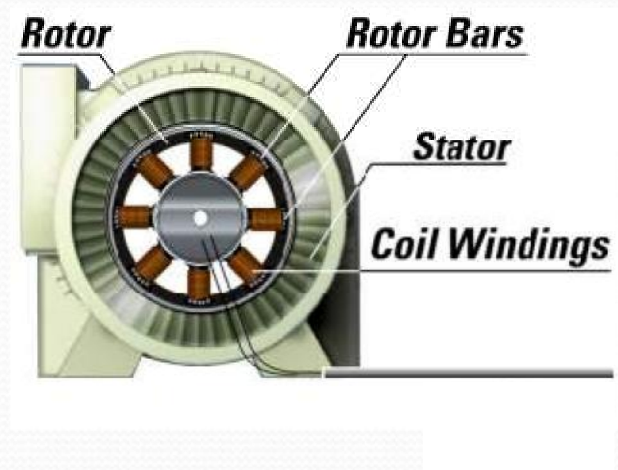


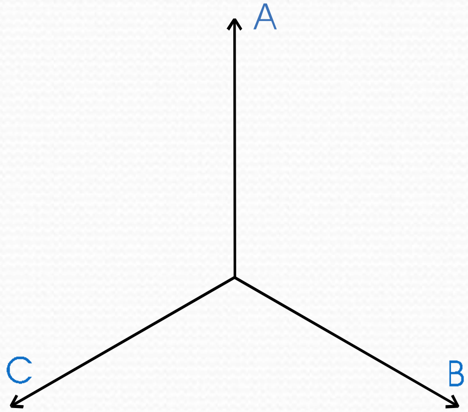
- **Ground faults in a motor occur:**
  - When its phase conductor's insulation is damaged for example due to voltage stress, moisture or internal fault occurs between the conductor and ground
- **To limit :-**the level of the ground fault current connect an resistance known as stablising resistance

$$R_{stab} = \frac{I_{st}}{I_O}\left(R_{ct} + kR_l + R_r\right)$$

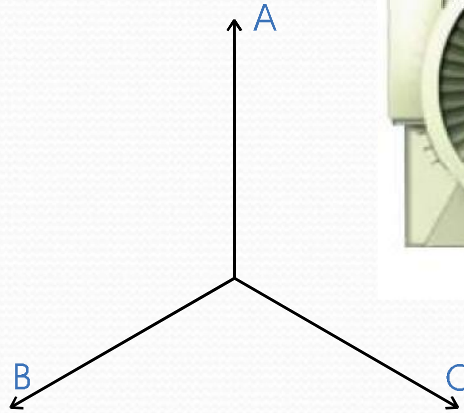
Phase Unbalance

- What is:-In a balanced system the three line-neutral voltages are equal in magnitude and are 120 degrees out of phase with each other. Otherwise, the system is unbalanced.





Positive Sequence



Negative Sequence

Main causes of current unbalance

- Blown fuses
- Loose connections
- Stator turn-to-turn faults
- System voltage distortion and unbalance
- Faults

Effects

- Motor winding overheating
- Excessive vibrations
- Cause motor insulation/winding/bearing damage

Motor Protection Stalling

What is:-It happens when motor circuits are energized, but motor rotor is not rotating. It is also called locked rotor.

- Effects:

  This will result in excessive currents flow given the same load. This will cause thermal damage to the motor winding and insulation.

Motor Protection Stalling

Required for

Stalling during starting　　　Stalling during running

Cases

- **Starting time < Stall withstand time**
- **Stall withstand time< Starting time**

CURRENT RELAYS

IDMT RELAYS :

These relays have inverse characteristic and the operating time decreases as the magnitude of current increases.

GENERAL RELAY EQUATION :

$$t = TMS \times K/((I/In)^n - 1)$$

t = RELAY OPERATING TIME

I = FAULT CURRENT

n = CONSTANT

K = CONSTANT

In = RELAY PLUG SETTING (PICK UP)

TMS = TIME MULTIPLIER SETTING

Pilot Relays

Why needed:-Overcome diffculties of overcurrent Relay ie

- Coordination
- Excessive fault clearance times

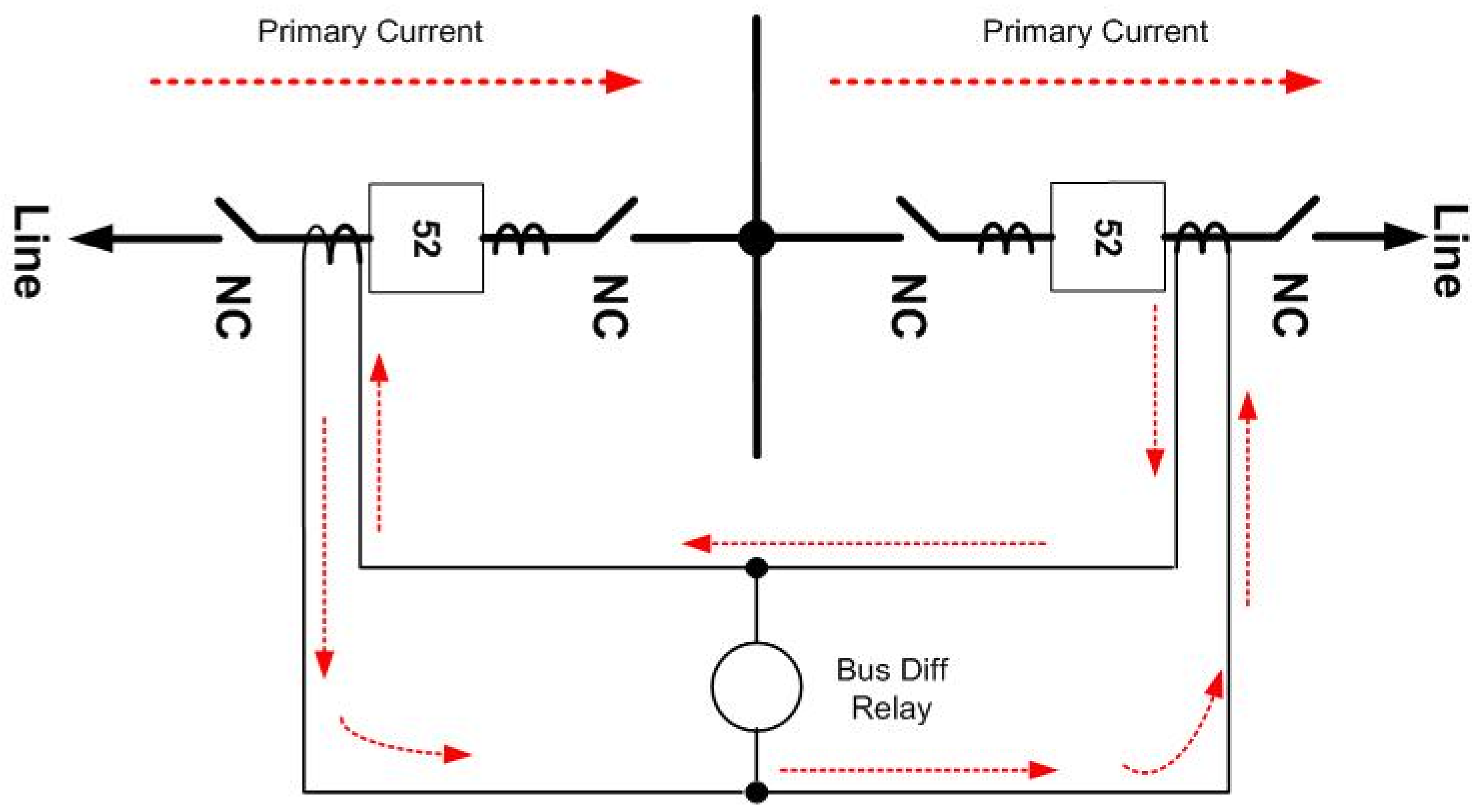
Principle:-

- Measurement of current at each end feeders
- Transmission of information
- No time and current gradation required
- Supervision facility.
- Merz price Circulating scheme

Protection of Bus bars

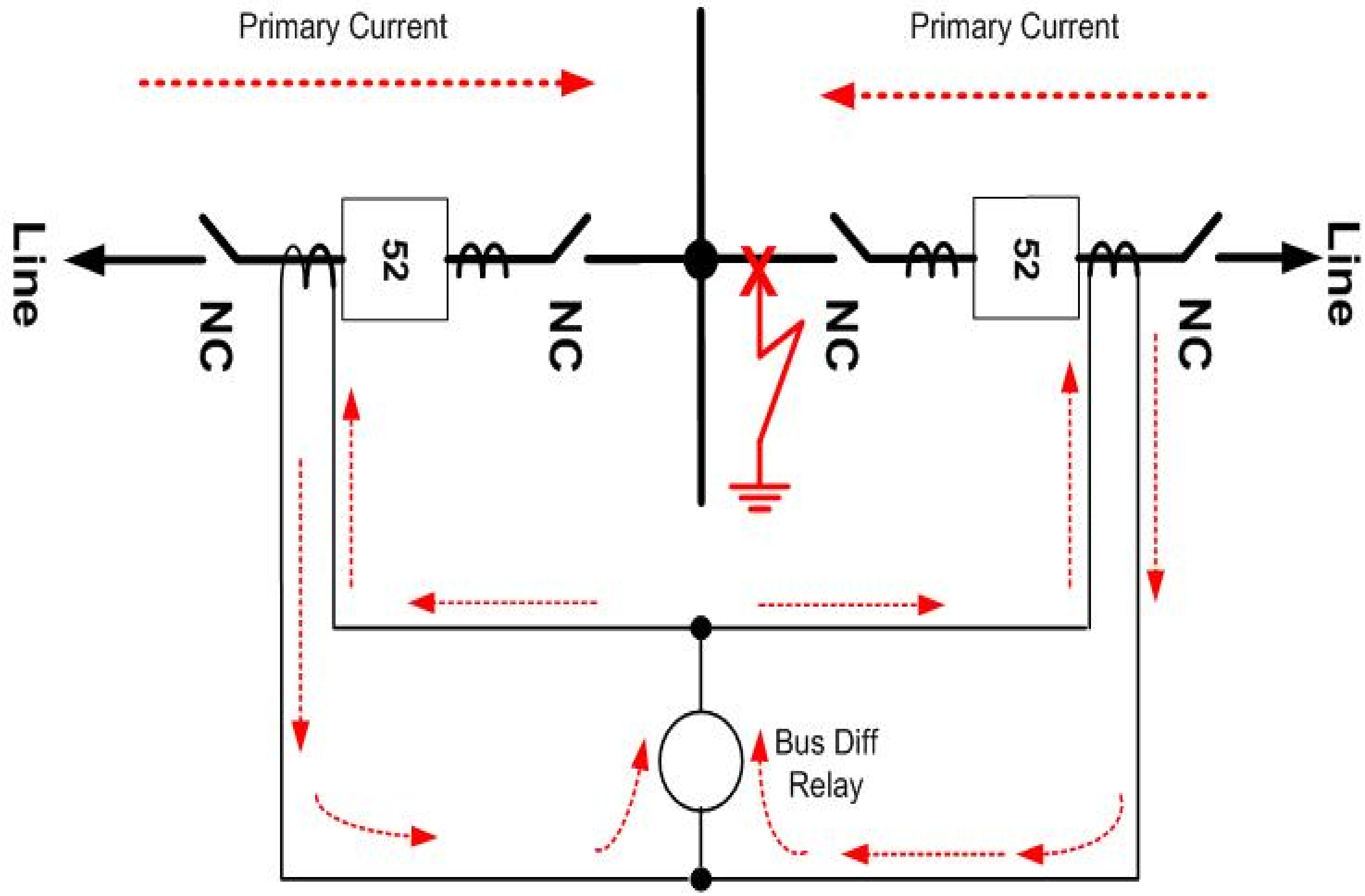
Bus Bar Protection

Bus Differential: Current into bus must equal current out of bus



Bus Protection

Bus Fault



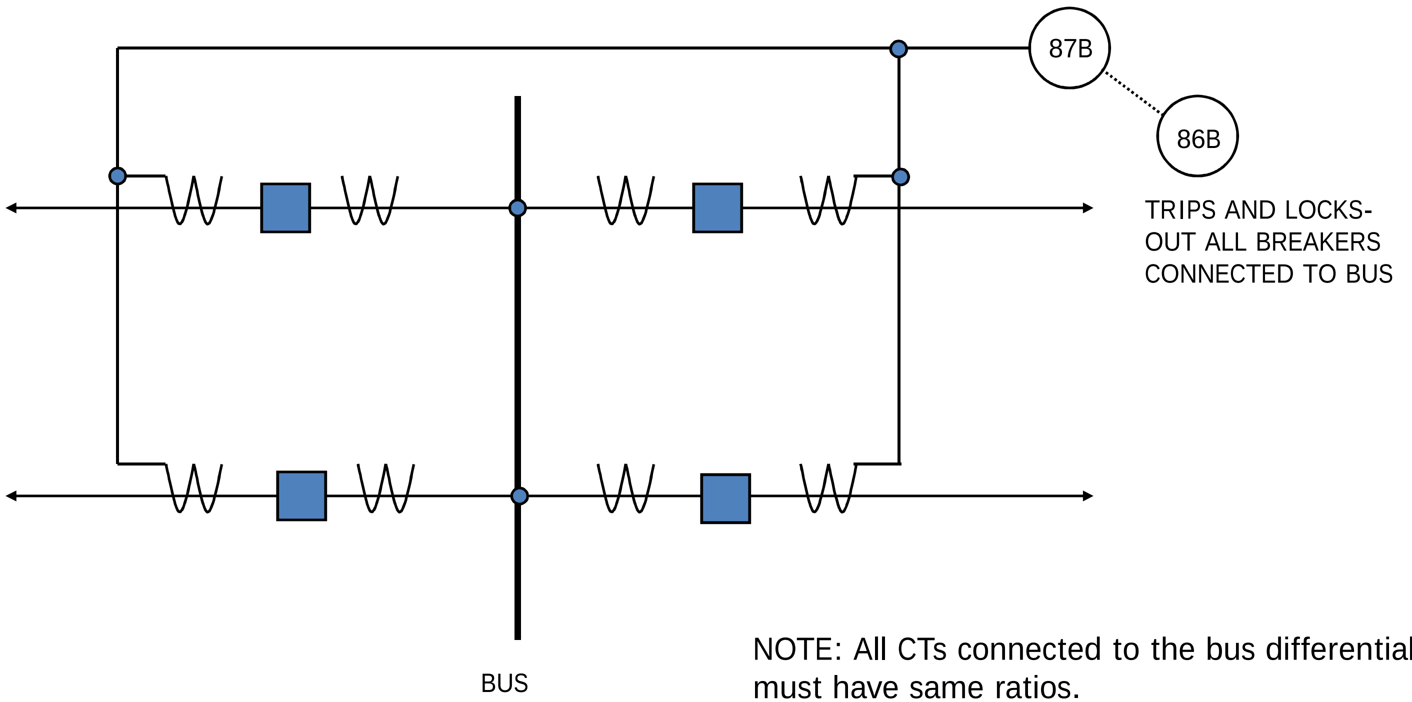
Busbar Protection

Typical Bus Arrangements:

- Single bus
- Double bus, double breaker
- Breaker-and-a-half
- Main and transfer buses with single breaker
- Ring bus

Busbar Protection

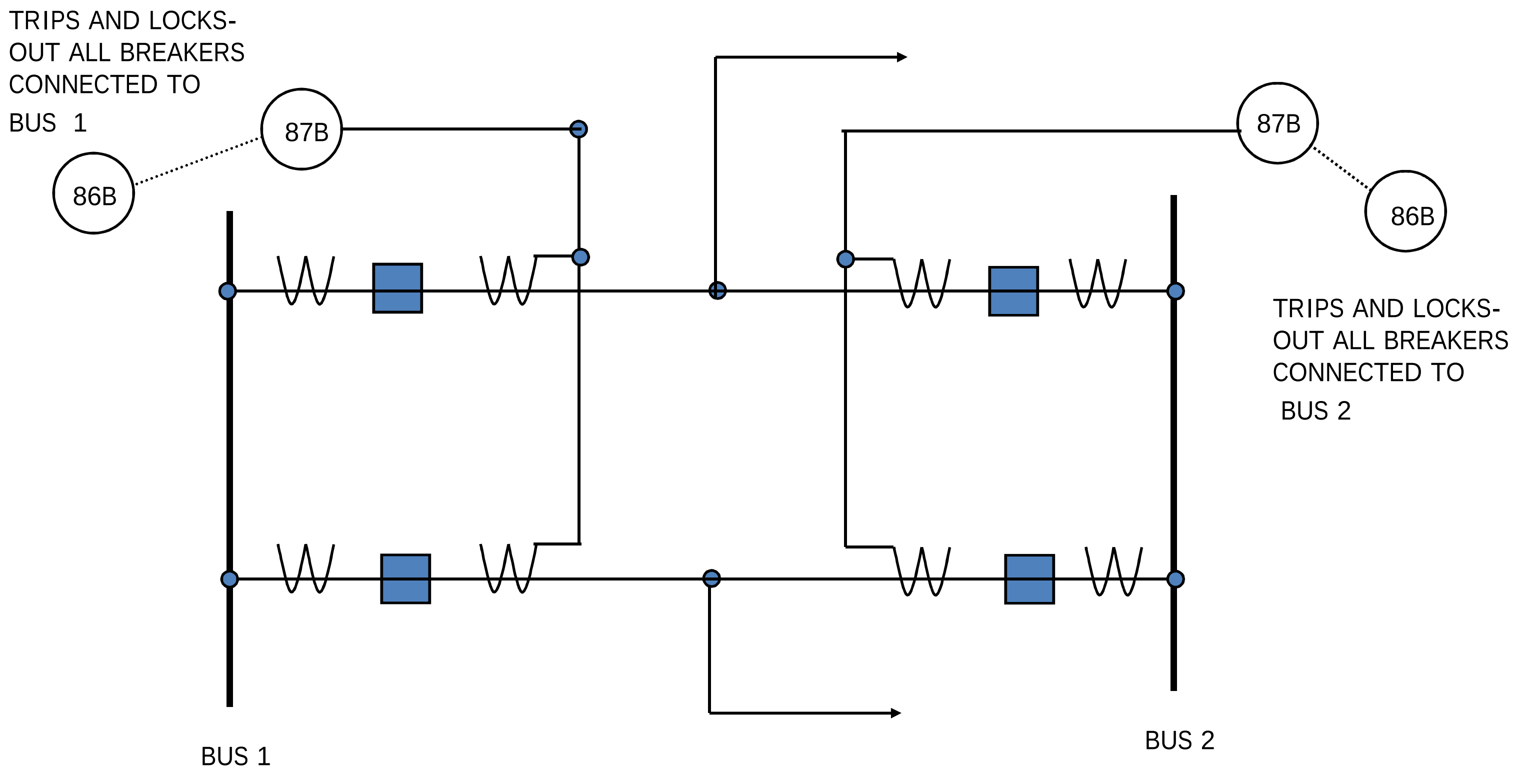
Bus differential connection (single-bus)



NOTE: All CTs connected to the bus differential must have same ratios.

