SELAMAT DATANG

TO INSTEP

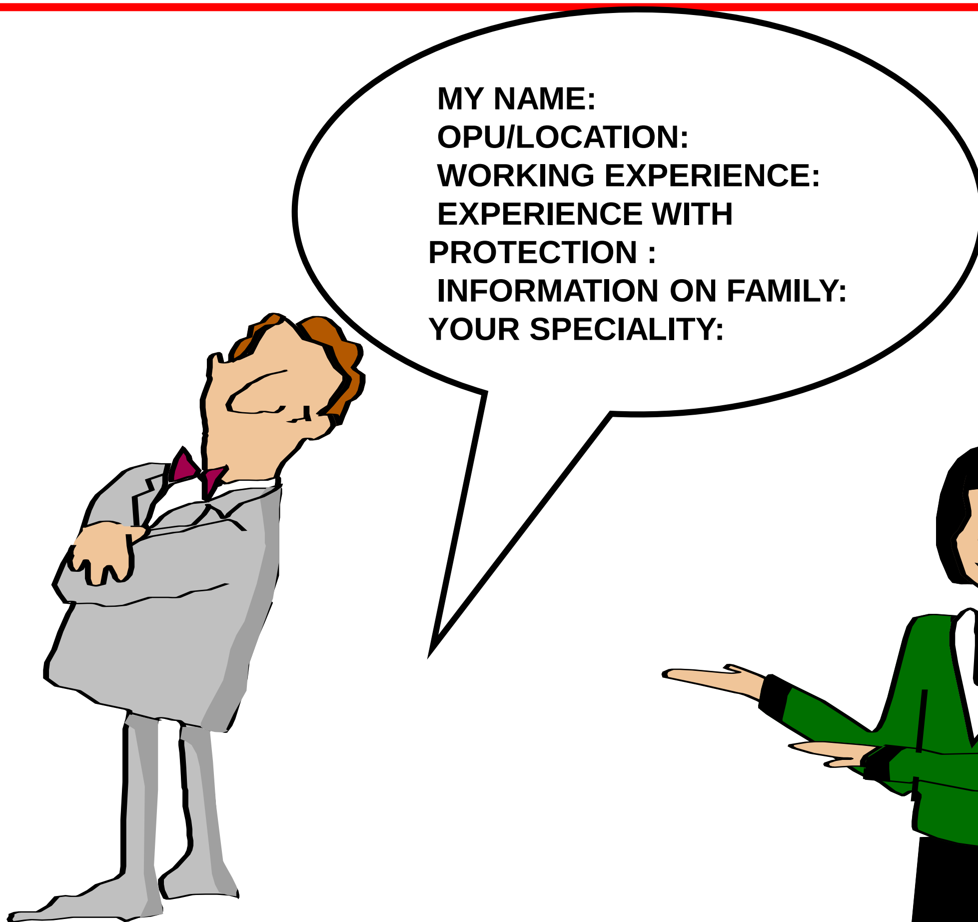
Electrical Protection Course

24 - 27 Mac 2008

Your Trainer

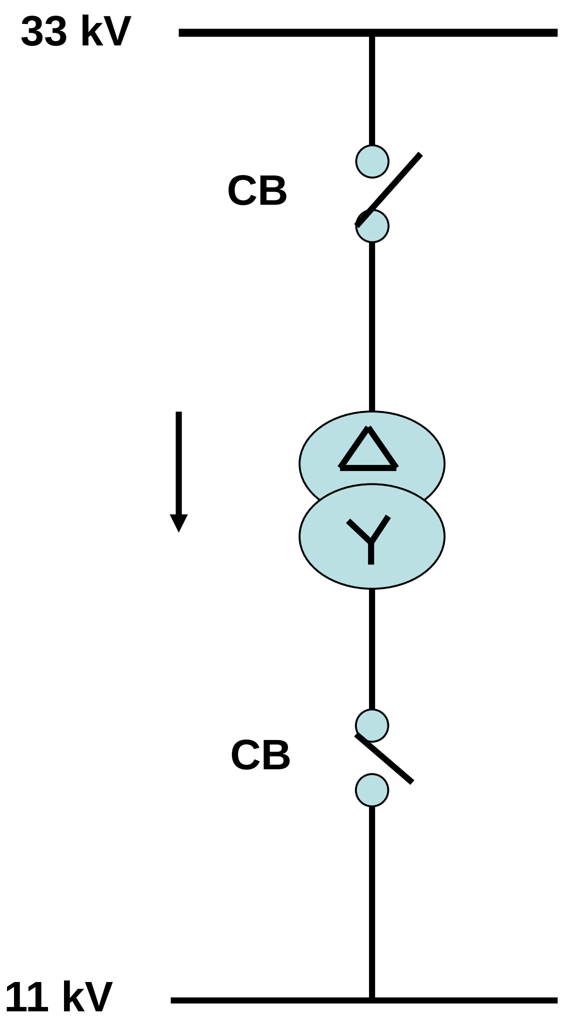
Hashim Othman

OPU: PETRONAS GAS BERHAD, CUFK
POSITION: STAFF ENGINEER (TPCP)
PROTECTION & CONTROL
YEAR OF SERVICE: 26 YRS
STATUS: MARRIED, 1 WIFE, 5 KIDS
AND 1 GRAND SON
My Speciality:



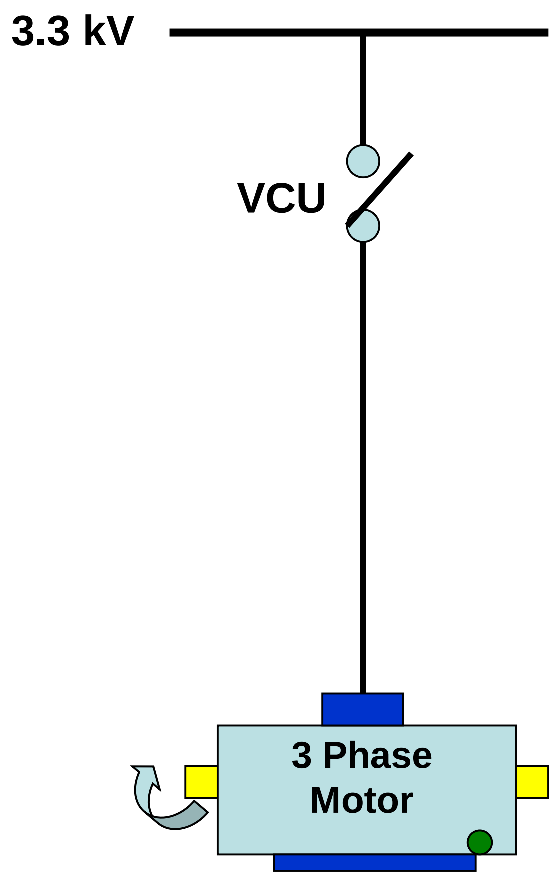
Accomplished or Do Not Begins

Time Table



Ice Breaking

State Protection Required



Ice Breaking

State Protection Required

Part 1

Protection Relay Introduction

WHAT IS THE FUNCTION OF THE ELECTRICAL PROTECTIONS ?

THE MAIN FUNCTION OF ELECTRICALPROTECTIONS IS TO

ENSURE THE MAXIMUM CONTINUITY OF POWER SUPPLY

HOW?

IT IS DONE BY DETERMINING THE LOCATION OF A FAULT

AND DISCONNECTING THE MINIMUM AMOUNT

OF EQUIPMENT NECESSARY TO CLEAR IT

WHEN?

WHEN A FAULT OCCURS

WHICH RELAY TO OPERATE?

ONLY RELAY WHICH IS ASSOCIATED WITH THE FAULTY EQUIPMENT ARE REQUIRED TO OPERATE

HOW DOES THIS IS ACHIVED?