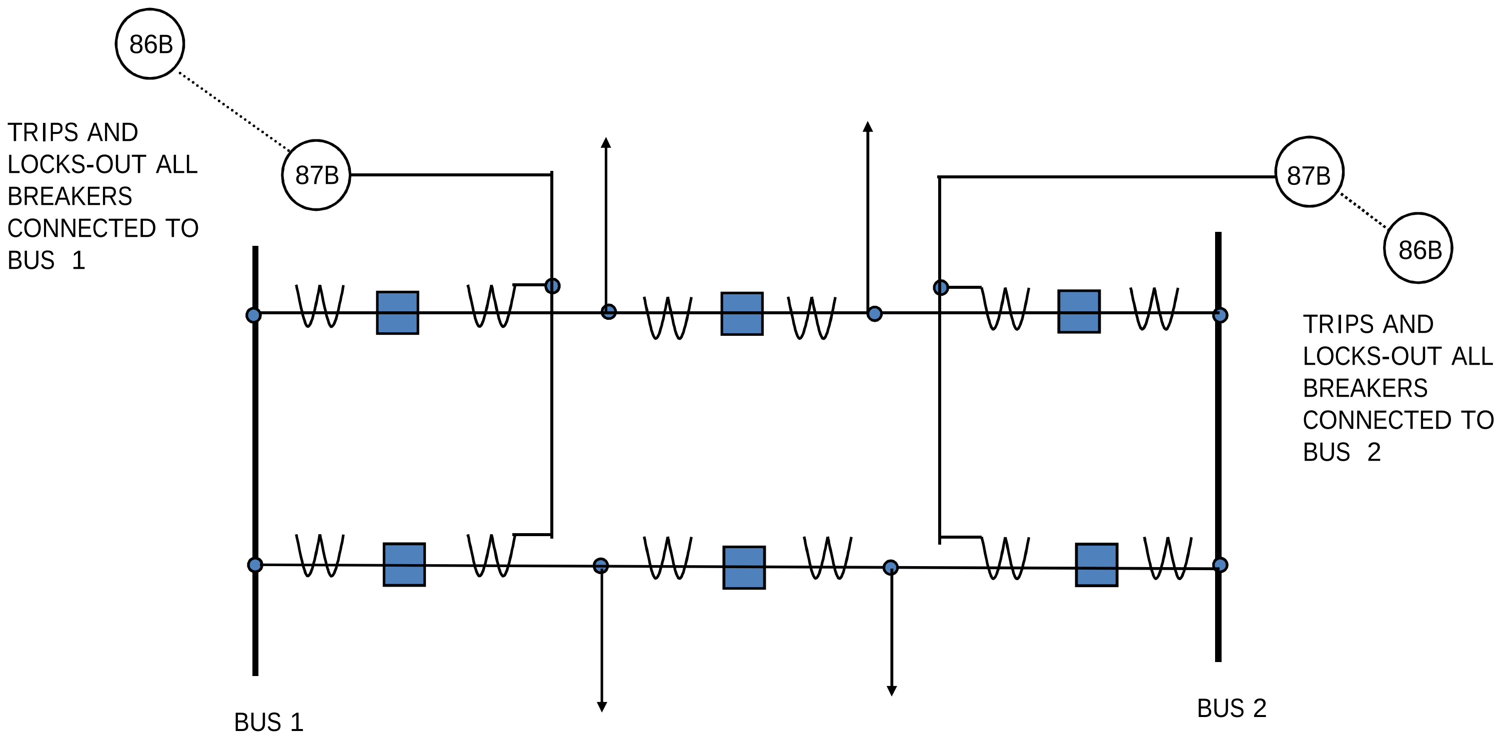
Busbar Protection

Bus differential connection (double-bus, double-breaker)



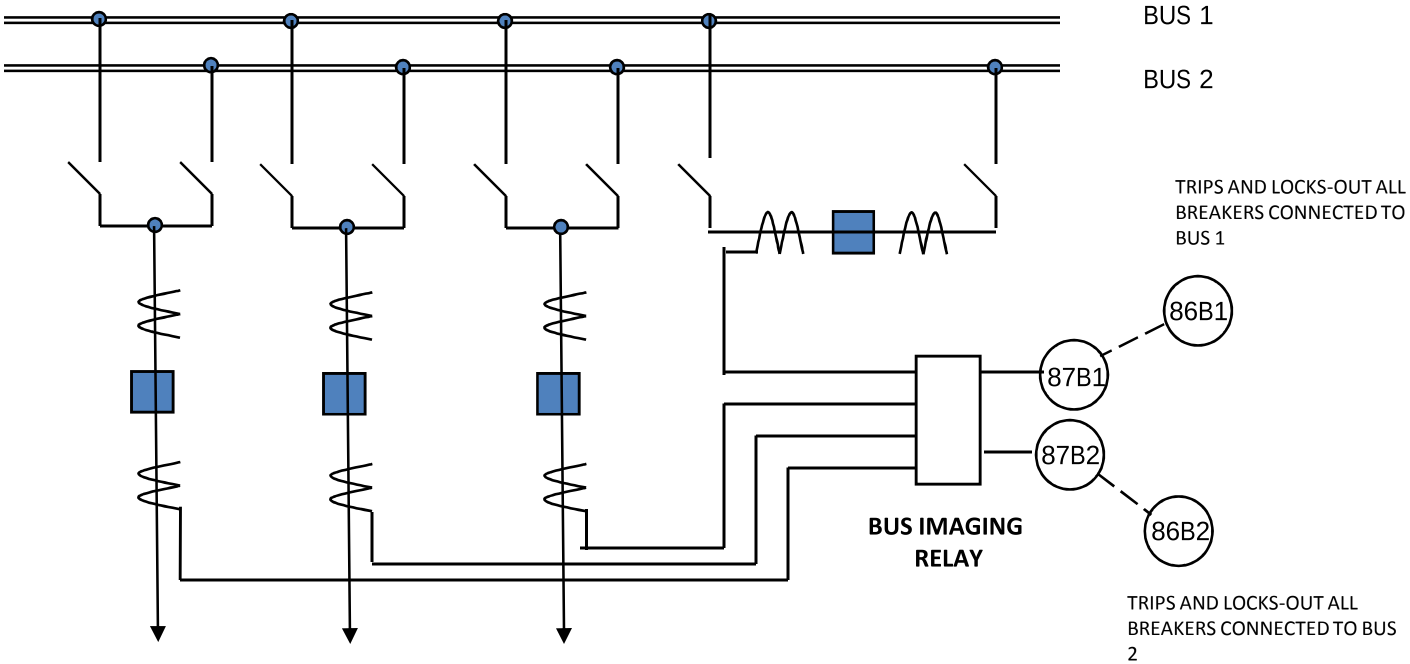
Busbar Protection

Bus differential connection (breaker-and-a-half)



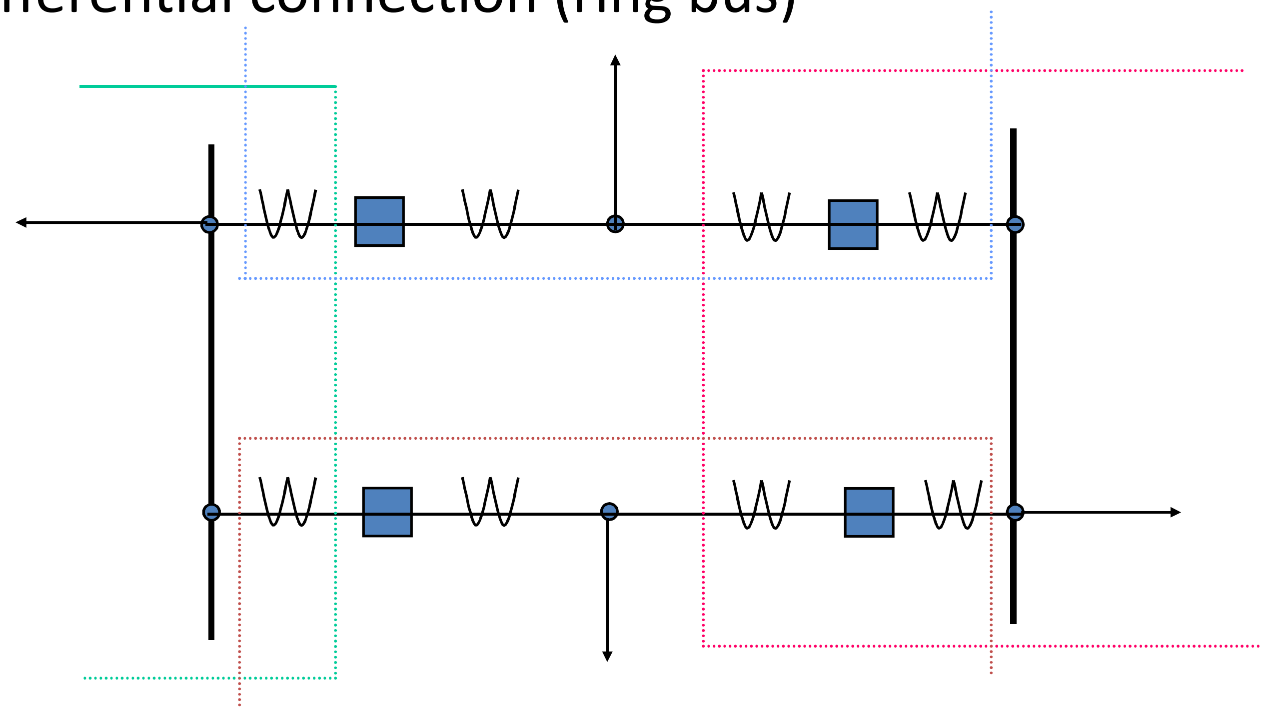
Busbar Protection

Bus differential connection (main and transfer bus)



Busbar Protection

Bus differential connection (ring bus)



NOTE: No bus differential protection is needed. The busses are covered by line or transformer protection.

Busbar Protection

Two Busbar Protection Schemes:

- Low Impedance - using time overcurrent relays
  - ✓ inexpensive but affected by CT saturation.
  - ✓ low voltage application; 34.5kV and below

- High Impedance - using overvoltage relays (*this scheme loads the CTs with a high impedance to force the differential current through the CTs instead of the relay operating coil*.)
  - ✓ expensive but provides higher protection security.
  - ✓ 115kV and above voltage application or some 34.5kV bus voltages which require high protection security.

Transmission Line Protection

Transmission Line Protection

- Distance Protection
- Over Current Protection
- Differential Protection.
- Main and Back up Protection

Distance Relay Protection

- The basic principle is that the apparent impedance seen by the relay reduces drastically in case of line fault.
- If the ratio of apparent impedance to the positive sequence impedance is less than unity, it indicates a fault.
- This protection scheme is inherently directional.
- Impedance relay and Mho relay use this principle.

Distance Relay Protection

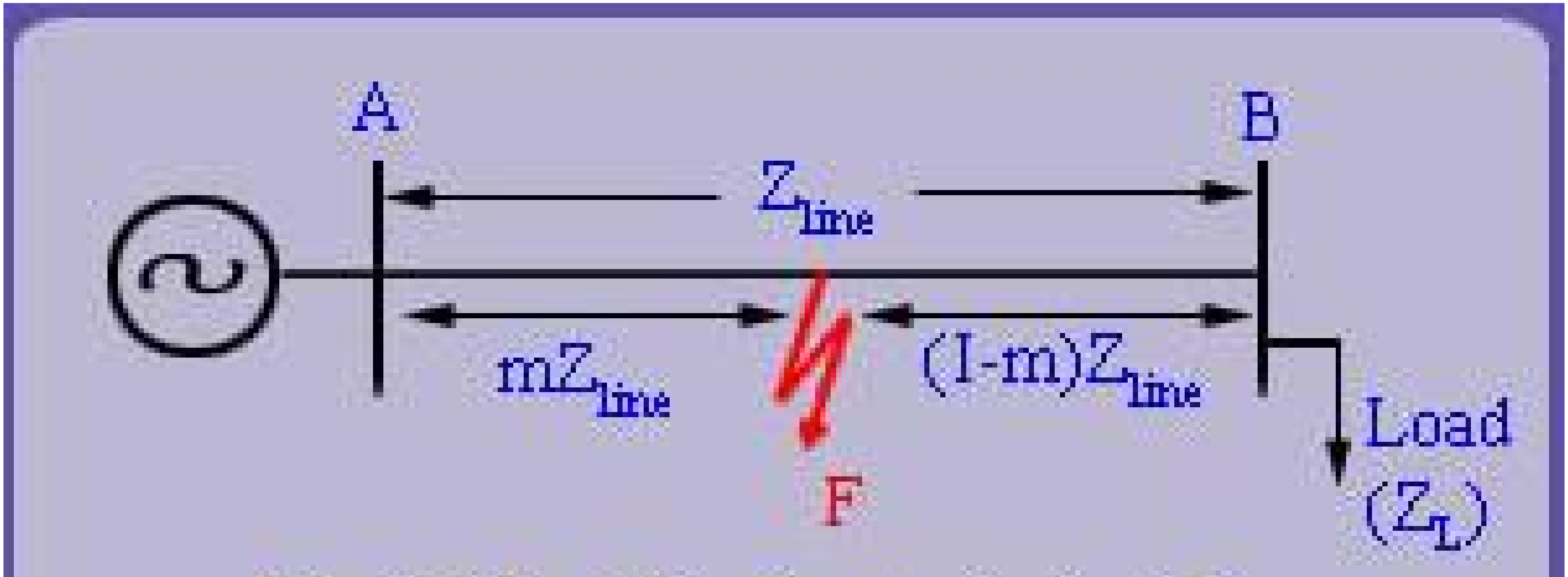


Fig 2.3 Fault in Transmission Line

Over Current Relay Protection

Principle of Over current Protection

- When the current in a system exceeds a predetermined value, it indicates the presence of a fault.
- Relaying decision is based solely on the magnitude of current.
- Over current relaying and fuse protection uses this principle
- Used in radial distribution systems.

Over Current Relay Protection

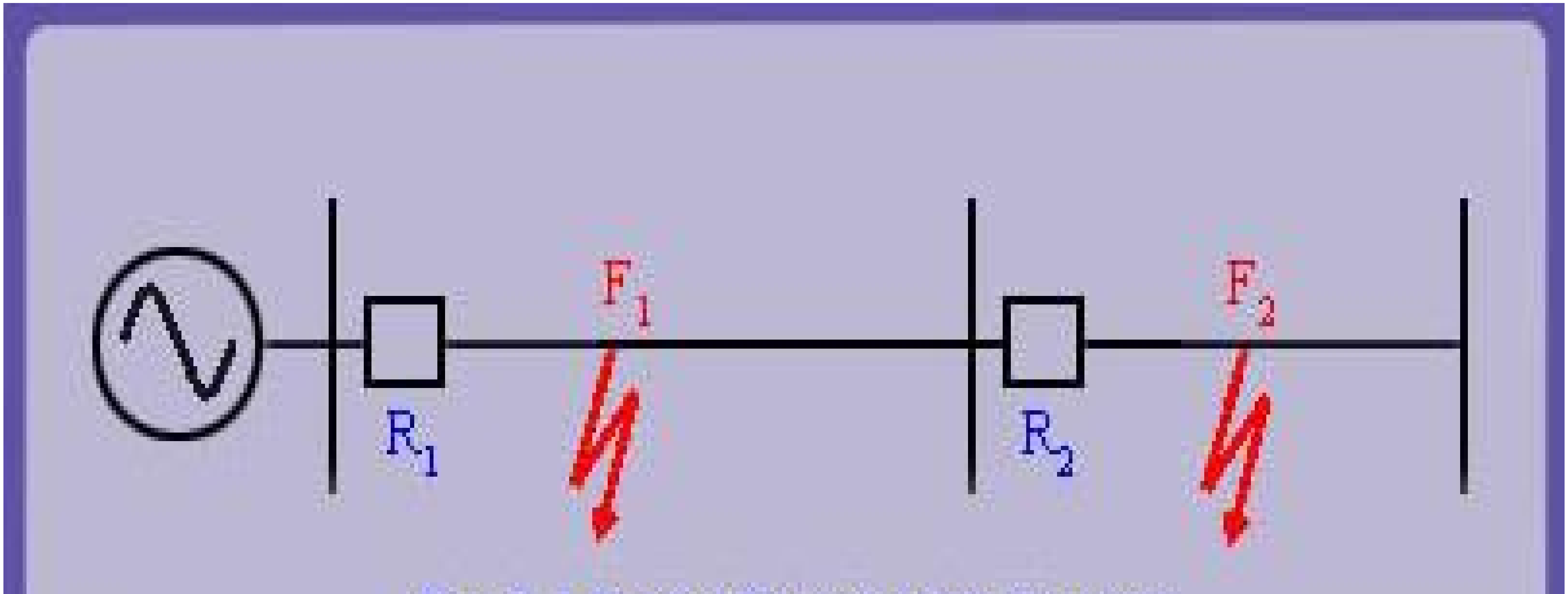


Fig 2.1 Radial Distribution System

Directional Over Relay Protection

- Directional Over current Protection Uses both magnitude of current and phase angle information for decision making.
- Used in radial distribution systems with source at both ends

Directional Over Relay Protection

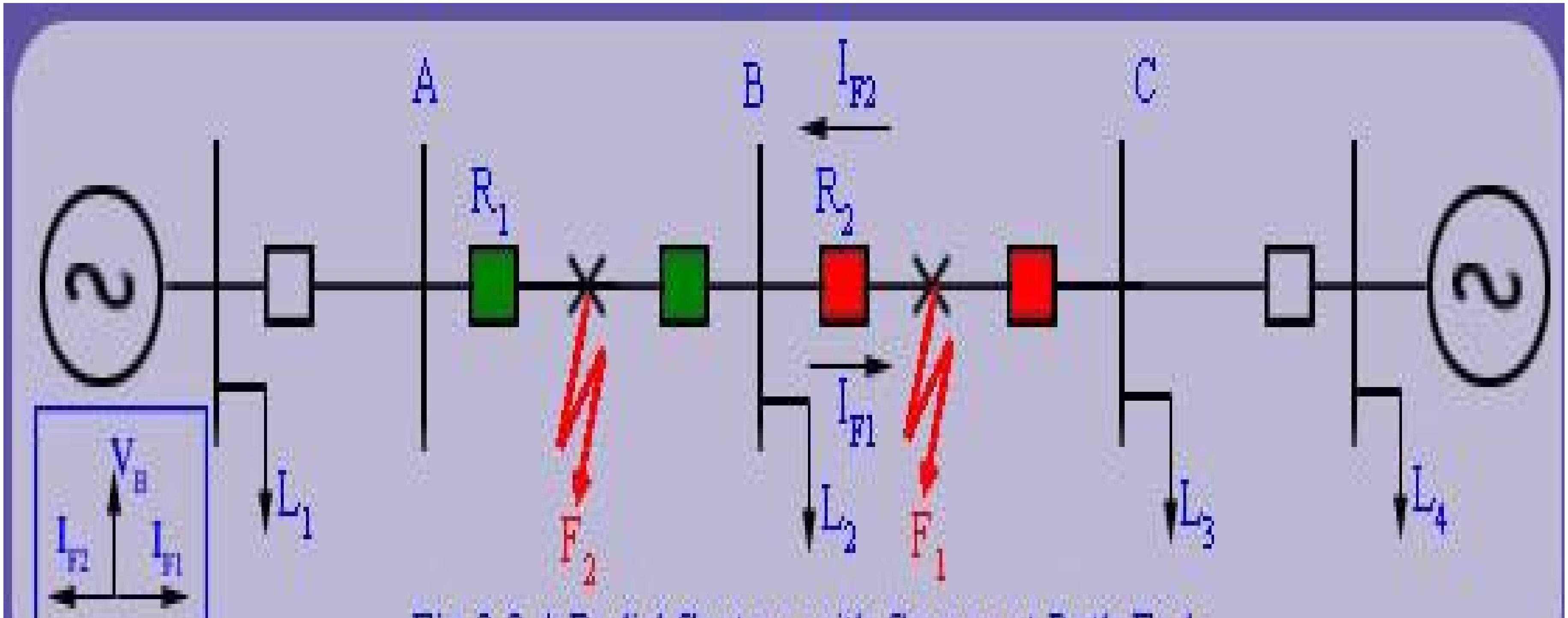


Fig 2.2 A Radial System with Source at Both Ends

Differential Relay Protection for Transmission Line

- By comparing the two currents either in magnitude or in phase or in both, fault can be determined.
- Its implementation requires a communication channel.
- It is extremely accurate.
- Its zone is demarkated by CTs

Differential Relay Protection for Transmission Line

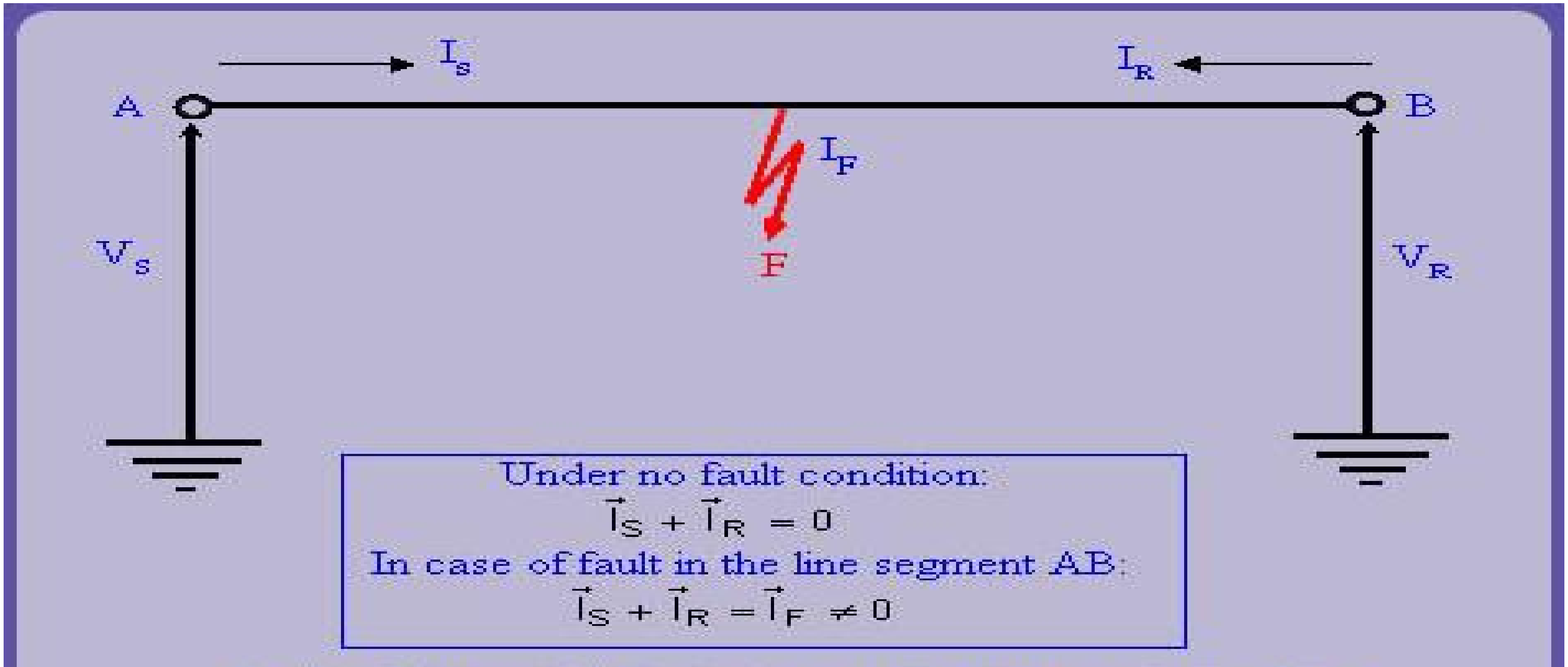


Fig 2.6 Differential Protection of Short Transmission Line

CT,PT & their applications in protective schemes

Current and Voltage Transformers in Protective Relaying System

- Protective Relays in A.C. Power Systems are connected from the secondary circuits of C.T. & P.T.
- Current Transformers : C.T. are used for measurement and Protection. Its step down the current from high value to low current value. Their ratio is constant for given range of Primary & Secondary Current.
- Potential Transformer : P.T. are used for measurement and Protection. Its step down the high voltage to low voltage value. The ratio is constant for given range of Primary and Secondary voltage.

Current Transformers

Current Transformer (CT) :

A device which transforms the current on the power system from large primary values to safe secondary values. The secondary current will be proportional (as per the ratio) to the primary current.

Potential Transformers

Potential Transformer (PT):
A device which transforms the voltage on the power system from primary values to safe secondary values, in a ratio proportional to the primary value.

UNIT 4

STATIC RELAYS & NUMERICAL PROTECTION

Presented by
C.GOKUL,AP/EEE
Velalar College of Engg & Tech , Erode

UNIT-4 Syllabus **STATIC RELAYS & 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.

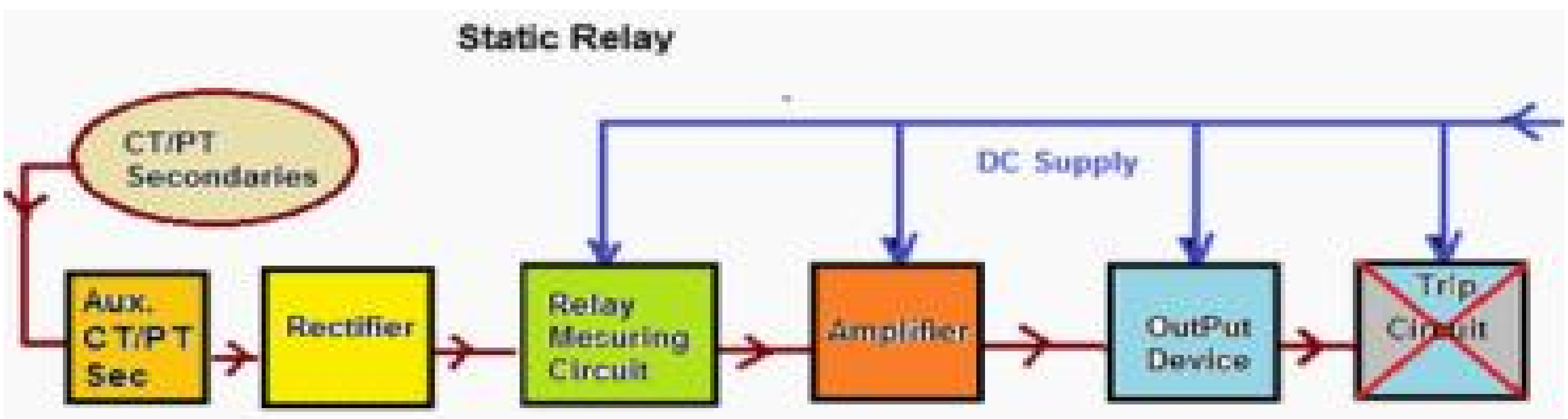
Static Relay

Refer Book for Detail Study

- The **<u>static relay</u>** is the next generation relay after electromechanical type.
- The Solid Static relays was first introduced in 1960's. The term '***static***' implies that the relay ***has no moving mechanical parts*** in it.
- Compared to the Electromechanical Relay, the Solid Static relay has ***longer life-span, decreased noise*** when operates and faster respond speed.
- The static relays have been designed to replace almost all the functions which were being achieved earlier by **electromechanical relays**.

Principle of operation

- The essential components of static relays are shown in figure below. The output of CT and PT are not suitable for static components so they are brought down to suitable level by auxiliary CT and PT. Then auxiliary CT output is given to rectifier.
- Rectifier rectifies the relaying quantity i.e., the output from a CT or PT or a Transducer.



- The rectified output is supplied to a measuring unit comprising of comparators, level detectors, filters, logic circuits.
- The output is actuated when the dynamic input (*i.e., the relaying quantity*) attains the threshold value. This output of the measuring unit is amplified by amplifier and fed to the output unit device, which is usually an electromagnetic one.
- *The output unit energizes the trip coil only when relay operates.*

Advantages of Solid State Relay

- Low Weight
- Arc less switching
- Static Relay burden is less than electromagnetic type of relays. Hence error is less.
- Fast response.
- Long life
- Less power consumption
- More Accurate compared to electromechanical Relay

Disadvantages

1.Reliability cannot be predicted

2.Construction is not very robust.

3.Easily affected by surrounding interference.

4.Auxiliarty DC supply is required

5,.Affected by voltage transients.

Applications

1.Ultra high speed protection of EHV AC transmission lines utilizing distance protection.

2.In over current and earth fault protection schemes

3.As main element in differential relay

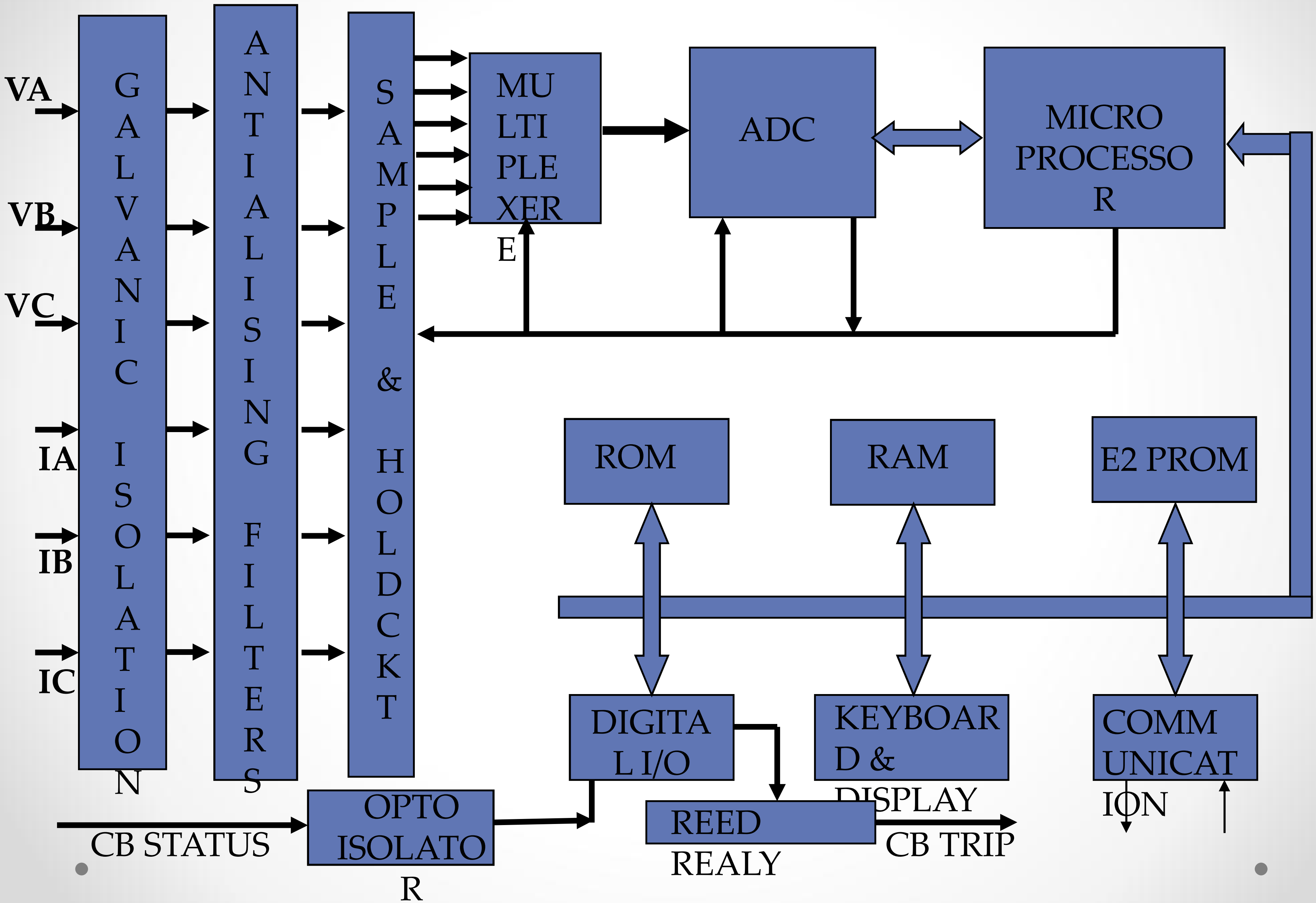
NUMERICAL RELAY

Refer Book for Detail Study

Fundamental requirements of numerical relay

- SPEED
- SENSITIVITY
- RELIABILITY
- SELECTIVITY
- SIMPLICITY
- ECONOMY

TYPICAL NUMERICAL RELAY HARDWARE



RELAY HARDWARE STRUCTURE

- GALVANIC ISOLATION MODULE :

  CONVERTS CURRENT SIGNAL TO VOLTAGE & ELECTRICALLY ISOLATES THE SIGNAL BETWEEN DIGITAL & ANALOGUE CIRCUIT.

- ANTIALIAS FILTERS :

  SAMPLING FREQUENCY SHOULD BE MORE THAN TWICE THAT OF HIGHEST FREQUENCY OF INTEREST.

- SAMPLE & HOLD CIRCUIT :

  ANALOGUE TO DIGITAL CONVERSATION REQUIRES SOME FINITE TIME(25µS). THIS CKT HOLDS THE SIGNAL FOR PROPER CONVERSATION.

- MULTIPLEXER :
  USES A SINGLE MICROPROCESSOR ANALOGUE MULTIPLEXER FOR SEQUENTIAL SELECTION OF SIGNALS

- A/D CONVERTER:
  CONVERTS TO DIGITAL SIGNALS FOR HANDLING IN MICROPROCESSOR.

- MICROPROCESSOR :
  DIGITAL SIGNAL HANDLED FOR ALGORITHMS & SCHEME LOGIC FUNCTION.

- ROM :
  CONTAINS THE RELAYING PROGRAMME

- RAM :
 USED FOR STORING SAMPLED QUANTITIES & INTERMEDIATE PRODUCTS IN RELAYING ALGORITHMS.

- E^2PROM :
 USED FOR STORING RELAY SETTINGS.

- KEYBOARD & DISPLAY :
 Used for change in settings & display functions.

- DIGITAL I/O :
 Device takes the breaker status through opto isolators & issues trip commands through reed relays.

- COMMUNICATION :

  Helps to communicate with other relays or with the system.

- POWER SUPPLY :

  In built switching mode power supply modules are used for quality aux. supply.

Advantages of numerical relay

- Flexibility in wide parameter adjustment.
- Programmable function setting
- Multiple functions by the same relay
- Internal fault diagnosis.
- Memory & recording function
- Programmable ct & pt ratio
- Digitally communication facility

Disadvantages of numerical relays

- High initial cost
- Requires stable power supply.
- If used for multifunction in a single feeder, failure of relay may cause total protection failure for the equipment.
- Requires emc environment.

Applications

- Control a high-voltage circuit with a low-voltage signal, as in some types of modems or audio amplifiers,
- Control a high-current circuit with a low-current signal, as in the starter solenoid of an automobile
- Detect and isolate faults on transmission and distribution lines by opening and closing circuit breakers (protection relays)

CONCLUSION

Numerical relays need to be incorporated in the design stage of the plant which will help to

- reduce the panel size.
- Panel wiring cost.
- Population of relays in the plant.
- Meet space constraints.
- Reduce the quantum of spares.

Comparisons of Different type of Relays

Characteristic	Electro-mechanical	Static	Micro-processor based	Micro-Controller based	Numerical
Speed of response	Slow	Fast	Fast	Fast	Very Fast
Timing Accuracy	Temp. Dependant	Temp. Dependant	Stable	Stable	Stable
Size	Bulky	Small	Small	Small	Very Compact
Draw-out required	Required	Required	Not required	Not required	Not required
CT Burden	High	Low	Low	Low	Low
Reset Time	Very High	Less	Less	Less	Less
Functions	Single function	Single function	Multi function	Multi function	Multi function
Maintenance	Frequent	Frequent	Low	Low	Very Low
Deterioration due to frequent operations	Yes	No	No	No	No
Reliability	High	Low	Low	High	High
SCADA Compatibility	No	No	Possible	Possible	Yes

Transformer differential protection

Refer Book

Refer Book

DIFFERENTIAL PROTECTION

Simple over current protection cannot define a distinct zone

Thus cannot provide instantaneous protection for the entire protected zone

Differential protection provides instantaneous protection for entire protected zone

Its thus also called as unit protection

Unit protection cannot provide back-up protection for adjacent zones

Differential protection

Refer Book

Why Needed ? - Overcomes application difficulties of simple overcurrent relays when applied to complex networks, i.e. co-ordination problems and excessive fault clearance times.

<u>Basic Principle</u>

Involves measurement of current at each end of zone

and

Operate when there is a difference between them

Thus protection would operate for faults inside the protected zone but will remain stable for faults outside the protected zone. Thus can be instantaneous in operation.

Refer Book

Differential protection application

Transformer windings

Generator Stator winding

Generator & Generator transformer overall

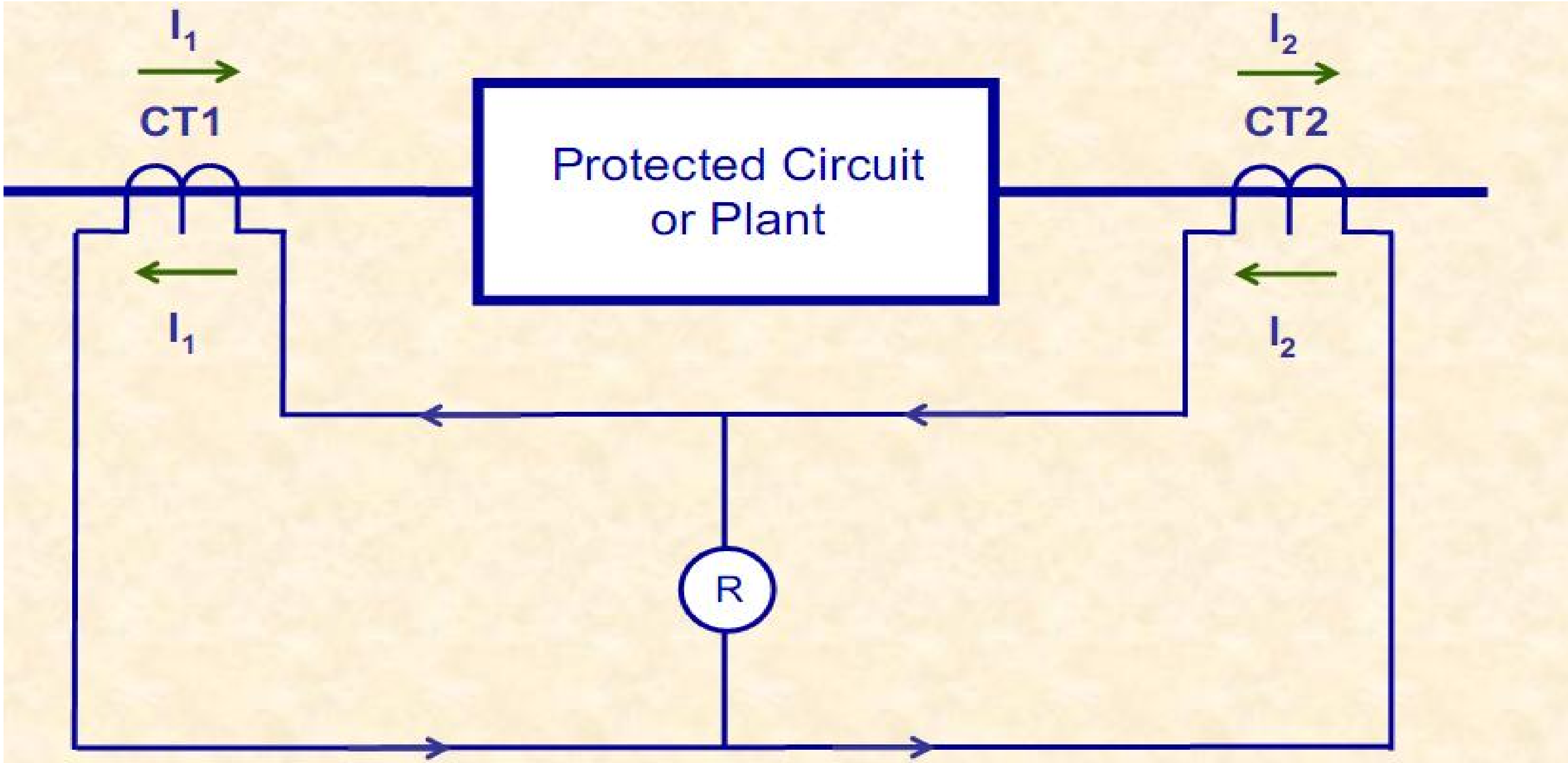
Busbar

Feeders (transmission and distribution)