THERE ARE THREE (3) METHODS OF DESCRIMINATION:

1. TIME:
> Time Relay e.g. IDMT

2. COMPARISON (known as Unit Protection):
> Differential Relays e.g. Earth Fault Relay
Differential Feeder Relay

3. MAGNITUDE:
> Over current Protection e.g. High-set or Instantaneous

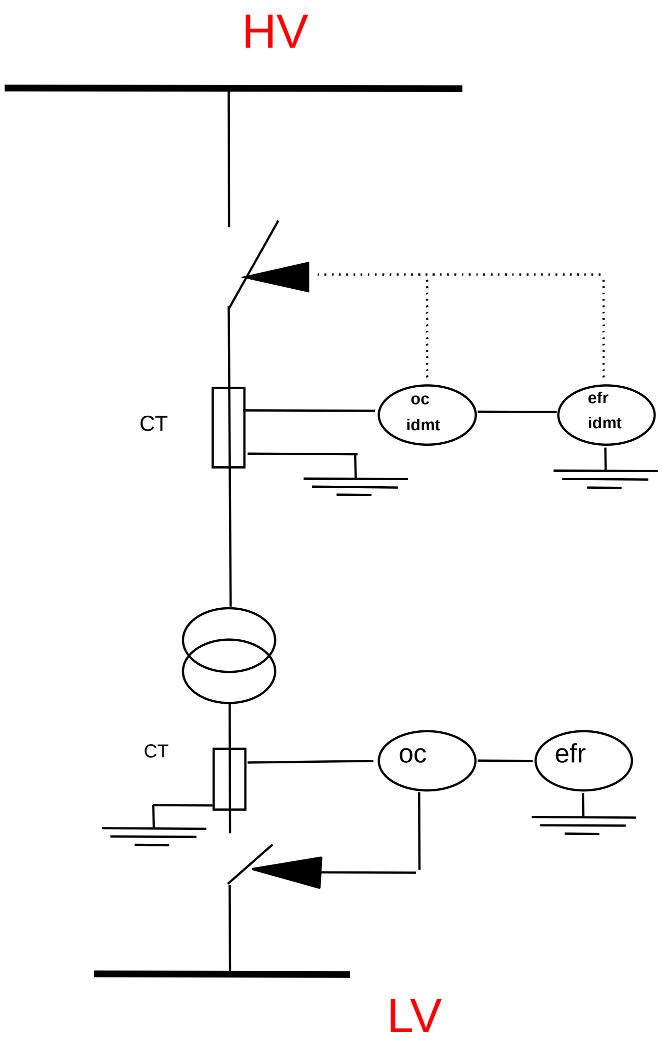
TIME RELAY

> Discriminate by time – IDMT (inverse definite minimum time)

> Used with associated with other relay or as a back-up

> Major disadvantage: Delay to remove fault which lead to increase damage to the faulty equipment or increase possibility of damage to healthy equipment which is carrying fault current.

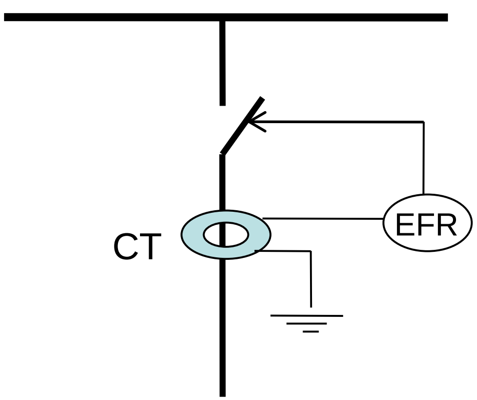
TIME RELAY

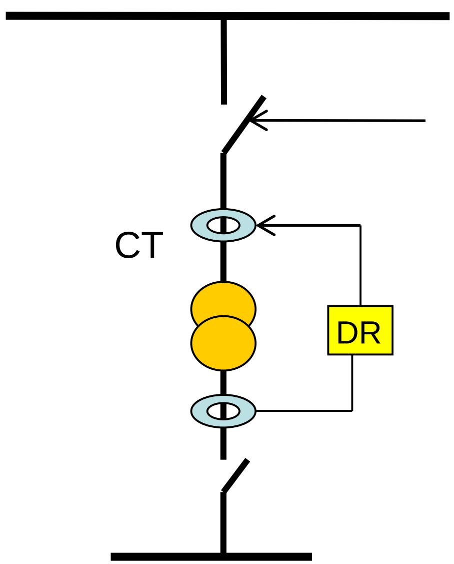


COMPARISON

> Discriminate by comparison i.e. the current entering and leaving are the same if it is healthy, but it is difference when unit is faulty

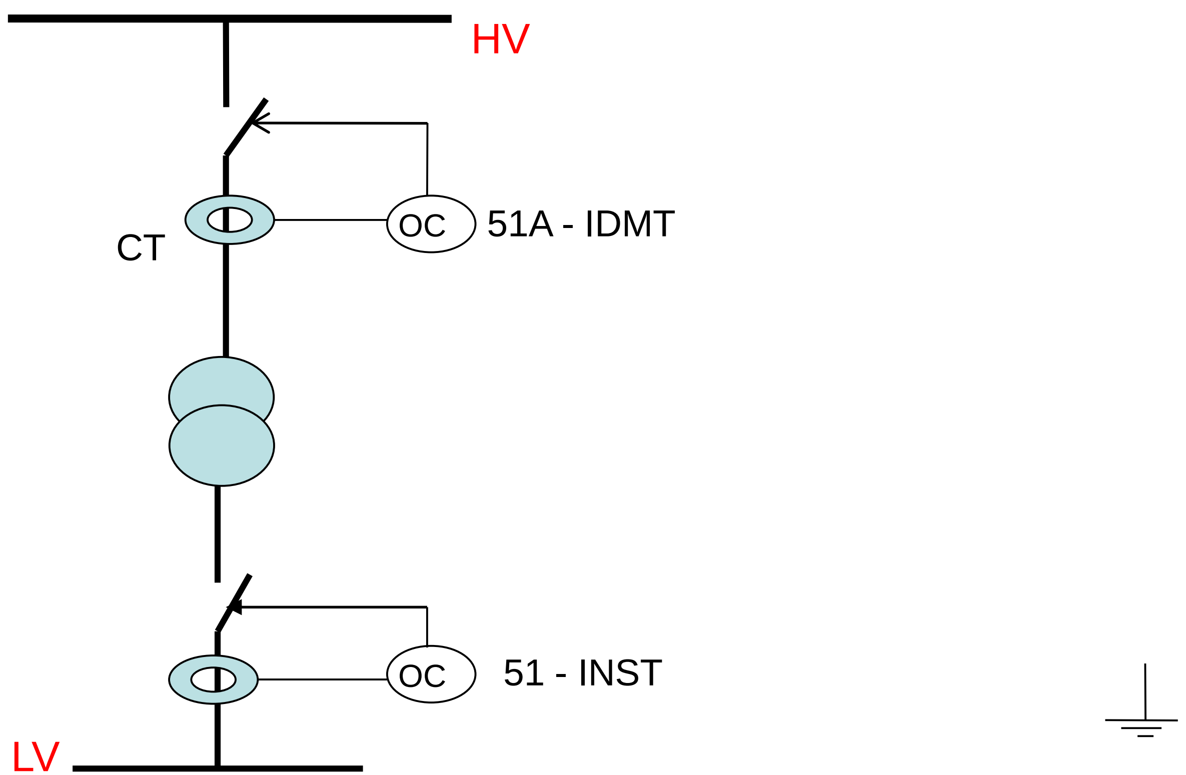
> Known as a Unit Protraction i.e. Protect only the equipment which they are associated





MAGNITUDE

- Used only where there is a large change in fault current e.g. between Primary and Secondary winding of the Transformer



PRINCIPLE OF DISCRIMINATION

> ONLY THE NEAREST RELAY TO THE FAULT OPERATES TO ISOLATE THE SMALLEST POSSIBLE AREA IN THE SHORTEST POSSIBLE TIME.

> THIS IS ACHIEVED BY MAKING EACH UPSTREAM RELAY SLOWER THAN ITS DOWNSTREAM RELAY.

Discrimination by time is the basis for many simple protection devices.

The time delay being in general *inversely proportional* to current level.

These scheme are applied to most medium voltage systems.

What is Protection Relays?

A Relay is a device that detects the fault and initiates the operation of the Circuit Breaker to isolate the defective section of the system with minimum Interruption of supply.

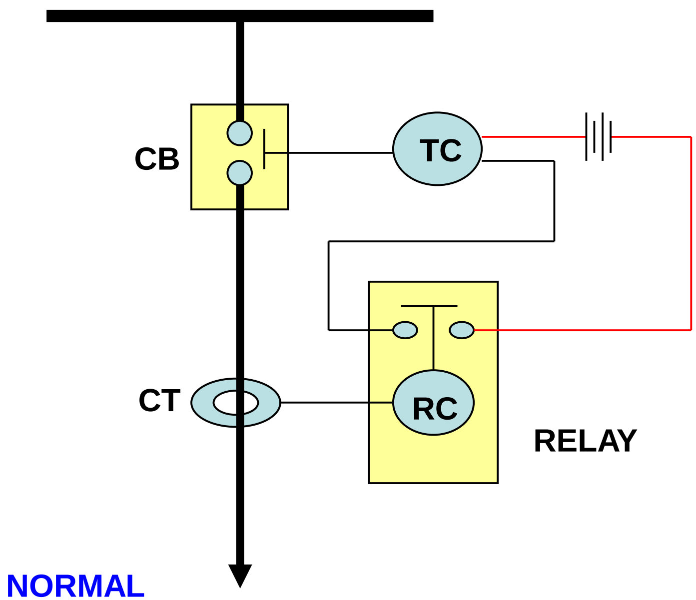
How does it's work?