Shunt Reactors

Large motors

Refer Book



Boundaries of protection coverage accurately defined

Protection responds only to faults in protected zone

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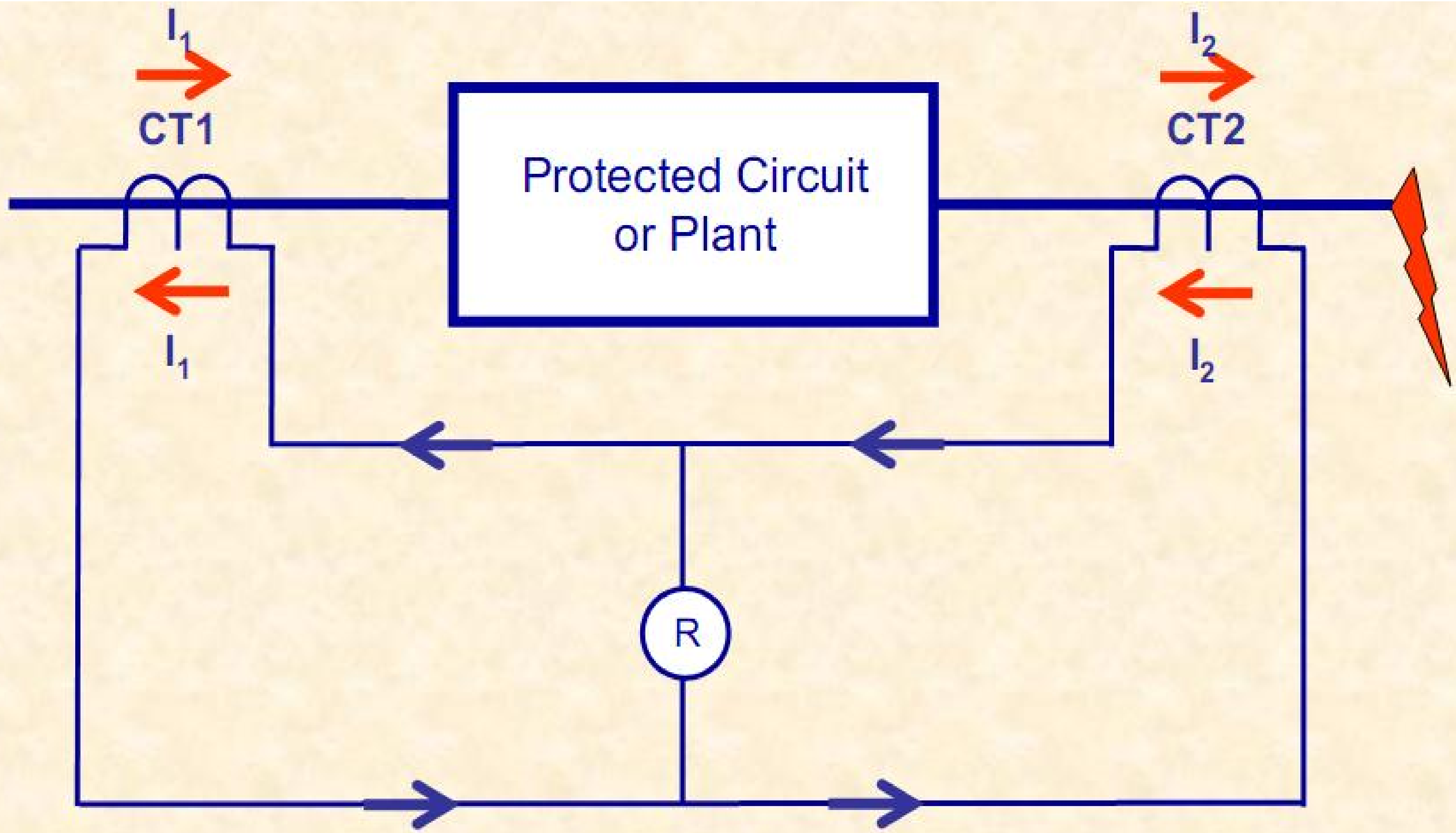
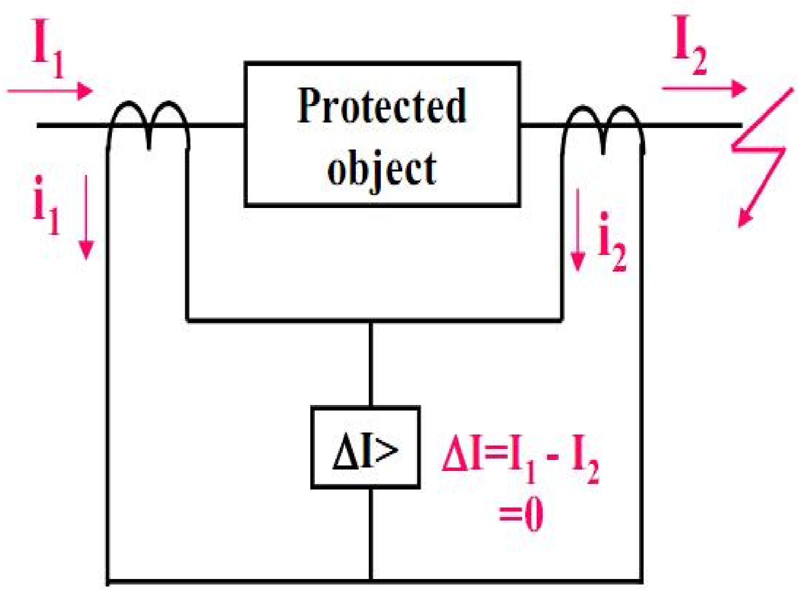


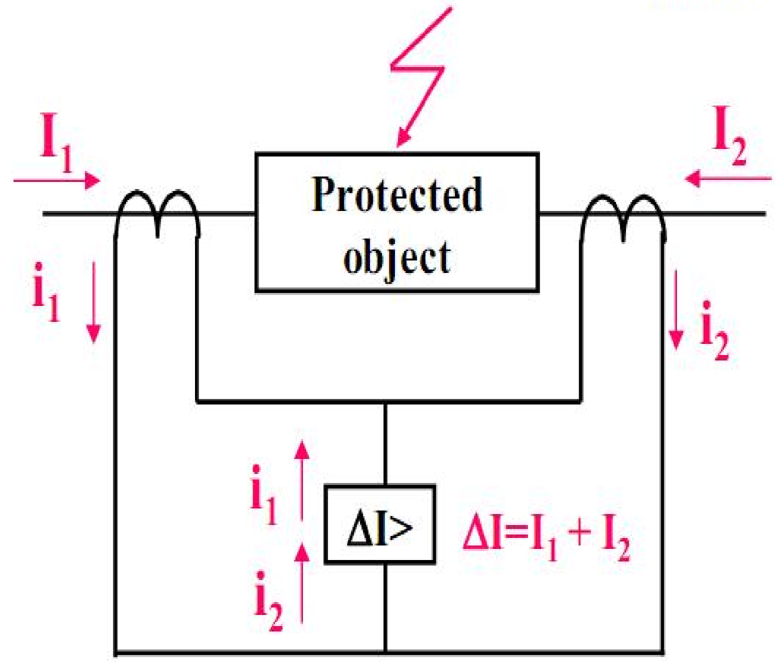
- Boundaries of protection coverage accurately defined
- Protection responds only to faults in protected zone

Refer Book

current



External fault or load
(Through flowing current)



Internal fault

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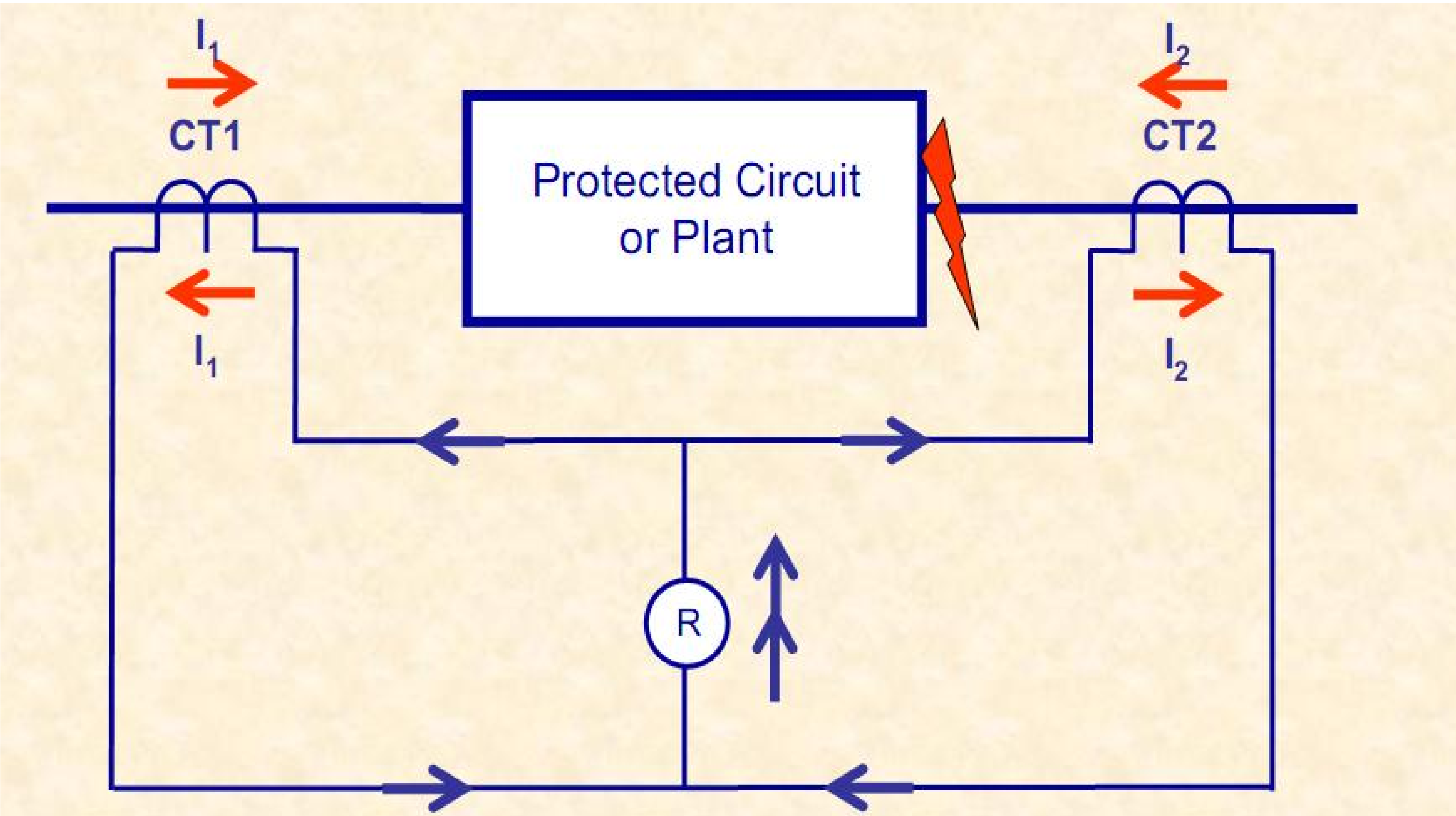


- Boundaries of protection coverage accurately defined

Refer Book

Steady state spill current during load

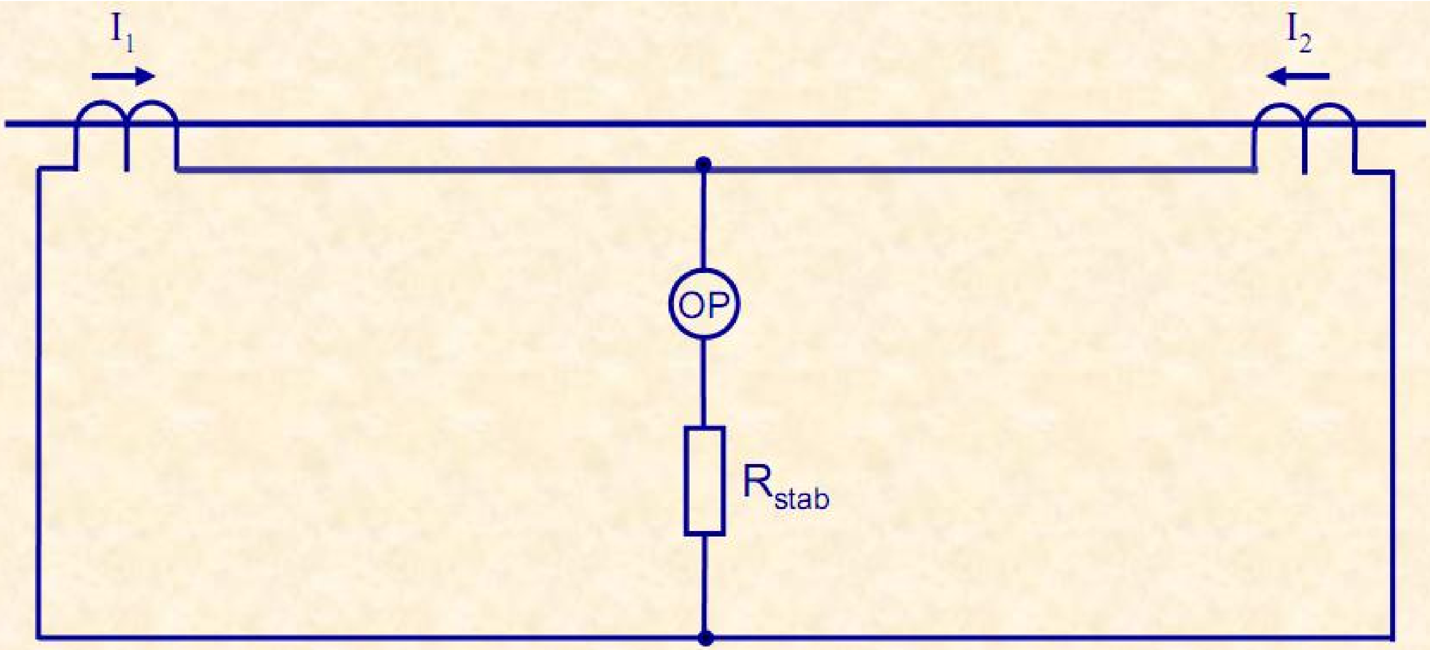
- Difference in current transformer magnetizing characteristics
- Leakage / charging current of the plant (line, cable, etc..)

Spill current during external faults

- Difference in current transformer magnetizing characteristics
- Current transformer saturation

Distance between the two end CTs

Refer Book



<u>Measurement</u>

- $I_{diff} = |I_1 + I_2|$

Stability provided by Stabilizing resistor (High impedance path)

INTRODUCTION

- Transformers are a critical and expensive component of the power system. Due to the long lead time for repair and replacement of transformers, a major goal of transformer protection is limiting the damage to a faulted transformer.
- Numerical relay protection of transformer is an advanced method of protection.
- The main aim of this project is to protect the transformer from the faulty conditions with in a short span of time.
- The type of protection for the transformers varies depending on the application of the transformer.

- DIFFERENTIAL PROTECTION:
- Differential protection is a unit-type protection for a specified zone or piece of equipment. It is based on the fact that it is only in the case of faults internal to the zone that the differential current (difference between input and output currents) will be high. However, the differential current can sometimes be substantial even without an internal fault. This is due to certain characteristics of current transformers (different saturation levels, nonlinearities) measuring the input and output currents, and of the power transformer being protected.
- It is based on the fact that any fault within an electrical equipment would cause the current entering it to be different from the current leaving it.
- By comparing the two currents either in magnitude or in phase or in both, fault can be determined.

NEED FOR PROTECTION:

- Transformer is an extream device in power system which has 99.99% of efficiency. Improved power transformer protection using numerical relays, Large power transformers belong to a class of very expensive and vital components in electric power systems.
- If a power transformer experiences a fault, it is necessary to take the transformer out of service as soon as possible so that the damage is minimized.
- The costs associated with repairing a damaged transformer may be very high. So there is a necessity of protection of transformer.

NEED FOR PROTECTION:

- Here in this project numerical Relay (Microprocessor Relay) plays a vital role to protect the large rating of power transformers.
- Fault detection and correction is necessary for the safe operation of transformer.
- Protection of large power transformers is perhaps the most challenging problem in the power system relaying.
- Here we are using numerical relay for the protection of Power Transformer.

WORKING:

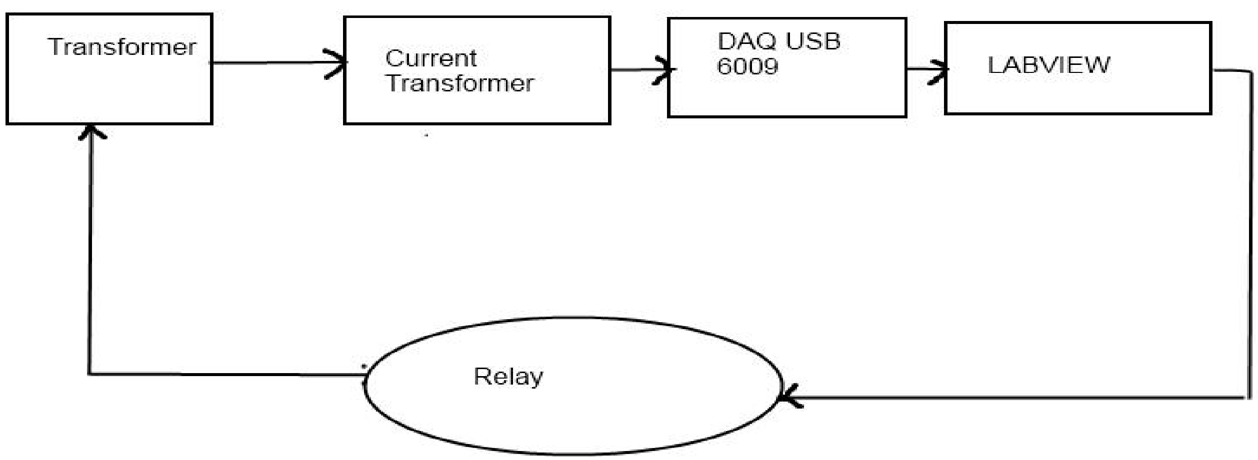
OVER LOADING PROTECTION:

- Initially the transformer is operated under normal condition the relay operation is absent.
- The transformer has a maximum safe current rating value for certain load, if the load is increased on the transformer then the load current is also increased.
- If the load current is exceeds the maximum rated current of the transformer then the relay will operate and the transformer is isolate from the main supply.

DIFFERENTIAL PROTECTION:

- At normal operating condition the differential currents of CTs is zero. So here in this case the differential relay will not operate. As we know that the differential relay is operate only for internal fault condition.
- If the fault occurred in internal zone(between transformer and CTs) then a differential current flows in the relay, the relay is tripped and isolate the transformer from the mains.