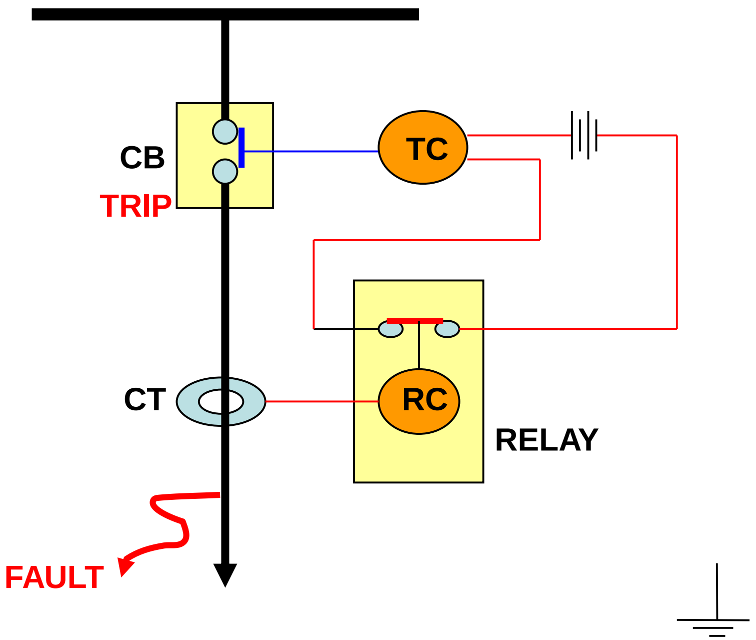
Relay detects any abnormal conditions in the electrical system by constantly measuring the electrical *quantities* which are different under normal & fault conditions.

What are the quantities?

The quantities which may changes during fault are *Current, Voltage, Frequency and Phase Angle.*

Changes of any one of these quantities, Relay to operates & to close the trip circuit of the circuit breaker





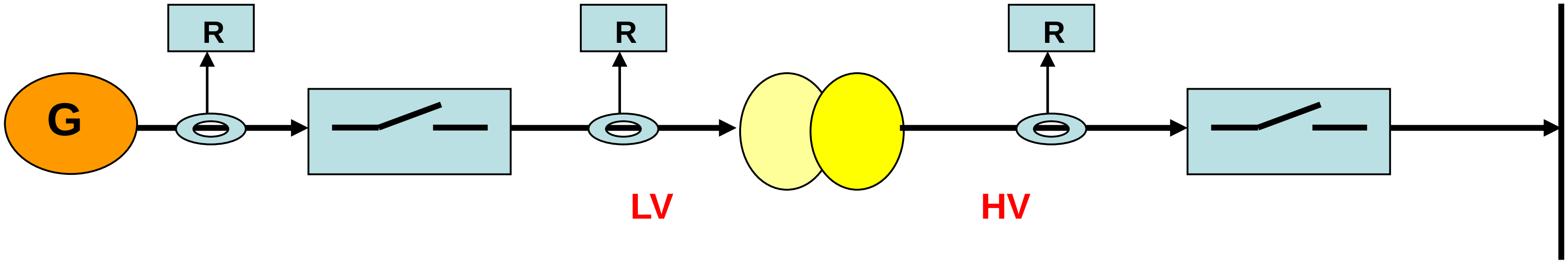
Fundamental Requirements of Protective Relaying

In order for relays to perform it functions satisfactorily, the following *Quantities* are required:

- **Selectivity**
- **Speed**
- **Sensitivity**
- **Reliability**
- **Simplicity**
- **Economic**

Selectivity

The ability of the protection system to select correctly the part of the system in trouble and disconnect the fault section without disturbing the other system.



Speed

The protective system shall disconnect the faulty section as fast as Possible due to:

- **The installation may be damaged under prolonged high fault**
- **Failure of the system may crated reduction of system voltage thus may shutdown other electrical equipment i.e. motors etc.**
- **High speed relay system may decrease the possibility development of more severe other fault**

Sensitivity

The ability of the protective system to operate with low value of actuating quantity.

Sensitivity of the relay is a function of volt-ampere input to the coil to cause operation.

The smaller the input volt-ampere, the more sensitive of the relay e.g. 1 VA relay is more sensitive then 3 VA relay.

Reliability

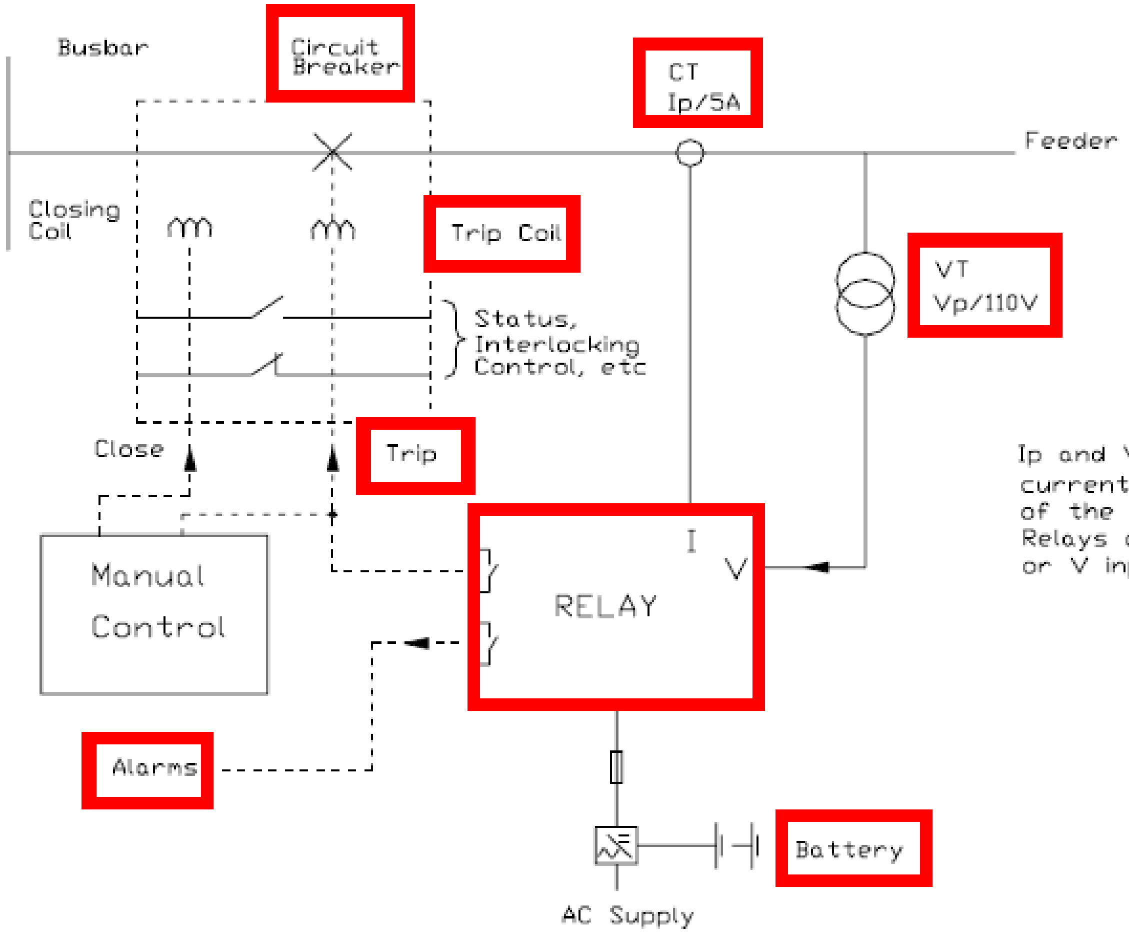
The ability of the relay system to operate under pre-determined condition

Simplicity

The relay system should be simple for ease maintenance. The simpler the protection scheme, the greater will be the reliability

Economy

The most important factor in the selection of the system and it depend on how the system would like to be.



Ip and Vp are the primary current and voltage ratings of the instrument transformers. Relays can have either I or V inputs or both.

COMPONENTS OF A PROTECTION SCHEME

UNIT AND NON-UNIT PROTECTIONS

UNIT PROTECTION (Zone Protection)

1. RELAY WITH A DEFINITE ZONE OF PROTECTION, DEFINED BY THE CT LOCATION. FOR INTERNAL FAULTS, IT MUST OPERATE INSTANTANEOUSLY. FOR EXTERNAL FAULTS, THE CURRENT PASSES THROUGH BOTH SETS OF CTS AND THE RELAY MUST BE STABLE.