BLOCK DIAGRAM:



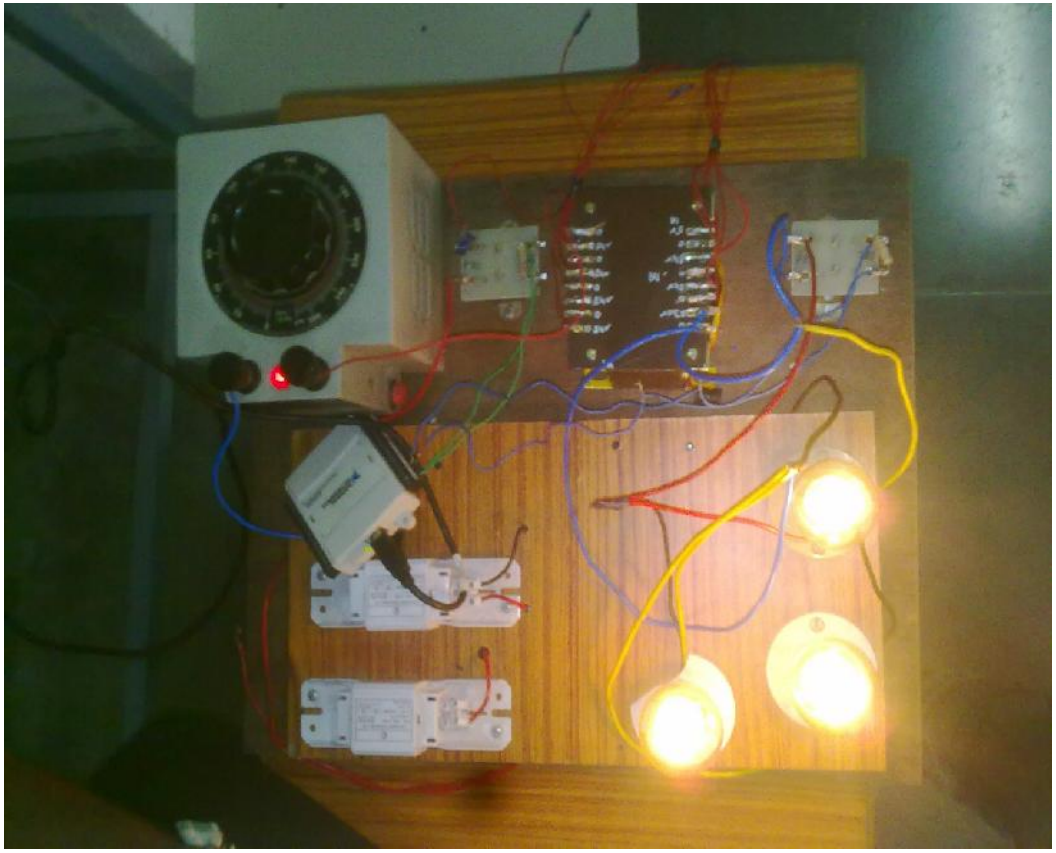
COMPONENTS USED:

- Potential transformer(24/230v, 1A)
- Current transformer
- Auto transformer (0 to 270v)
- Data acquisition (DAQ USB-6009)
- Resistive load (15w bulb -2, 60w bulb -1)

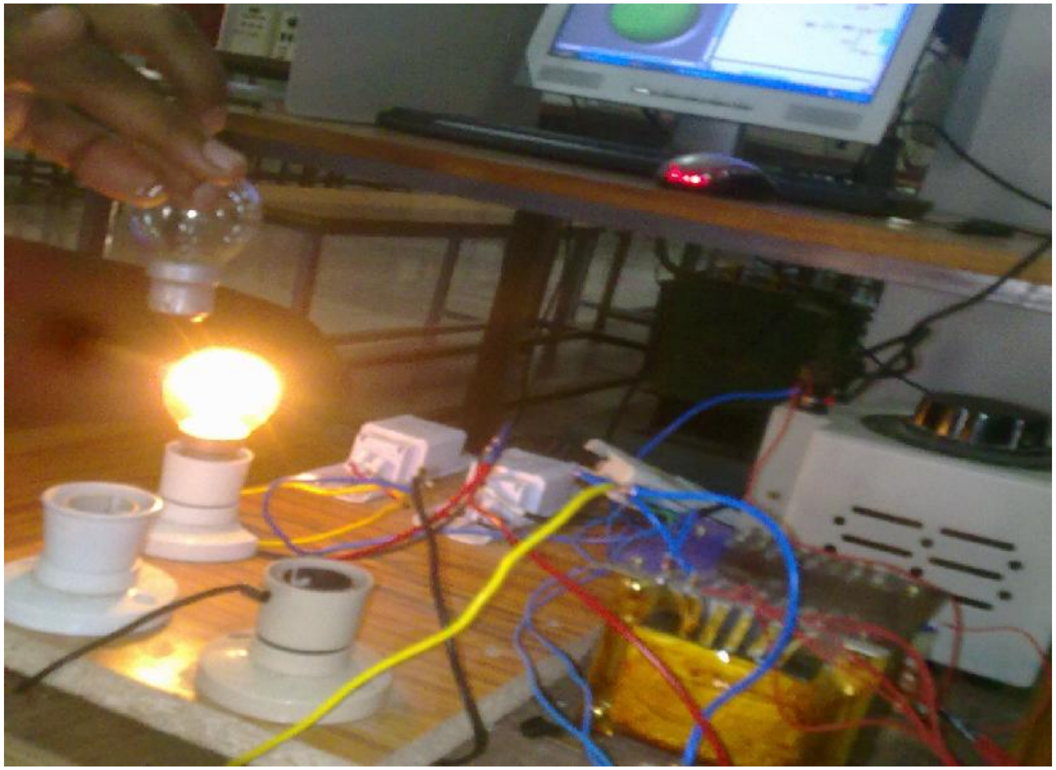
▪ RESULTS:

- When ever the fault occured on transformer the relay will trip.
- Numerical relay protection is a very fast acting,when comparing with other protection schemes.
- The output results are shown in figures.

Normal operating condition

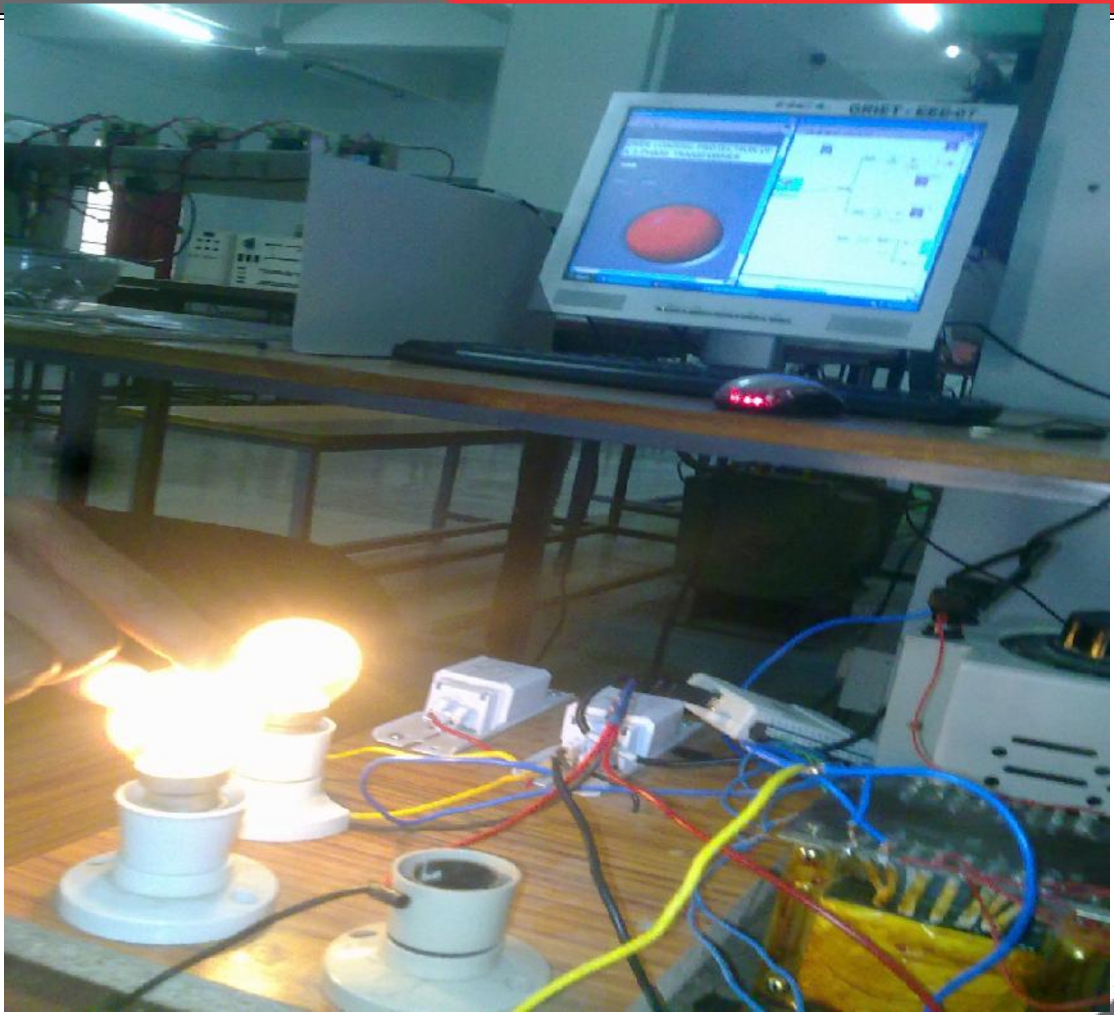


Over loading condition



Before internal fault

Numerical Relay Protection Of Transformer



Internal fault condition

ADVANTAGES:

1.It is the simplest form of transformer protection.

2.It detects the incipient faults at a stage much earlier than is possible with other forms of protection.

DISADVANTAGES:

3.It can only be the used with oil immersed transformer equipped with conservator tanks.

4.The device can detect only faults below oil level in the transformer. Therefore, separate protection is needed for connecting cables.

CONCLUSION:

Relay control output circuits of a much higher power.

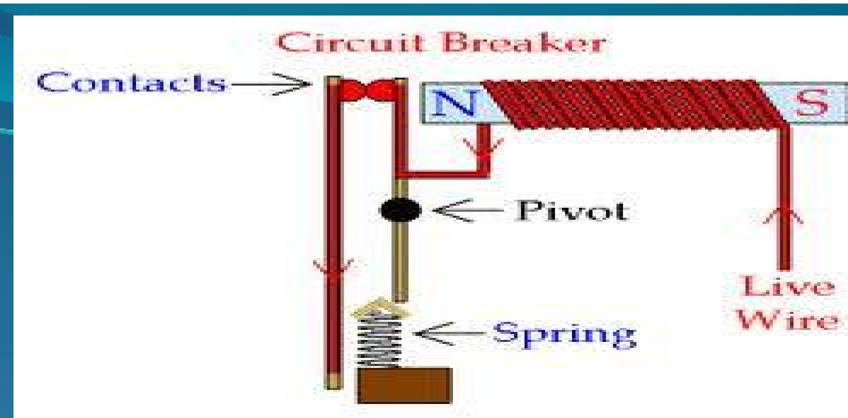
- Safety is increased.
- Protective relays are essential for keeping faults in the system isolated and keep equipment from being damage.

- **SCOPE:**

- This project aimed at providing protection to the transformer from numerical relay. This project can be used for many faults which are sensed by current.
- For overload protection of transformers this project is to be modified by using numerical relay. The actual operating current of transformer is monitored continuously and that is compared with the safe value of current limit.
- This project not only provides overload protection but also provides different charecteristics protection of transformer protection over wide range of faults whose presence can be known by numerical relay.

Distant protection of transmission lines

Refer Book



CIRCUIT BREAKERS

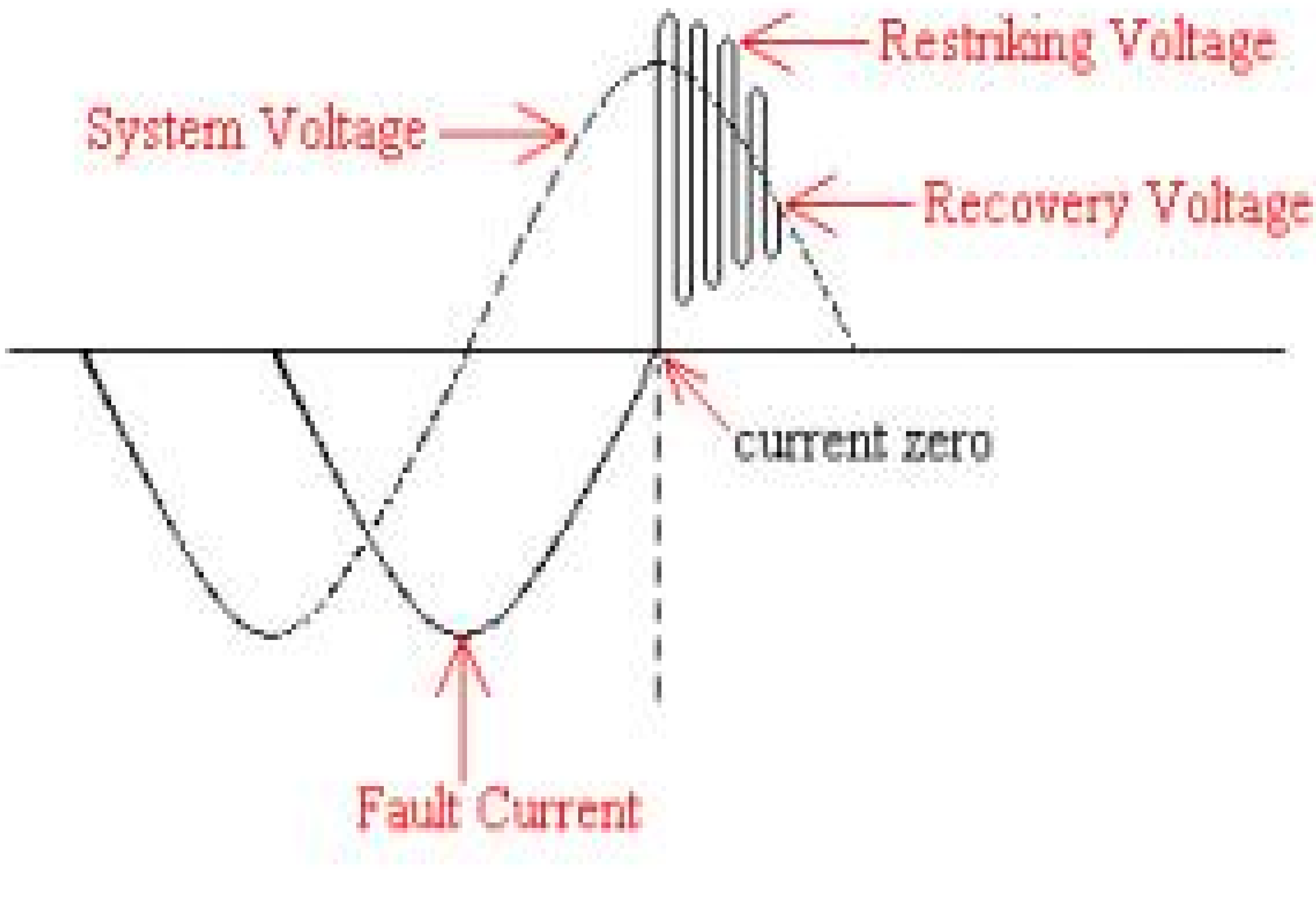
UNIT 5

CIRCUIT BREAKERS

Presented by
C.GOKUL,AP/EEE
Velalar College of Engg & Tech , Erode

Unit-5 Syllabus: 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
  - Vacuum circuit breakers
- Comparison of different circuit breakers
- Rating and Selection of Circuit breakers.



Restriking Voltage
System Voltage
Recovery Voltage
current zero
Fault Current

The ARC

The electric arc constitute a basic ,indispensable and active element in the process of current interruption.

1.Basic theory of electric discharge

The conduction of electricity is through the gases or vapors which contain positive and negative charge carriers and all types of discharge involve the very fundamental process of production ,movement & absorption of these carriers which is the mode of carrying the current between the electrodes. The gas discharge phenomena can broadly classified as:

a. The non-self sustained discharge

b. The self sustaining discharges

Initiation of an Arc

- By high voltage gradient at the cathode resulting into field emission.

- By increase of temperature resulting into thermo ionic emission

Maintenance of Arc

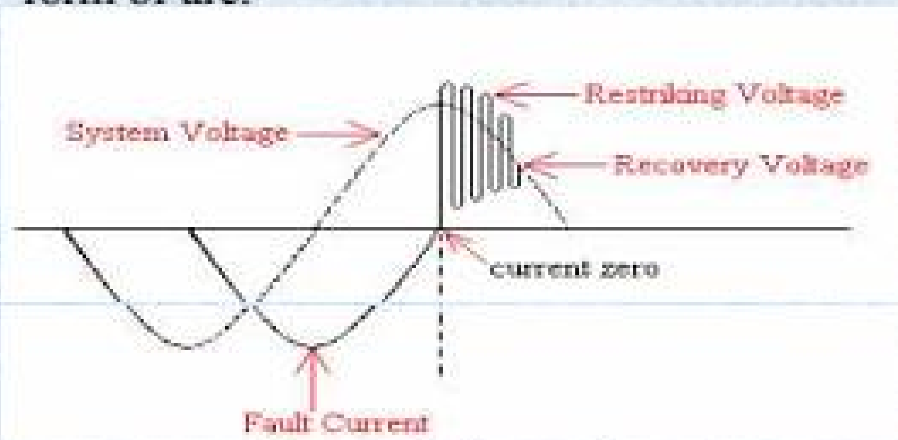
- High temperature of the medium around the contacts caused by high current densities, with high temp the kinetic energy gained by moving electrons increased.
- The field strength or volt. gradient which increases the kinetic energy of the moving electrons and increases the chances of detaching electrons from neutral molecule.
- An increase in mean free path-the distance through which the electron moves freely.

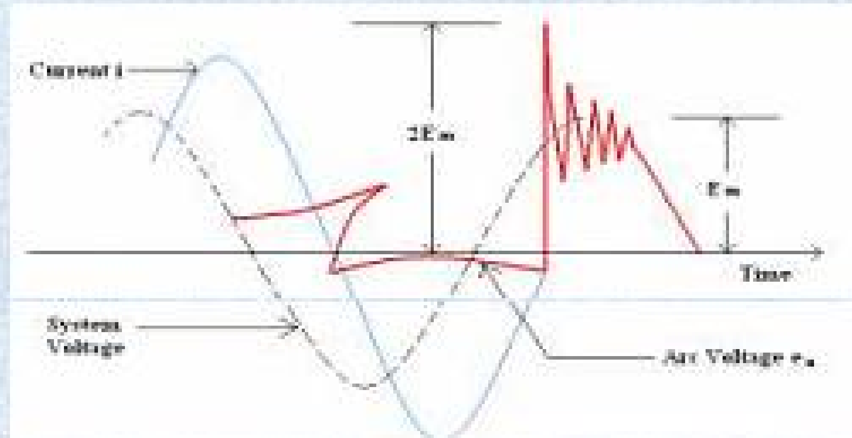
ARC VOLTAGE

The voltage that appears across the contacts of circuit breaker during the arcing period is known as arc voltage. It tends to maintain the current flow in the form of arc.

RESTRIKING VOLTAGE

It's the transient voltage that appear across the contacts at or near current zero during arcing Period.





RECOVERY VOLTAGE

It's the normal frequency voltage (rms) that appear across the contacts of circuit breaker after final arc extinction. It is approximately equal to the system voltage. When contacts are opened current drops to zero at every half cycle. At current zero dielectric strength of the medium can be increased and thus prevent the break down by restriking voltage. Consequently the final arc extinction takes place and circuit current is interrupted. After this current interruption the voltage appearing across the contacts is known as recovery voltage

CURRENT CHOPPING

•It is the phenomenon of circuit interruption before the natural current zero is reached.