2. *UNIT PROTECTION* – IT PROTECTS A CERTAIN "UNIT" OF EQUIPMENT WITHIN THE ZONE OF PROTECTION. OPERATES ON THE DIFFERENTIAL PRINCIPLE. VERY FAST BUT MORE EXPENSIVE.

3. EXAMPLES ARE DIFFERENTIAL RELAYS FOR TRANSFORMERS AND GENERATORS, PILOT WIRE PROTECTION FOR CABLES AND RESTRICTED EARTH FAULT RELAYS FOR TRANSFORMERS.

NON-UNIT PROTECTION

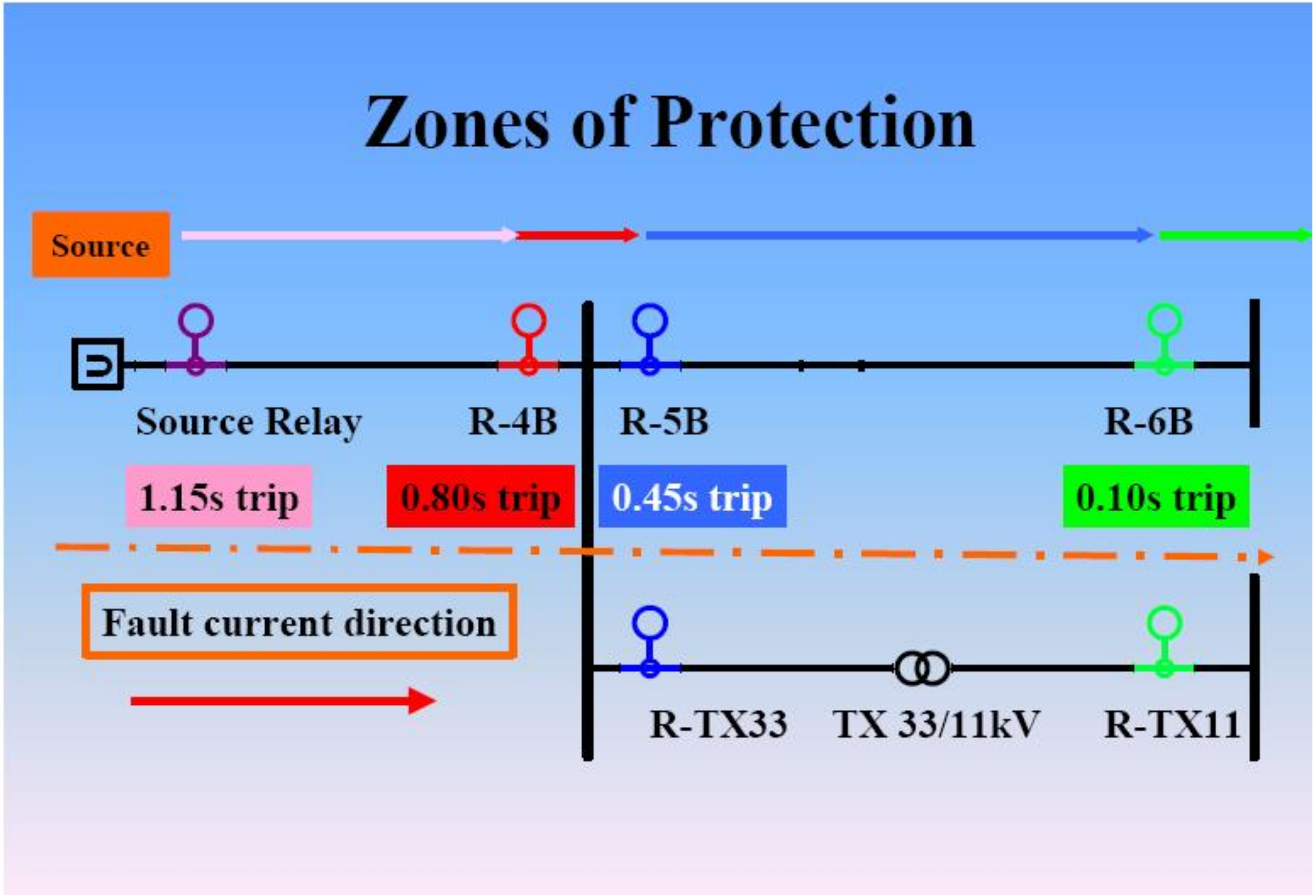
1. **OVERCURRENT- EARTH FAULT RELAY WILL ALWAYS PICK-UP OR START TO OPERATE WHENEVER IT SEES A FAULT CURRENT.**

2. **RELAY DOES NOT REALLY KNOW WHERE THE FAULT IS. IT JUST WAITS FOR ITS TIME TO OPERATE. GIVEN ENOUGH TIME, THE RELAY WILL OPERATE.**

3. ***NON-UNIT PROTECTION* – IT PROTECTS FOR FAULTS INSIDE AND OUTSIDE ITS MAIN ZONE OF PROTECTION**

WHEN A FAULT OCCURS:

- **THE FAULT CURRENT WILL FLOW FROM THE SOURCE THROUGH A NUMBER OF RELAYS TO THE FAULT**
- **SOME OF THESE RELAYS WILL PICK-UP OR START TO OPERATE.**
- **BUT ONLY ONE RELAY IS TO TRIP AND INTERRUPT THE FAULT CURRENT.**
- **ONCE THAT IS DONE, ALL THE RELAYS WILL RESET OR RETURN TO ITS ORIGINAL POSITION.**
- **THE CURRENT FLOW IS FROM UPSTREAM SOURCE TO THE DOWNSTREAM LOADS, LIKE THE FLOW OF WATER IN A RIVER.**


Zones of Protection
Source
Source Relay
R-4B
R-5B
R-6B
1.15s trip
0.80s trip
0.45s trip
0.10s trip
Fault current direction
R-TX33
TX 33/11kV
R-TX11