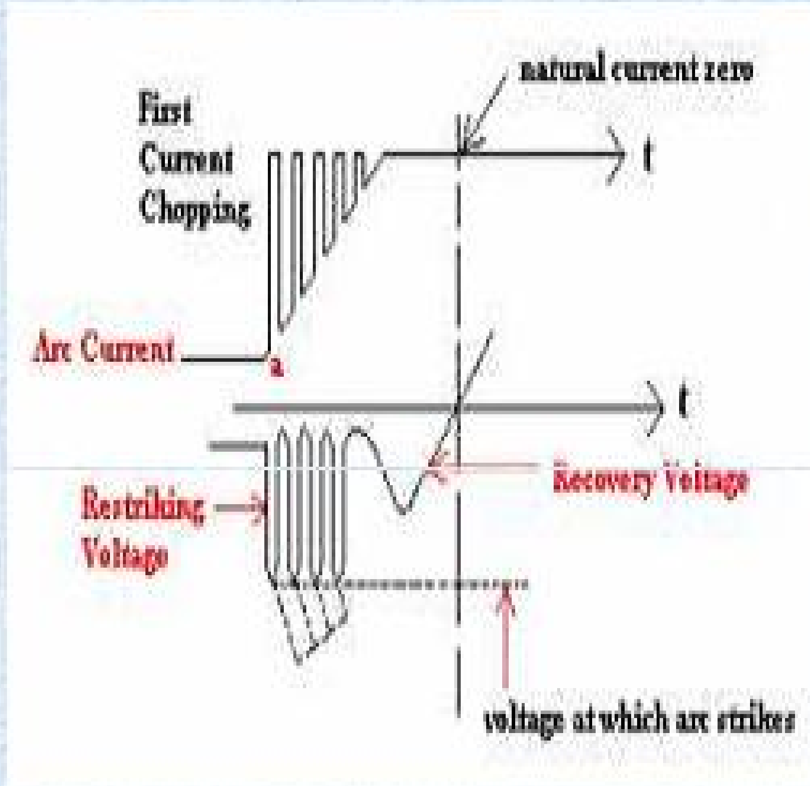
•It mainly occurs in air blast circuit breakers because they retain the same extinguishing power irrespective of the magnitude of current to be interrupted.

•

The powerful deionising effect of air blast causes the current to fall abruptly to zero well before the natural current zero is reached.

•This phenomenon is known as current chopping and results in high voltage transient across the contacts of the circuit breaker.

•The arc current *i* is chopped down to zero value as shown by point

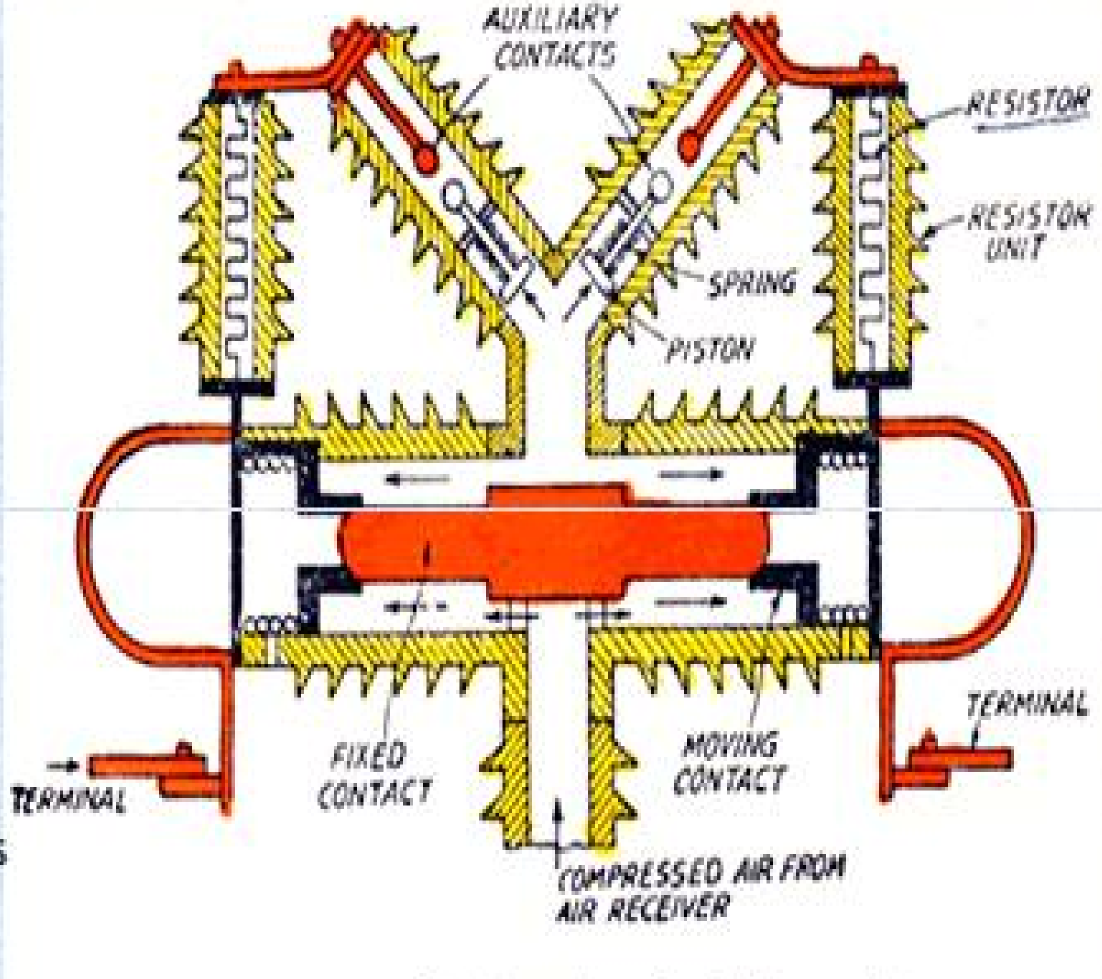


Resistance Switching

•The post zero resistance of contact space is high in air blast circuit breakers.

•This is because the contact clearance space is filled with high pressure air after final current zero and high pressure air has high dielectric strength.

•The high restriking voltage appears across the contacts does not damp out through the gap because of the high post zero resistance.



Configuration of switching resistors.

Methods of Arc Extinction

- High resistance method
  - a. cooling of arc
  - b. increasing the arc length
  - c. reducing the cross section of arc
  - d. splitting of arc
- Low resistance or current zero interruption
  - a. Lengthening of the gap
  - b.increasing the pressure in the vicinity of the arc
  - c. Cooling
  - d. Blast Effect

Phenomenon of arc extinction

- Energy Balance or Cassie Theory

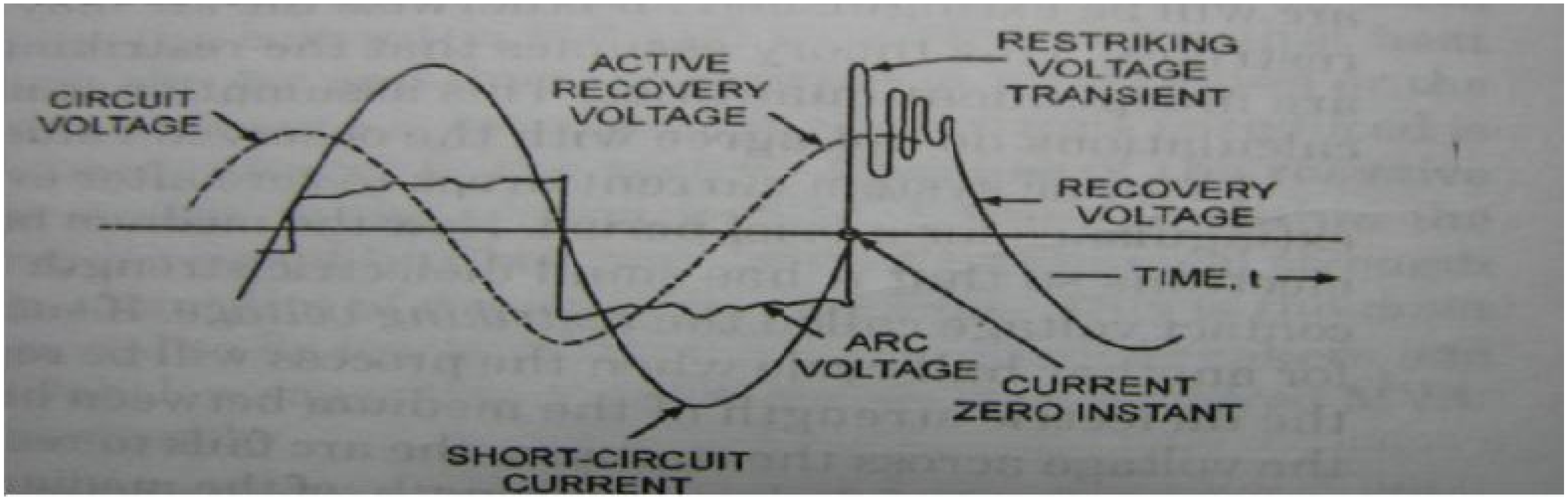
  This theory states that if the rate of heat dissipation between the contacts is greater then the rate at which heat is generated ,the arc will be extinguished ,otherwise it will restrike.

- Recovery rate or Slepian’s Theory

  This theory states that if the rate at which the ions and electrons combine to form or replaced by neutral molecules.

Restriking Voltage & Recovery Voltage

- The transient voltage which appears across the breaker contacts at the instant of arc being extinguished is known as restriking voltage.
- The power frequency rms voltage ,which appears across the breaker contacts after the arc is finally extinguished and transient oscillation die out is called recovery voltage.



Arc Extinction

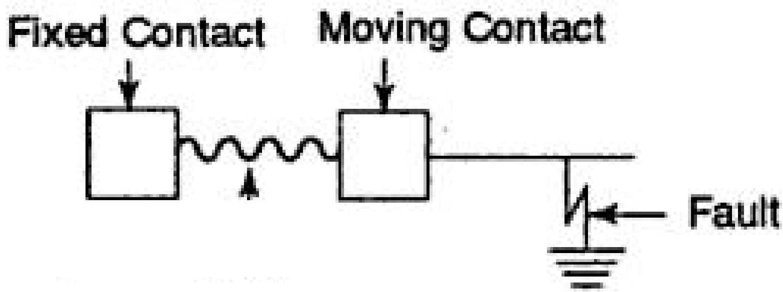


FIGURE 9.1 Separation of the contacts of circuit breaker

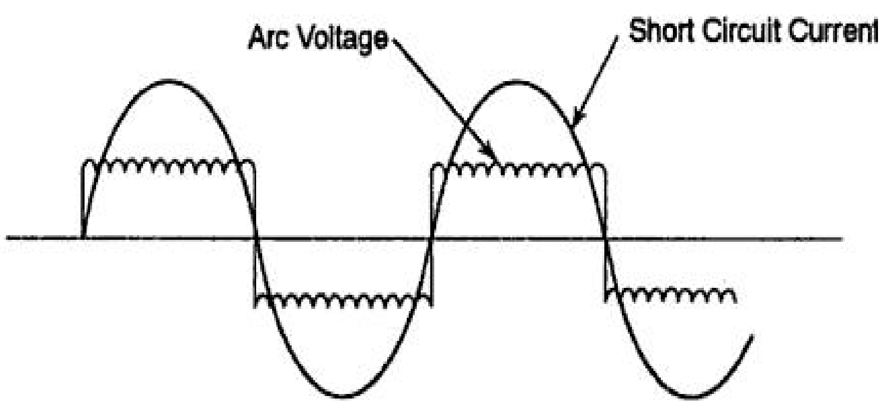


FIGURE 9.2 Short circuit current and arc voltage

Arc Voltage:

The Voltage drop across the arc is called **Arc Voltage**.

Arc Quenching: (C.B)

- The Arc Produced not only delays the current interruption process but it also generates enormous heat which may cause damage to the system or to the circuit breaker itself.
- Therefore main problem in a C.B is to extinguish the arc within the shortest possible time so the heat generated by it may not reach a dangerous value.

ARC PHENOMENON

During arcing period, the current flowing between the contacts depends upon the resistance. The greater resistance smaller the current that flows between the contacts.

The arc resistance depends upon

i) Degree of ionisation (Arc resistance increases with the decrease in number of ionised particles b/w the contact)

ii) Length of Arc (Arc resistance increases with the length of arc)

iii) Cross section of Arc (Arc resistance increases with the decrease in X- section of the arc)

The factors that are responsible for maintenance of arc between the contacts are:

i) Potential Difference between the contacts.

ii) ionised particles between the contacts.

Methods of Arc Interruption

- There are two methods of Arc Interruption or Extinction are

  i) High resistance interruption

  ii) Current zero interruption

High resistance interruption

The arc resistance can be increased by cooling, lengthening, reducing x- section and splitting the arc.

It is employed for low power AC and DC circuit breakers.

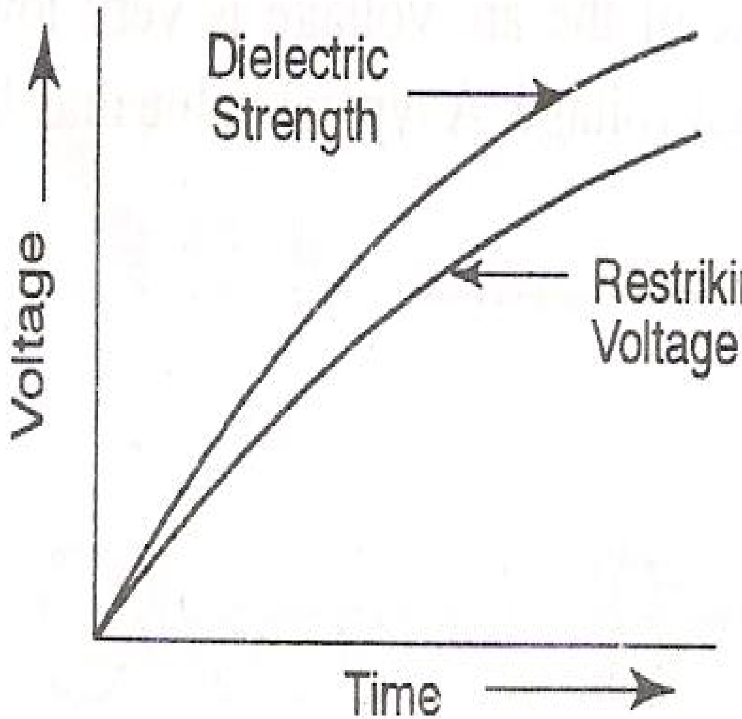
Current zero interruption

There are two theories to explain the zero current interruption of the arc.

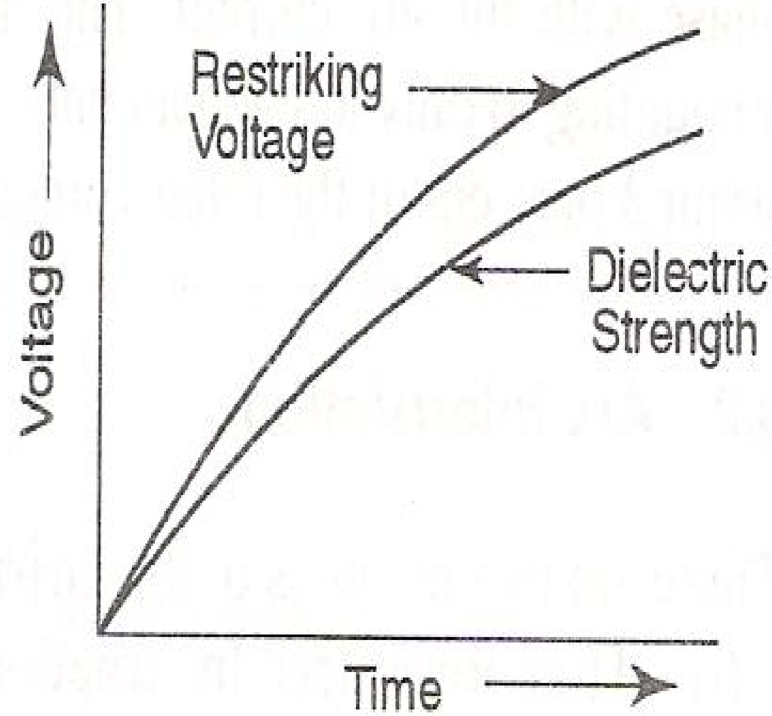
i) Recovery rate theory(Slepain's Theory)

ii) Energy balance theory(Cassie's Theory)

Recovery rate theory

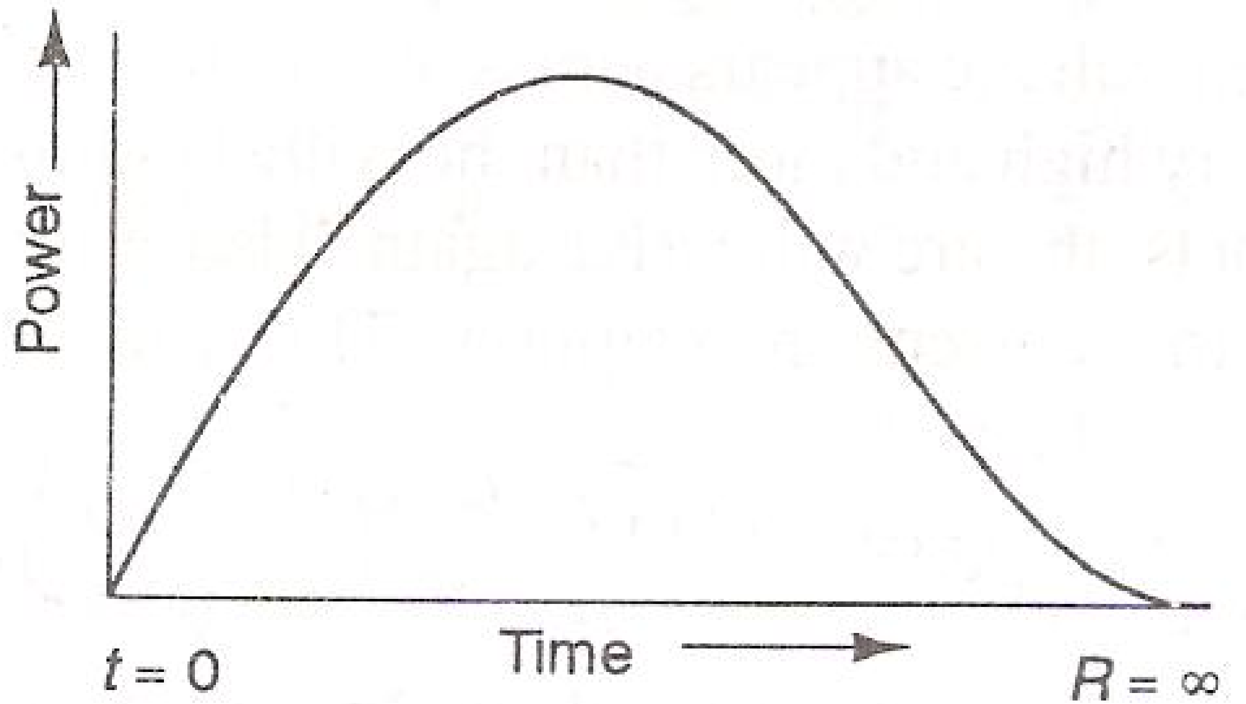


(a) Arc extinguishes



(b) Arc does not extinguishes

Energy balance theory



Arc Extinction in oil Circuit Breaker

In case of oil circuit breaker the opening of contact which heats the oil surrounds the contact due to arc which causes hydrogen gas bubble to evolve and its removes the heat from the surface. If the rate of heat removal is faster than its generation then the arc is extinguished.

Arc interruption (or) Extinction methods

(1) High resistance

(2) Low resistance or zero point-interruption.

(3) Artificial current zero interruption.

The arc resistance depends upon the following factors :

(i) *Degree of ionisation*— the arc resistance increases with the decrease in the number of ionised particles between the contacts.