WHEN A RELAY FAILS

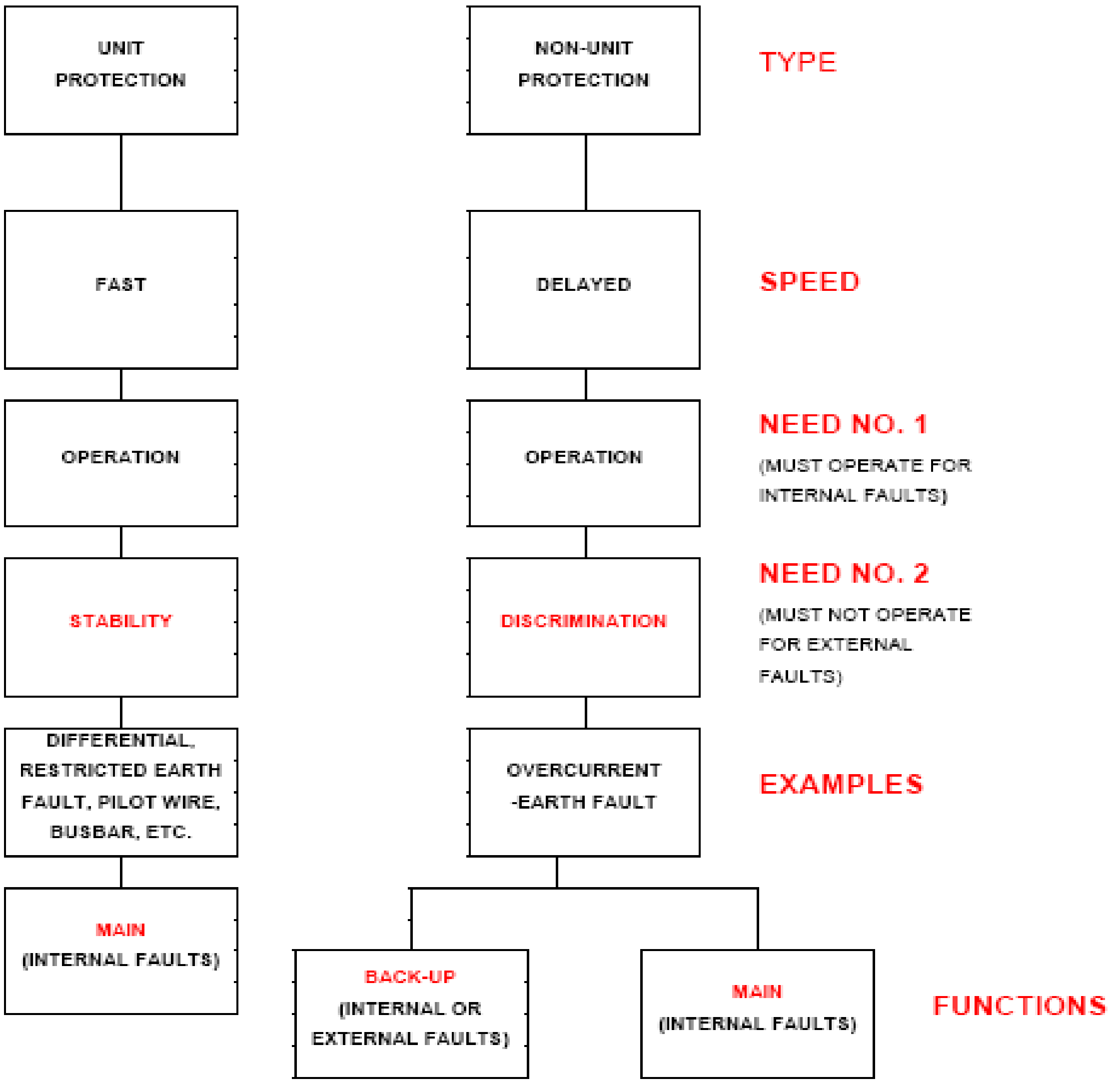
> THE FIRST RELAY TO TRIP DURING A FAULT IS CALLED THE *MAIN PROTECTION.*

> IF SOMETHING GOES WRONG AND THE FAULT IS NOT CLEARED, ANOTHER RELAY MUST OPERATE. THIS IS KNOWN AS *BACK-UP PROTECTION.* IT WILL TAKE A LONGER TIME AND CAUSE MORE EXTENSIVE TRIPPING.

> PRINCIPLE OF BACK-UP PROTECTION – *ANOTHER RELAY MUST OPERATE IF ONE RELAY FAILS.*

> OVERCURRENT- EARTH FAULT RELAYS *PROVIDE INHERENT BACK-UP PROTECTION.*

> UNIT PROTECTION RELAYS *DO NOT PROVIDE ANY BACK-UP FUNCTION*.


UNIT PROTECTION
NON-UNIT PROTECTION
TYPE
FAST
DELAYED
SPEED
OPERATION
OPERATION
NEED NO. 1
(MUST OPERATE FOR INTERNAL FAULTS)
STABILITY
DISCRIMINATION
NEED NO. 2
(MUST NOT OPERATE FOR EXTERNAL FAULTS)
DIFFERENTIAL, RESTRICTED EARTH FAULT, PILOT WIRE, BUSBAR, ETC.
OVERCURRENT -EARTH FAULT
EXAMPLES
MAIN (INTERNAL FAULTS)
BACK-UP (INTERNAL OR EXTERNAL FAULTS)
MAIN (INTERNAL FAULTS)
FUNCTIONS

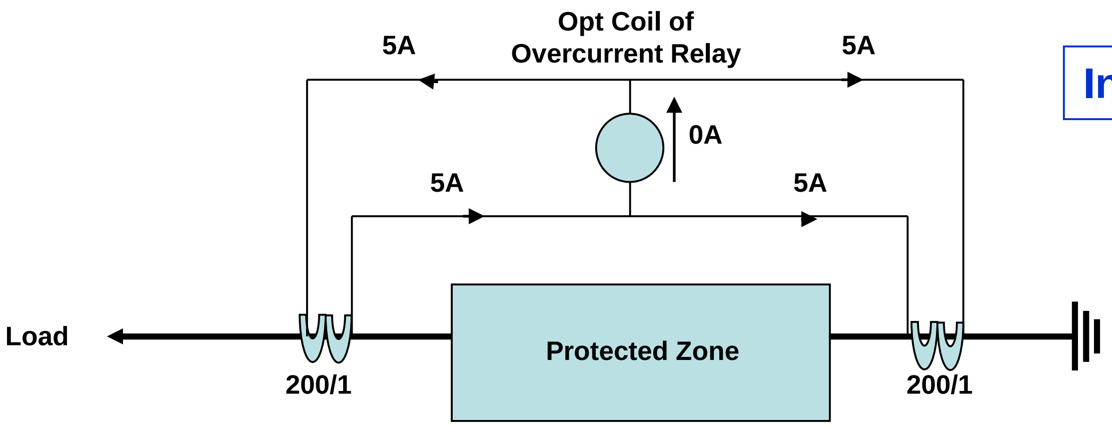
DIFFERENTIAL RELAY

(1) RELAY USED TO PROTECT MORE IMPORTANT CIRCUITS. INSTANTANEOUS OPERATION.

(2) OPERATES FOR FAULTS WITHIN THAT CIRCUIT. MUST BE STABLE FOR EXTERNAL FAULTS, I.E. OUTSIDE ITS ZONE OF PROTECTION.

(3) EXPENSIVE.

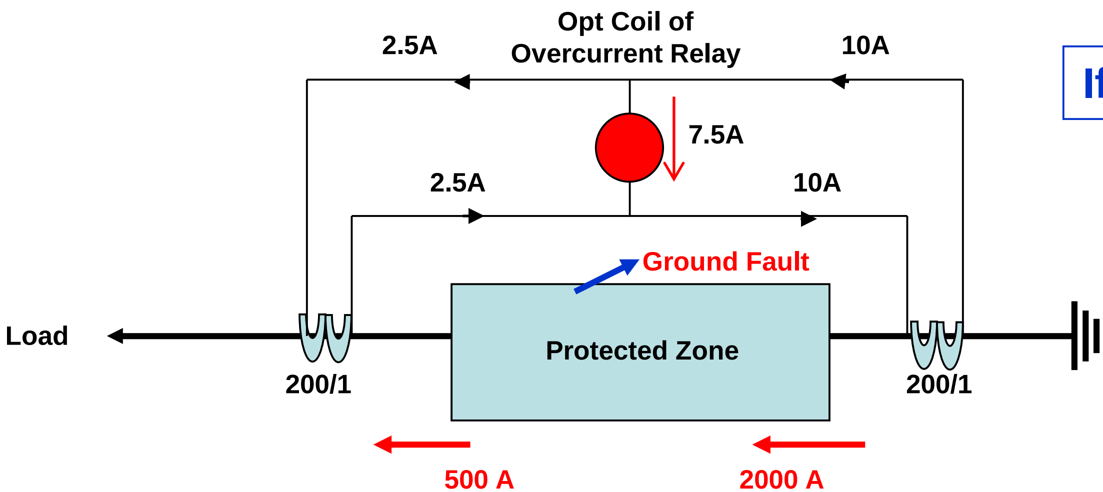
Current Differential Relay



In Normal Sate

- No fault
- Both CT carries same secondary current & circulates around CTs
- No current flow to Operating Differential Relay Coil - NO TRIP

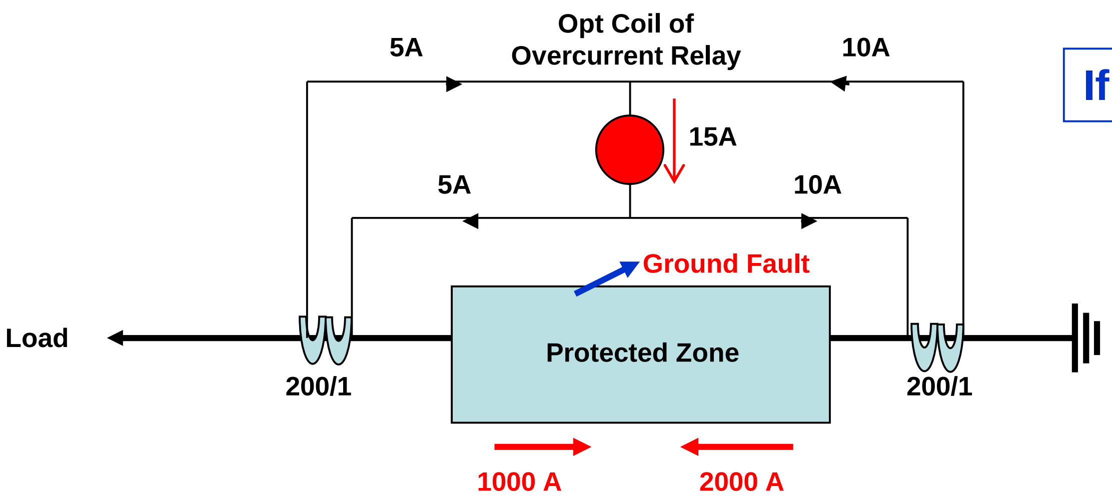
Current Differential Relay



If Ground Fault

- **Internal Ground fault – current 500A flow out in one side larger than 2000 A**
- **Both CT carries NOT equal secondary current i.e. 10 – 2.5 = 7.5A**
- **Current flows to Operating Differential Relay Coil - RELAY TRIP**