(ii) *Length of the arc*— the arc resistance increases with the length of the arc *i.e.*, separation of contacts.

The high resistance interruption is obtained by increasing the resistance of the arc.

$$r_{arc} = \frac{V_{arc}}{i_{arc}}$$

Assuming i_{arc} to be constant the resistance of the arc can be increased by increasing voltage of the V_{arc}.

$$V_{arc} = A + Bd + \frac{C + Dd}{i_{arc}}$$

hence the arc resistance can be increased by increasing length of the arc.

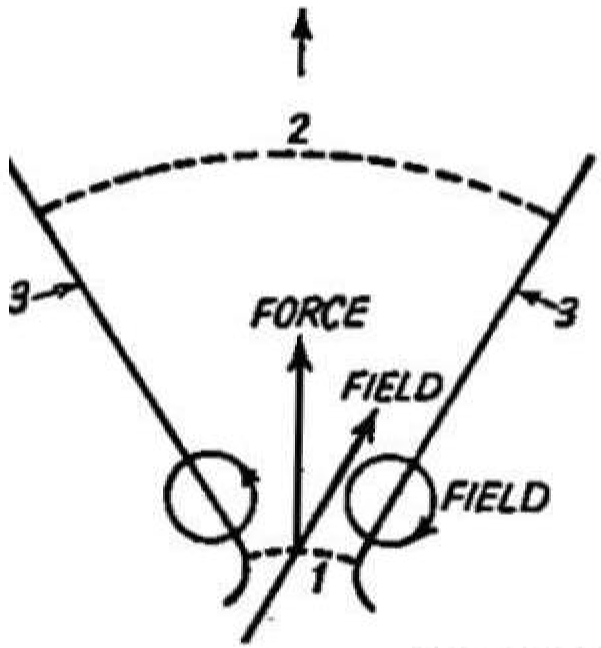
In high resistance interruption method the length of the arc is increased so as to increase the voltage across the arc.

The voltage of the arc is increased till it more than the system voltage across the contacts. At this point the arc gets extinguished.

The method is used in low and medium voltage a.c. and d.c. circuit breakers

The arc resistance is increased by the following methods :

a) Lengthening the arc : by arc runners

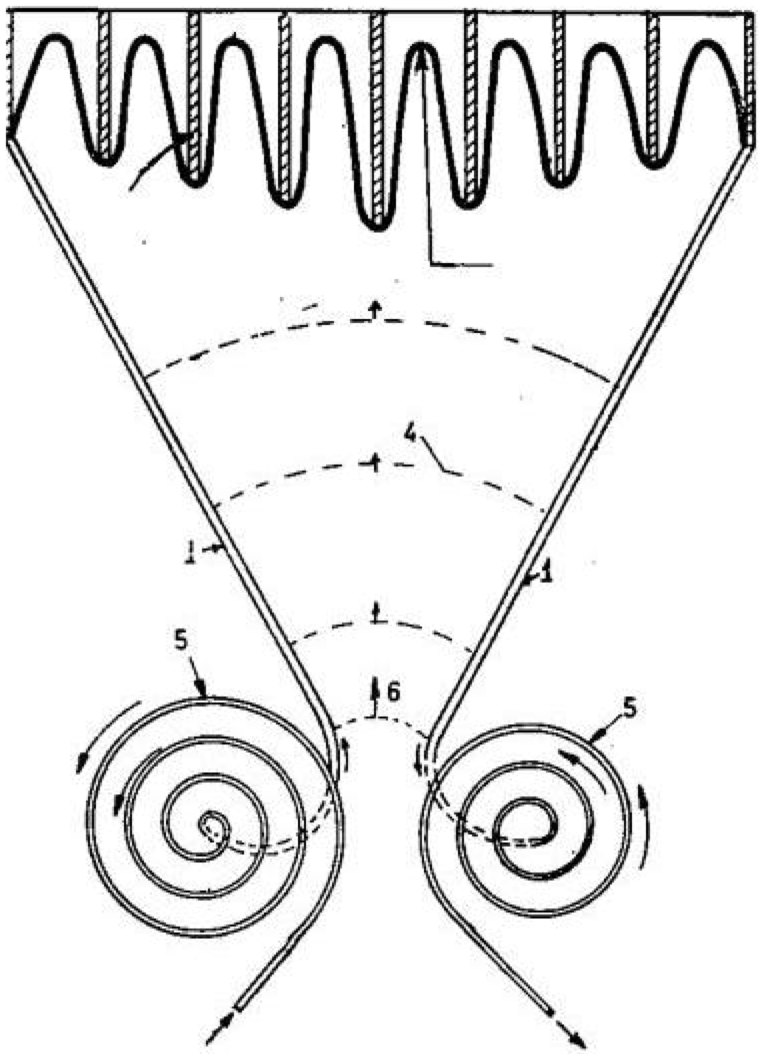


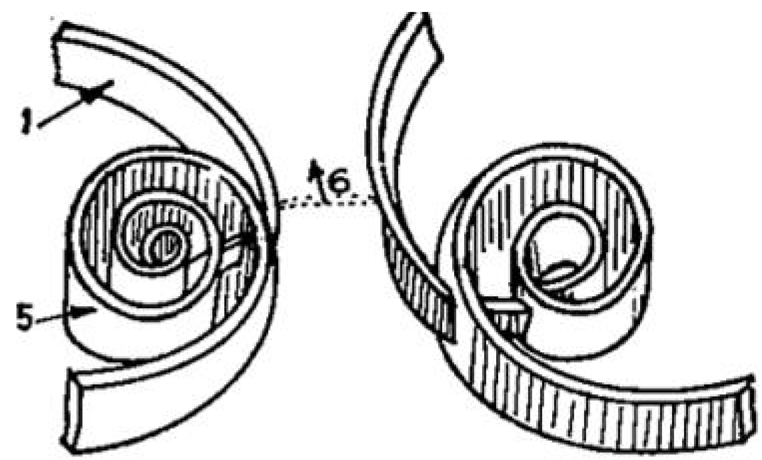
1. Initial position of arc
2. Final position of arc.
3. Arc runners (in vertical plane)
4. Field (in horizontal plane)
5. Force due to electrodynamic forces (in vertical plane)

Function of the arc runners.

b) Splitting the Arc:

In this method the arc is elongated and splitted by arc splitters. These are made with plates of resin bonded fiber gas. These are placed perpendicular to arc and arc is pulled into them by electromagnetic forces.





1. Arc runners (metallic)
2. Arc splitters
3. Elongated arc
4. Arc in process of travelling
5. Blow-out coils (metallic)
6. Origin of Arc

c) Cooling of Arc :

It causes recombination of ionized particles. Cooling remove the heat from the Arc. Efficient cooling may be obtained by gas blast directed along Arc .

2) Low resistance (or) current zero interruption:

This method is used for Arc Extinction in A.C circuit breakers. In this method the resistance kept low until current is zero.

In a.c. circuit-breakers the arc is interrupted at a current zero. At current zero, the space between contacts is deionized quickly by introducing fresh unionized medium such as oil or fresh air, or SF_6 gas, between the contacts.

The dielectric strength of the contact space increases to such an extent that the arc does not continue after current zero. A high voltage may appear across the contacts. The voltage may re-established the arc if the dielectric strength of gap is less than the restriking voltage. In that case the arc continues for another half cycle and may get extinguished at next current zero.

The rapid increase of dielectric strength of the medium near current zero can be achieved by

1)Lengthening of Arc

2)Cooling

3)Blast effect

AC CIRCUIT BREAKING

Refer Book

DC CIRCUIT BREAKING

How is dc breaking done?

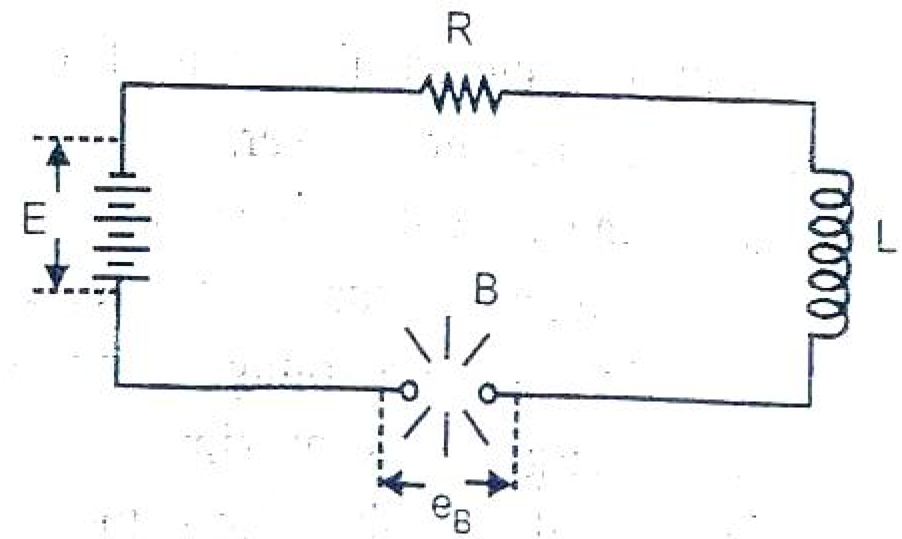
The contacts of the DC breaker separate and the arc is transferred from contacts to the runners where it rises upwards and extinguishes on its own.

Drawbacks of HVDC circuit breaking

- The amount of energy to be dissipated during the short interval of breaking is very high as compared to the conventional a.c circuit breakers

- The natural zero current does not occur as in the case of a.c cb, resistance switching and the efficient cooling by forcing the liquid or air blast are used to dissipate the high amount of energy.

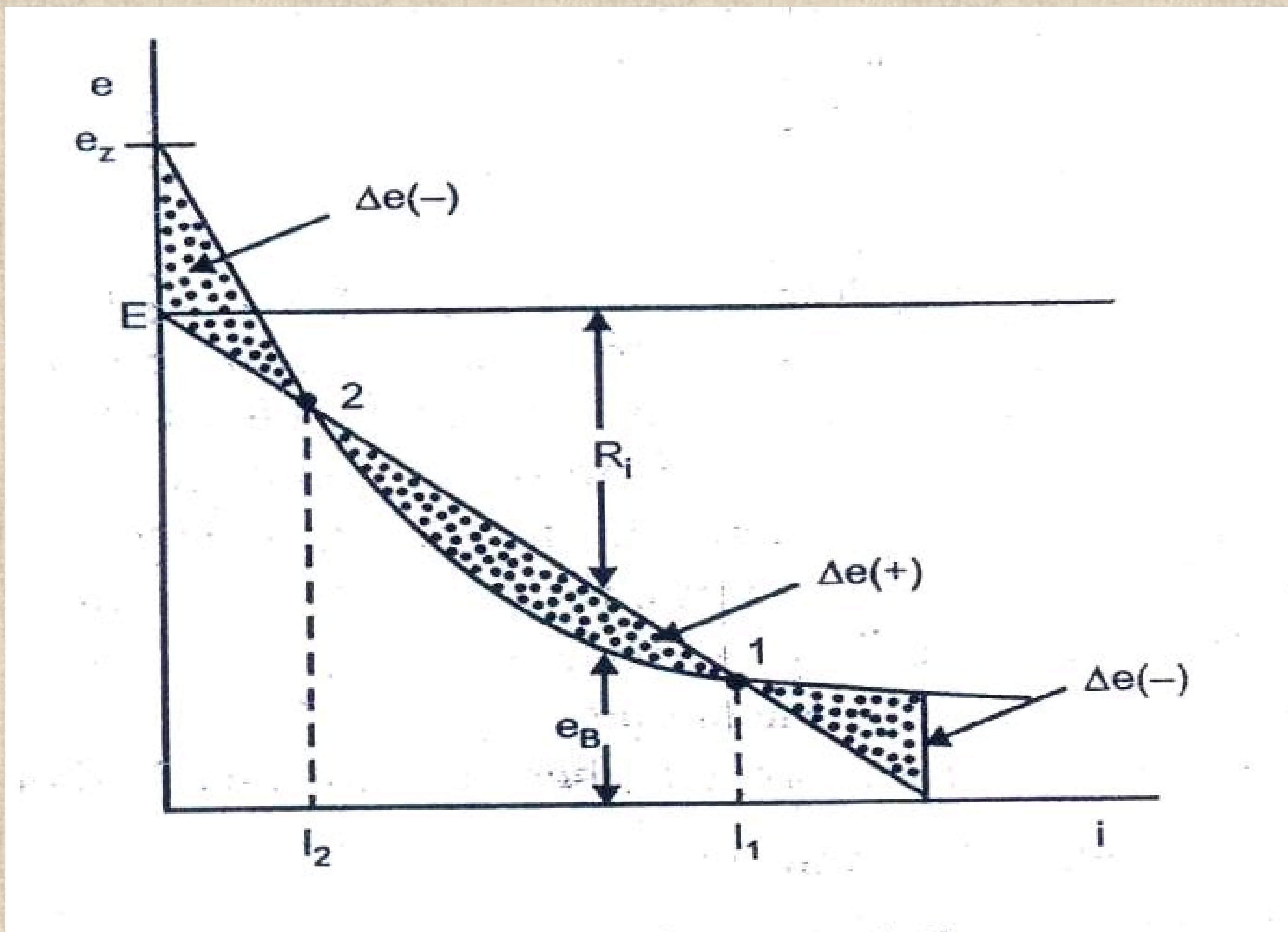
SIMPLE D.C CIRCUIT



16 An inductive d.c circuit showing the burn

- B ⟶ circuit breaker.
- Assuming CB "B" breaks the current I (=E/R)

Arc characteristics



- The diff equn of the ckt is,

L(di/dt)+Ri+eb=E

⟹ L(di/dt)=(E – Ri)-eb(i)=Δe

- *Δe negative:*

Current will decrease

- *Δe positive:*

Increase the current

Basic requirement

- Progressive lengthening of arc is a basic requirement of dc circuit breakers.

In designing an HVDC circuit breaker there are there main problems to be solved

- How to produce a current zero?
- How to prevent restriking?
- How to dissipate the stored energy?

Producing current zero

- This approach involves changing the form of arc current by commutation principle
- Quenching gear of well proven HVAC ckt breaker
- Principle of oscillatory circuit

Prevention of restrikes

- To produce a good ionizing arc the space between two walls of arc chute can be narrowed to restrict the arc
- At the same time it can be broken into number of arcs by inserting a grating of vertical metal plane

Dissipation of stored energy

- A protective spark gap can be used across the CB to reduce the size of the commuting capacitor.
- It will keep the abnormal voltage produced at the switching time below the undesired level
- By means of high frequency currents the spark gap acts as an energy dissipating device

Interruption of capacitive current

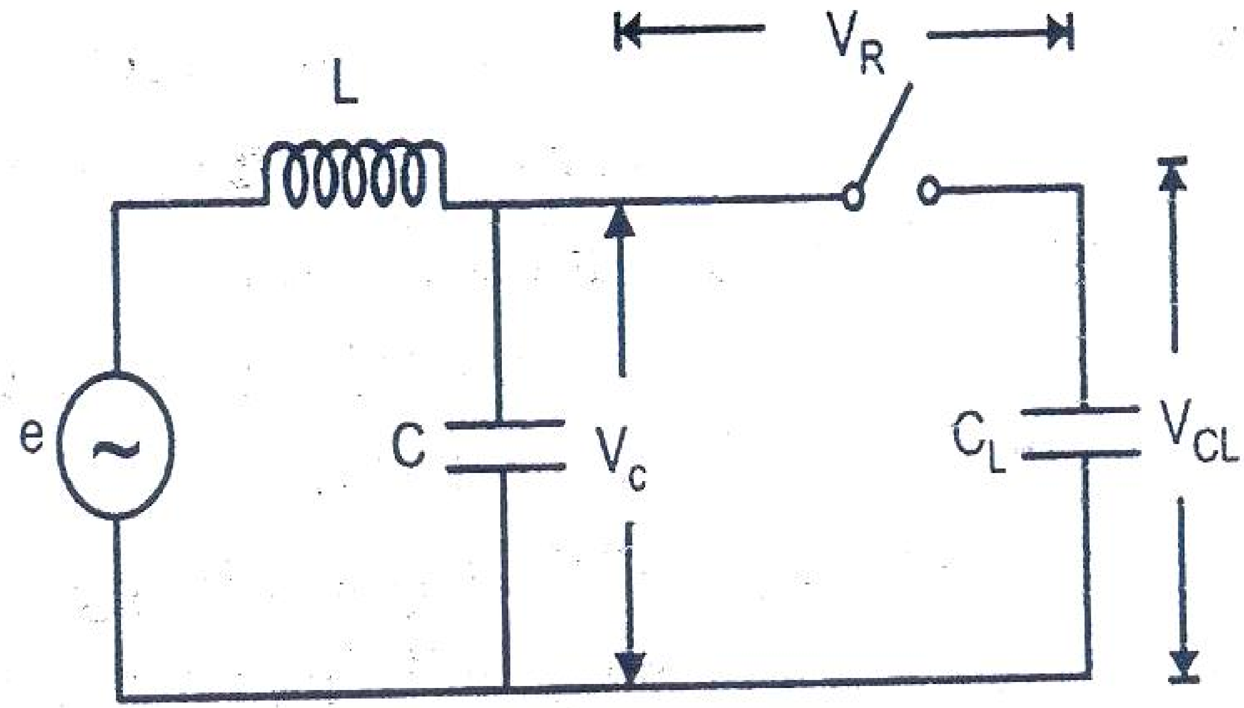
INTERRUPTION OF CAPACITIVE CURRENT

Effect:

- The interruption of capacitive current produces high voltage transients across the gap of the circuit breaker.

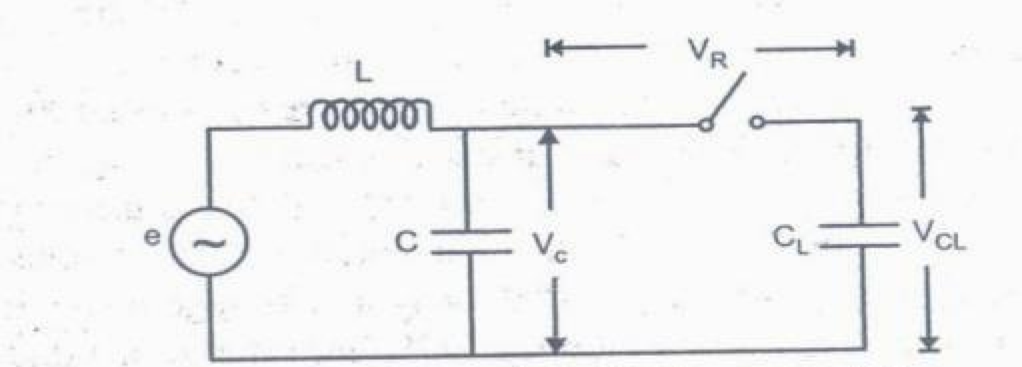
When?

- This occurs when an unloaded long transmission line or a capacitor bank is switched off.



(a) Electrical circuit of a simple power system

•Considering a electrical circuit of a simple power system

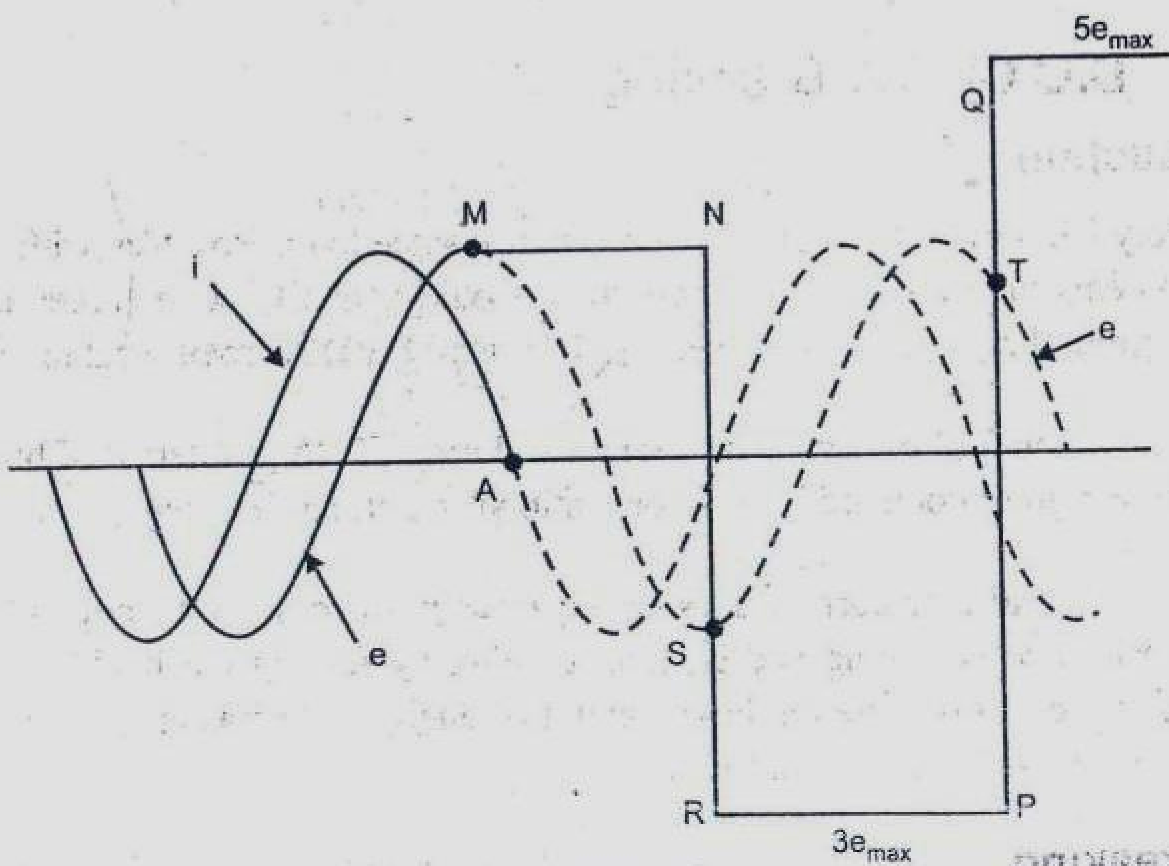


(a) Electrical circuit of a simple power system

•C → stray capacitance of the circuit breaker

•C L → line capacitance

Transient voltage across the gap of the circuit breaker when the capacitive current is interrupted



(b) Transient voltage across the gap of the circuit breaker

At the instant M

- The capacitive current is 0.
- System voltage is maximum
- <u>If interruption occurs</u>
- Capacitor C_L remains charged at the maximum value of system voltage.

After the instant M

- Voltage across the breaker gap is
  the difference of V_c and V_{cL}.

At the instant N

- The voltage across the gap is twice the maximum
- Value of Vc.

If the breaker restrikes

- The voltage across the gap become partially zero.
- Voltage falls from $2Vc_{max}$ to zero.
- A severe high frequency oscillation occurs (about the point S)
- Interrupted again.(if restriking current=0)
- The capacitor C_L at the voltage $-3e_{max}$.

At the instant P

- The system voltage reaches its positive maximum.(point T)
- Voltage across the gap becomes $4e_{max}$.
- The capacitive current reaches zero again and there may be an interruption.
- The transient voltage oscillates between $-3e_{max}$ and $+5e_{max}$. (point P—Q)

✓ Thus voltage across the gap goes on increasing

UNIT 5
PART-2

- Types of circuit breakers

1. Air Blast circuit breaker
2. Vacuum circuit breaker
3. Oil circuit breaker
4. SF_6 circuit breaker

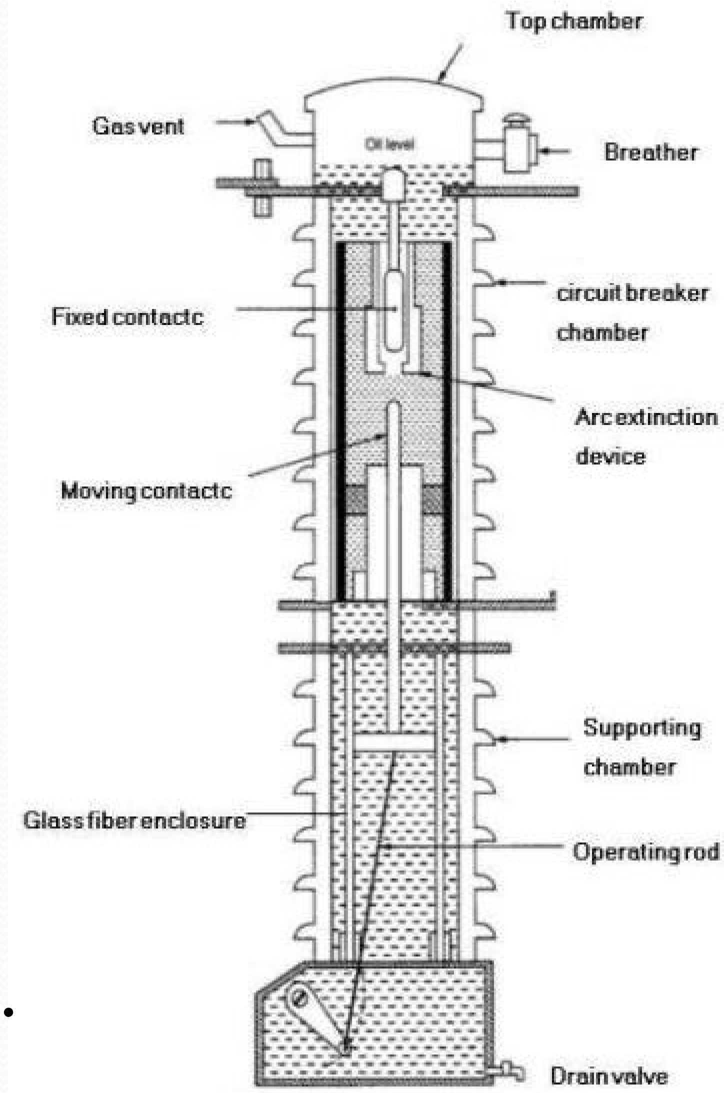
- Comparison of Airblast,Vacuum,Oil,SF6
- Testing of circuit breakers.

Types Of Circuit Breakers

- Oil Circuit Breakers
- Vacuum Circuit Breakers
- Air Blast Circuit Breakers
- SF_6 Circuit Breakers

1. OIL CIRCUIT BREAKER

- It is designed for 11kv-765kv.
- These are of two types
  - BOCB (Bulk oil Circuit Breaker)
  - MOCB (Minimum oil Circuit Breaker)
- The contacts are immersed in oil bath.
- Oil provides cooling by hydrogen created by arc.
- It acts as a good dielectric medium and quenches the arc.



Advantages:

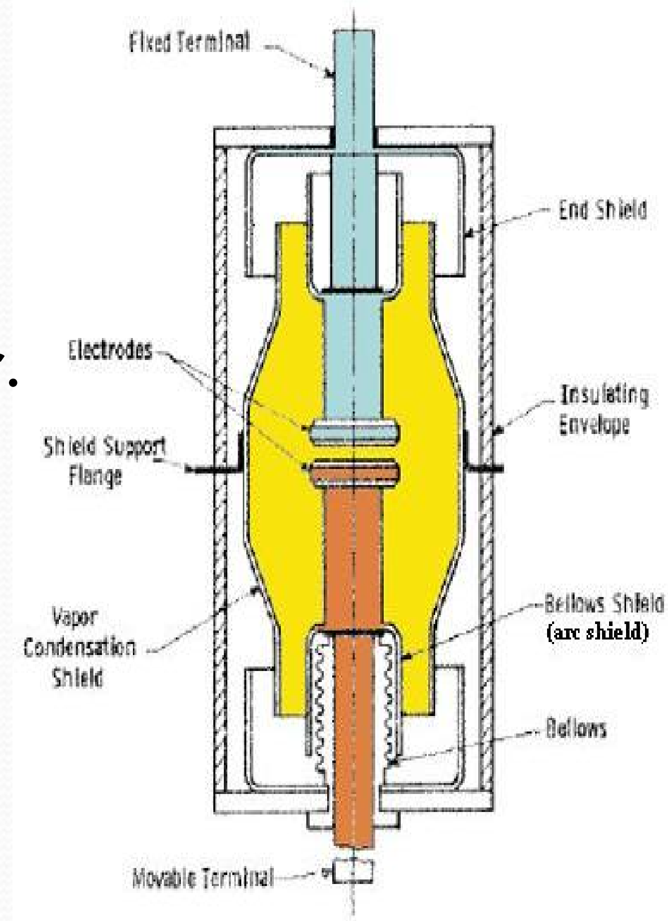
- Oil has good dielectric strength.
- Low cost.
- Oil is easily available.
- It has wide range of breaking capability.

Disadvantages:

- Slower operation , takes about 20 cycles for arc quenching.
- It is highly inflammable , so high risk of fire.
- High maintenance cost.

2. VACCUM CIRCUIT BREAKER

- It is designed for medium voltage range (3.3-33kv).
- This consists of vacuum of pressure ($1*10^{-6}$) inside arc extinction chamber.
- The arc burns in metal vapour when the contacts are disconnected.
- At high voltage , it's rate of dielectric strength recovery is very high.
- Due to vacuum arc extinction is very fast.
- The contacts loose metals gradually due to formation of metal vapours.



Representation of vacuum interrupter chamber in vacuum circuit breaker

Advantages:

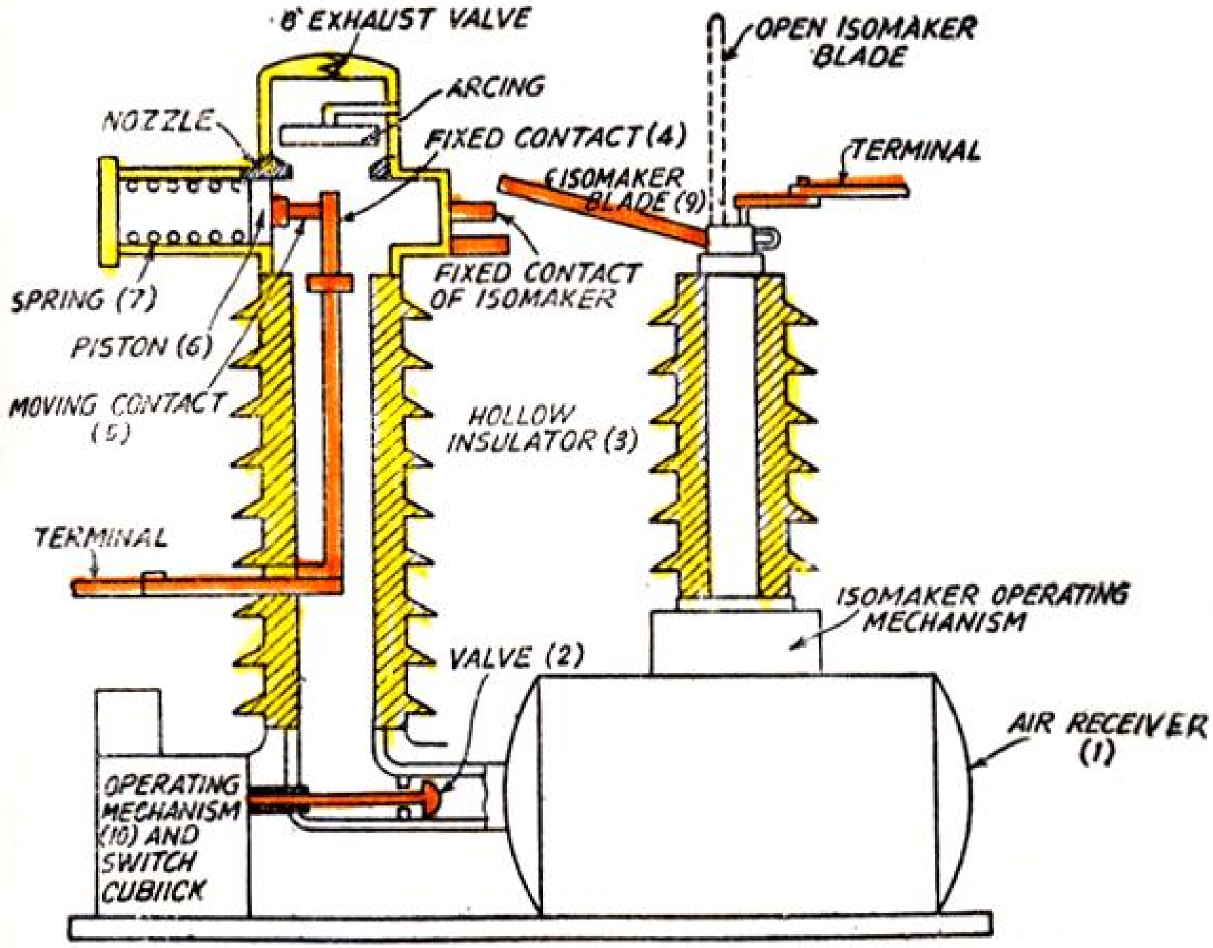
- Free from arc and fire hazards.
- Low cost for maintenance & simpler mechanism.
- Low arcing time & high contact life.
- Silent and less vibrational operation.
- Due to vacuum contacts remain free from corrosion.
- No byproducts formed.

Disadvantages:

- High initial cost due to creation of vacuum.
- Surface of contacts are depleted due to metal vapours.
- High cost & size required for high voltage breakers.

3. AIR BLAST CIRCUIT BREAKERS

- This operates using high velocity blast of air which quenches the arc.
- It consists of blast valve , blast tube & contacts.
- Blast valve contains air at high pressure.
- Blast tube carries the air at high pressure & opens the moving contact attached to spring.
- There is no carbonization of surface as in VCB.
- Air should be kept clean & dry to operate it properly.



1. Air receiver, 2. Valve, 3. Hollow insulator.
4. Fixed contact, 5. Moving contact, 6. Piston.
7. Spring, 8. Exhaust valve, 9. Isomaker,
10. Operating mechanism.

25 kV Single Phase Air Circuit Breaker.

Advantages:

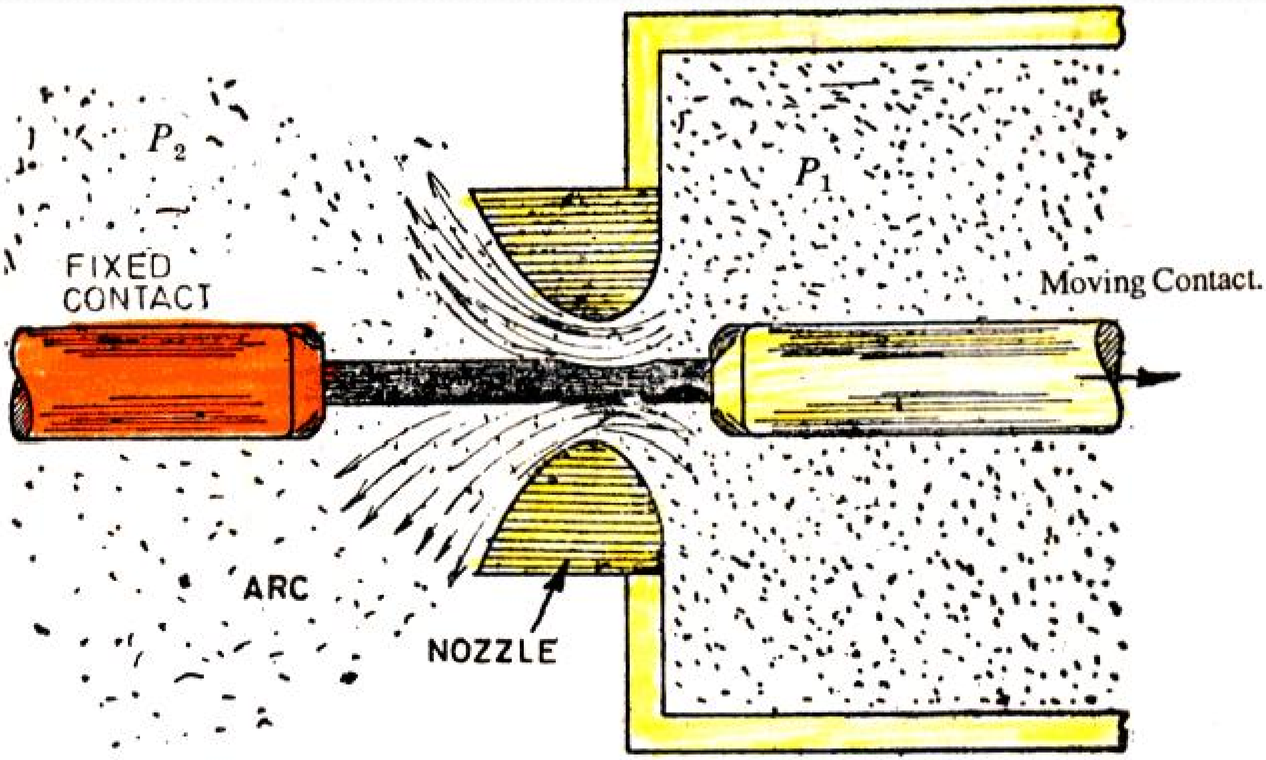
- High speed operation as compared to OCB.
- Ability to withstand frequent switching.
- Facility for high speed reclosure.
- Less maintenance as compared to OCB.

Disadvantages:

- Little moisture content prolongs arcing time.
- Pressure should be checked frequently for frequent operation.
- Risk of fire hazards due to over voltages.
- It can’t be used for high voltage operation due to prolonged arc quenching.

4. SF_6 CIRCUIT BREAKERS

- It contains an arc interruption chamber containing SF_6 gas.
- In closed position the contacts remain surrounded by SF_6 gas at a pressure of 2.8 kg/cm^2 .
- During opening high pressure SF6 gas at 14 kg/cm^2 from its reservoir flows towards the chamber by valve mechanism.
- SF_6 rapidly absorbs the free electrons in the arc path to form immobile negative ions to build up high dielectric strength.
- It also cools the arc and extinguishes it.
- After operation the valve is closed by the action of a set of springs.
- Absorbent materials are used to absorb the byproducts and moisture.



(*a*) Arc extinction in gas flow circuit-breakers (Gas flow from high pressure P_1 to low pressure P_2 *via* an insulating nozzle)

Advantages:

- Very short arcing period due to superior arc quenching property of SF_6 .
- Can interrupt much larger currents as compared to other breakers.
- No risk of fire.
- Low maintenance, light foundation.
- No over voltage problem.
- There are no carbon deposits.

Disadvantages:

- SF_6 breakers are costly due to high cost of SF_6.
- SF_6 gas has to be reconditioned after every operation of the breaker, additional equipment is required for this purpose.

Comparison of Circuit Breakers

Factor	Oil Breakers	Air Breakers	Vacuum/SF6
Safety	Risk of explosion and fire due to increase in pressure during multiple operations	Emission of hot air and ionized gas to the surroundings	No risk of explosion
Size	Quite large	Medium	Smaller
Maintenance	Regular oil replacement	Replacement of arcing contacts	Minimum lubrication for control devices
Environmental factors	Humidity and dust in the atmosphere can change the internal properties and affect the dielectric		Since sealed, no effect due to environment
Endurance	Below average	Average	Excellent

CONCLUSION:

Therefore, we conclude that circuit breaker is the most essential part of the electrical networks as it protects every device from damage. It helps us to detect the fault and area affected by it. Nowadays vacuum and SF_6 circuit breakers are widely used due to their reliable and fast operations.

Rating and Selection of Circuit breakers

REFER BOOK