Current Differential Relay



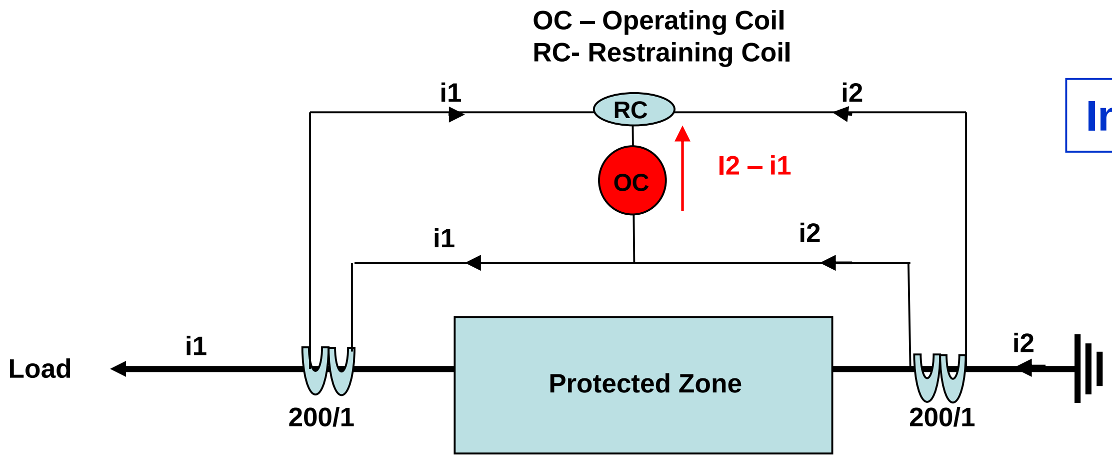
If Ground Fault

- Internal Ground fault – current flows to the fault from both sides
- Both CT carries NOT equal secondary current i.e 10 + 5 = 15A
- Current flows to Operating Differential Relay Coil - RELAY TRIP

Disadvantages:

- The impedance of pilot cable may slight difference between current at two end of zone under protection.
- Pilot cable capacitance causes incorrect operation of the relay when large through flows.
- Accurate matching of CT become difficulties due to pilot circuit impedance.

Current Bias Differential Relay



In Normal State

•

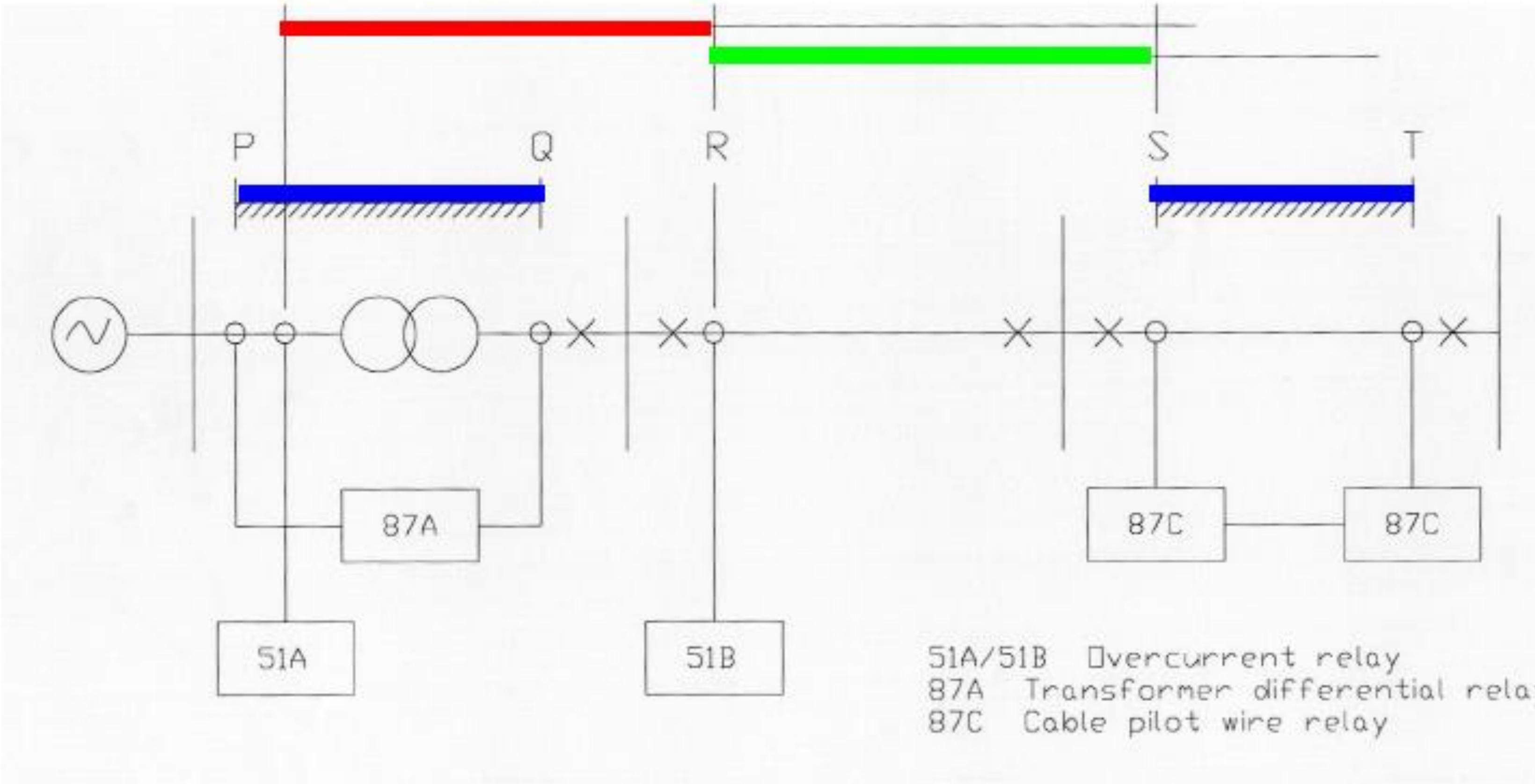
Next slide to create bias diff relay & volt diff relay

IEC AND ANSI REPRESENTATION OF PROTECTIVE DEVICES

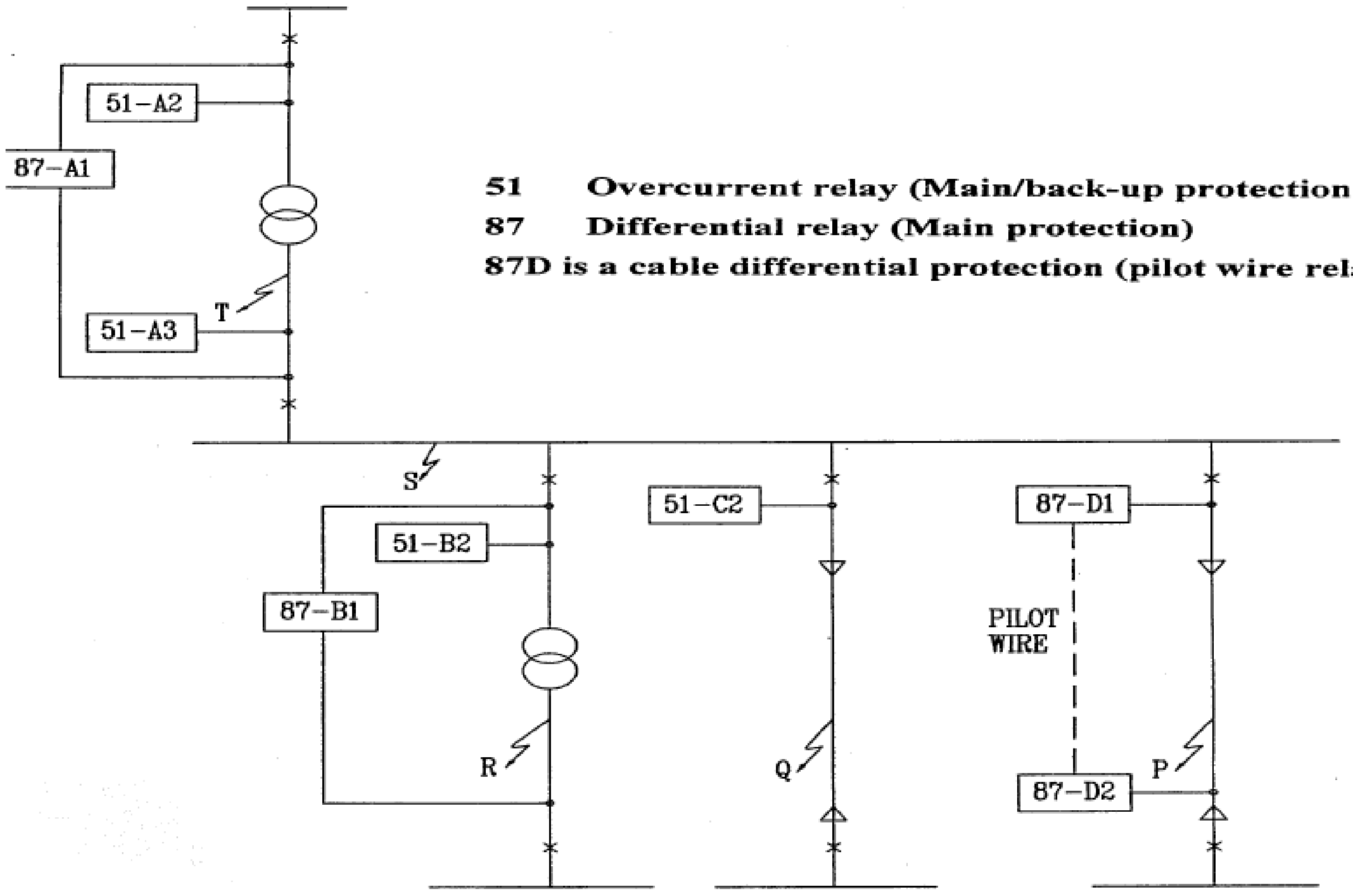
- IEC USES DRAWINGS TO REPRESENT RELAYS. EASIER TO UNDERSTAND BUT MORE DIFFICULT TO DRAW.
- ANSI USES NUMBERS. MORE CONVENIENT BUT NEED TO REMEMBER

ANSI NO.	DEVICE
27	UNDERVOLTAGE RELAY
32	DIRECTIONAL POWER RELAY
49	THERMAL RELAY
50/50N	INSTANTANEOUS OVERCURRENT EARTH FAULT RELAY
51/51N	AC TIME OVERCURRENT/EARTH FAULT RELAY
52	AC CIRCUIT BREAKER
59	OVERVOLTAGE RELAY
64	RESTRICTED EARTH FAULT RELAY
67	AC DIRECTIONAL OVERCURRENT RELAY
81	FREQUENCY RELAY
86	LOCKOUT RELAY
87	DIFFERENTIAL PROTECTIVE RELAY

ANSI STANDARD



ZONES OF PROTECTION FOR TYPICAL POWER SYSTEM



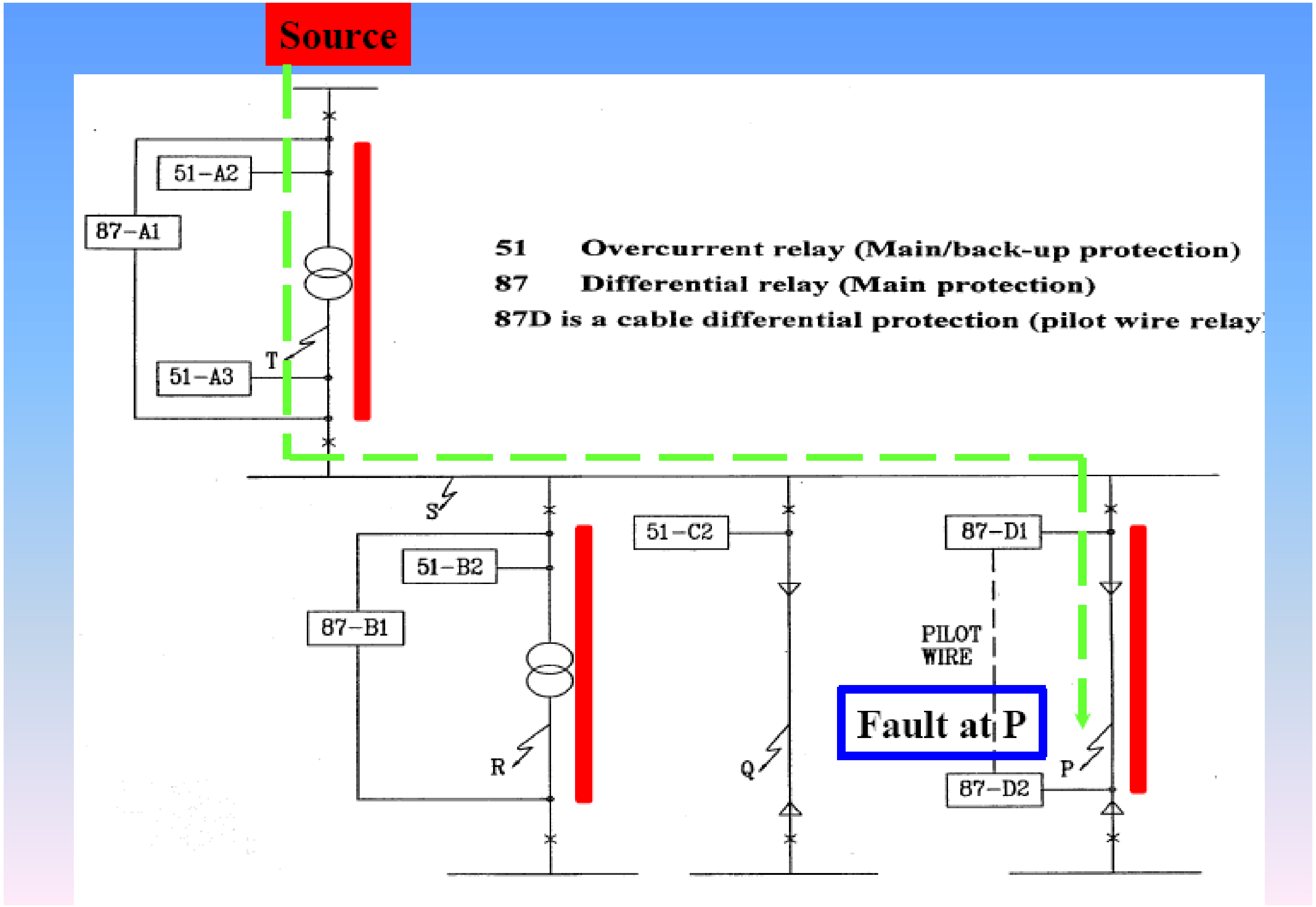
51 **Overcurrent relay (Main/back-up protection)**

87 **Differential relay (Main protection)**

87D is a cable differential protection (pilot wire relay

Sequence of relay operate during fault

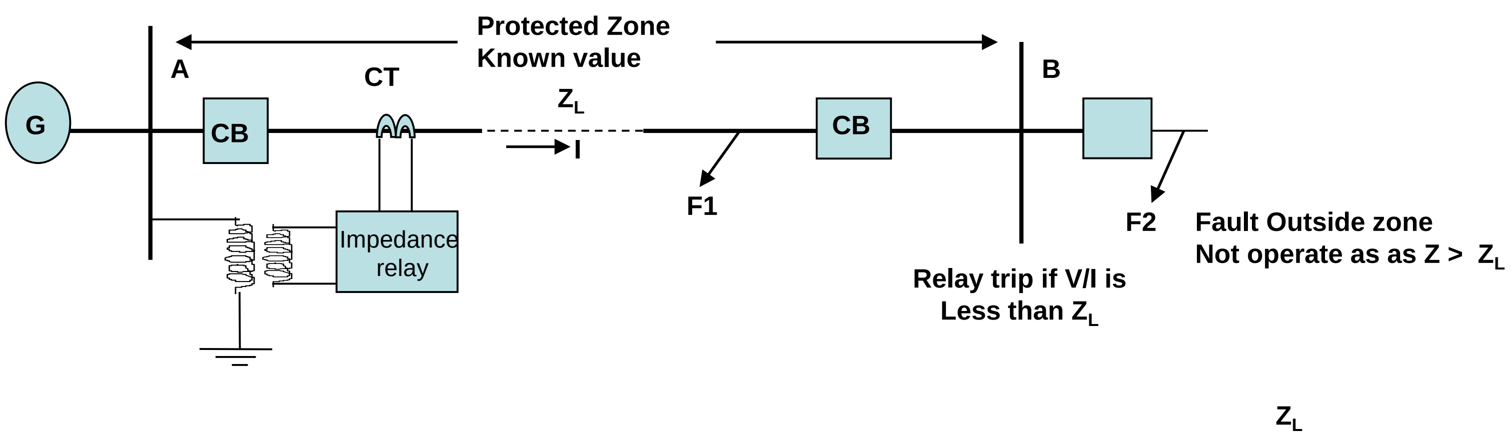
FAULT LOCATION	MAIN PROTECTION	BACK-UP NO. 1	BACK-UP NO. 2
P	D1/D2	A3	A2
Q	C2	A3	A2
R	B1	B2	A3
S	A3	A2	
T	A1	A2	


Source
51–A2
87–A1
T
51–A3
51 Overcurrent relay (Main/back-up protection)
87 Differential relay (Main protection)
87D is a cable differential protection (pilot wire relay)
S
51–B2
87–B1
R
51–C2
Q
87–D1
PILOT WIRE
Fault at P
P
87–D2

Distance Impedance Relay

> We had discussed so far the relay operates upon magnitude of the current or power in the protected circuit.

- There is another group of relays in which the operation is governed the ratio of applied voltage to current in the protected area.
- Such relays called distance or Impedance Relays.
- Relay to operates when the torque of the current element is opposed by the torque produce by the voltage element i.e. when the ratio V/I is less than a pre-determined value.



Characteristic and effect of disturbance

OVERVOLTAGE

- LIGHTNING STRIKE (DIRECT OR INDIRECT).
- SWITCHING SURGE.
- RESONANCE OF HARMONICS.
- PHYSICAL CONTACT WITH HIGHER VOLTAGE SYSTEM.
- DURING EARTH FAULTS FOR SOME TYPES OF SYSTEM EARTH.
- CAN CAUSE INSTALLATION FAILURE.

UNDERVOLTAGE

- CAUSED BY REACTIVE POWER DEMAND.
- CAN OCCUR DUE TO HIGH CURRENT WITH LOW POWER FACTOR DURING SHORT CIRCUIT OR MOTOR STARTING.
- EFFECTS:

(1) 10% UNDERVOLTAGE INCREASES RUNNING MOTOR CURRENT BY ABOUT 10% BECAUSE OF CONSTANT MECHANICAL LOAD

(2) 20% UNDERVOLTAGE DECREASES MOTOR STARTING CURRENT TO 80% AND THE STARTING TORQUE TO 64%

(3) 30% UNDERVOLTAGE – POSSIBLE CONTACTOR CHATTER/DROP-OUT.

UNDERFREQUENCY

- REAL POWER DEFICIENCY.
- MAY BE DUE TO LOSS OF MAJOR POWER STATION IN TRANSMISSION NETWORK.
- CAUSES MECHANICAL DAMAGE TO GENERATORS AND OVERHEATING OF INDUCTION MOTORS.
- USE OF UNDERFREQUENCY RELAY TO SHED LOAD.
- OPPOSITE OF THIS IS OVERFREQUENCY WHEN A POWER STATION LOSES SOME MAJOR LOADS.

OVERLOAD

- HIGHER CURRENT CAN CAUSE EXCESSIVE I^2R LOSSES AND RAISE EQUIPMENT TEMPERATURE.

- CAN CAUSE INSULATION FAILURE OR HOT SPOTS.

TYPES OF FAULTS

THREE-PHASE FAULTS.

- MOST SEVERE OF ALL FAULTS.
- RARE IN PRACTICE WITH EXCEPTION OF BOLTED FAULTS.
- MAXIMUM FAULT LEVELS WIDELY USED IN POWER SYSTEM ANALYSIS.

EARTH FAULTS

- MOST COMMON OF ALL SYSTEM FAULTS (85%).
- CALCULATION REQUIRES POSITIVE, NEGATIVE AND ZERO SEQUENCE IMPEDANCE COMPONENTS.

SHORT-CIRCUIT (OVERCURRENT)

- INSULATION FAILURE.
- DAMAGE TO EQUIPMENT.
- INJURIES.
- VOLTAGE COLLAPSE.

EARTH FAULT

- PHASE TO EARTH FAILURE.
- CURRENT FLOW THROUGH EARTH
- MAY BE LIMITED BY EARTHING DEVICE
- MAY BE INTERMITTENT OR ARCING.
- POSSIBLE OVERVOLTAGES.

OTHER SYSTEM FAULTS.

- PHASE-TO-PHASE, TWO PHASE-TO-EARTH, THREE PHASE-TO-EARTH FAULTS. USUALLY OF LIMITED INTEREST.

THE ***MOST COMMON FORM OF PROTECTION*** IS AGAINST ***SHORT-CIRCUITS AND EARTH FAULTS*** BY USING ***OVERCURRENT-EARTH FAULT RELAYS AND FUSES.***

FAULT CURRENT FLOW IN POWER SYSTEMS

- FAULT CURRENT FLOW DEPENDS OF THE TYPE OF SYSTEMS

- RADIAL SYSTEM

(1) FAULT CURRENT FROM THE SOURCE UNTIL THE FAULT

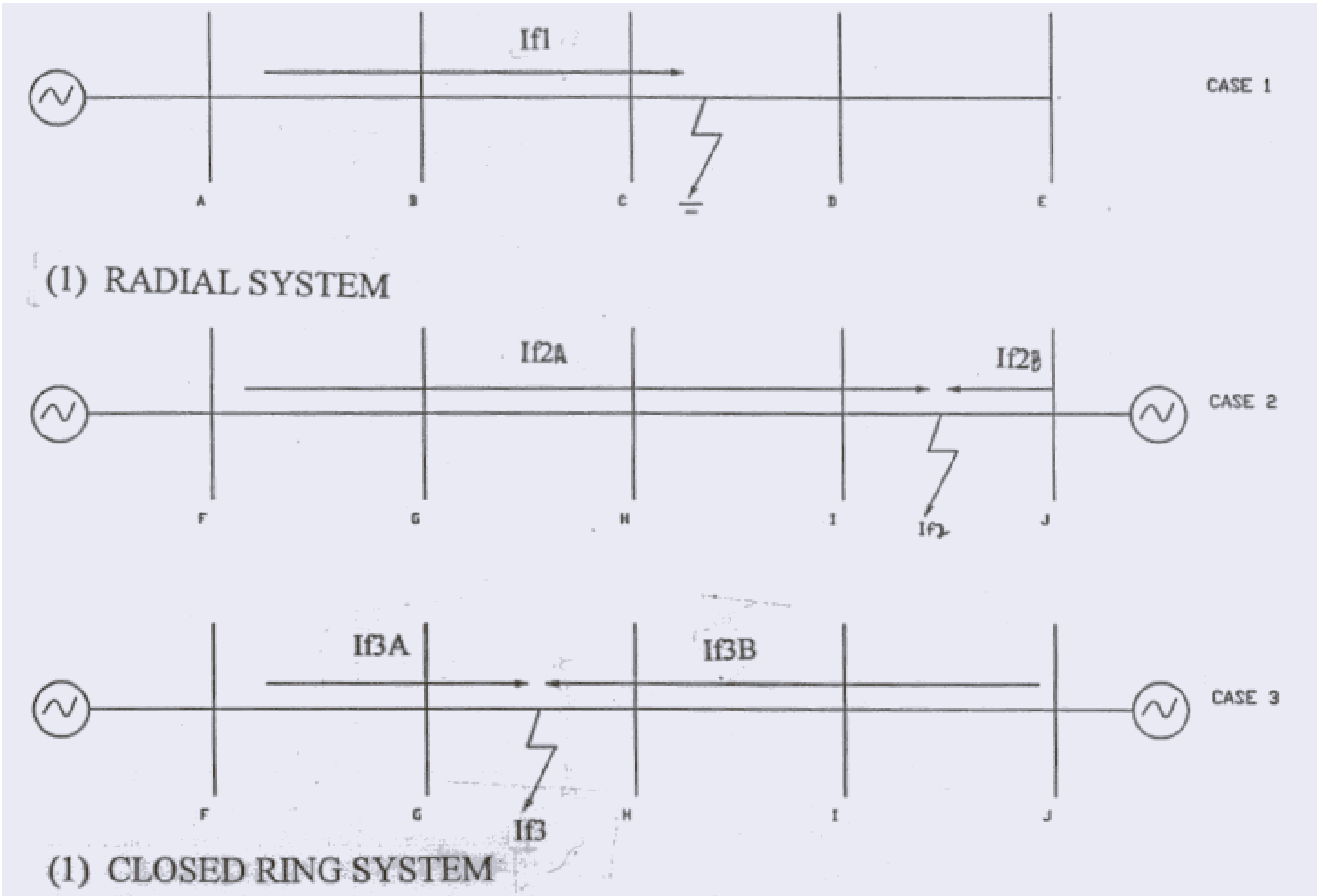
(2) NO FAULT CURRENT BEYOND THE FAULT POINT

(3) TYPICAL OF ALMOST ALL DISTRIBUTION AND INDUSTRIAL SYSTEMS

- CLOSED RING SYSTEM

(1) FAULT CURRENTS IN TWO DIRECTIONS TOWARDS THE FAULT

(2) DIRECTION AND MAGNITUDE OF CURRENT THROUGH RELAY WILL DEPEND ON FAULT LOCATION. CURRENT FLOW CAN BE IN EITHER DIRECTION.


If1
CASE 1
A
B
C
D
E
(1) RADIAL SYSTEM
If2A
If2B
CASE 2
F
G
H
I
J
If3A
If3B
CASE 3
If3
(1) CLOSED RING SYSTEM

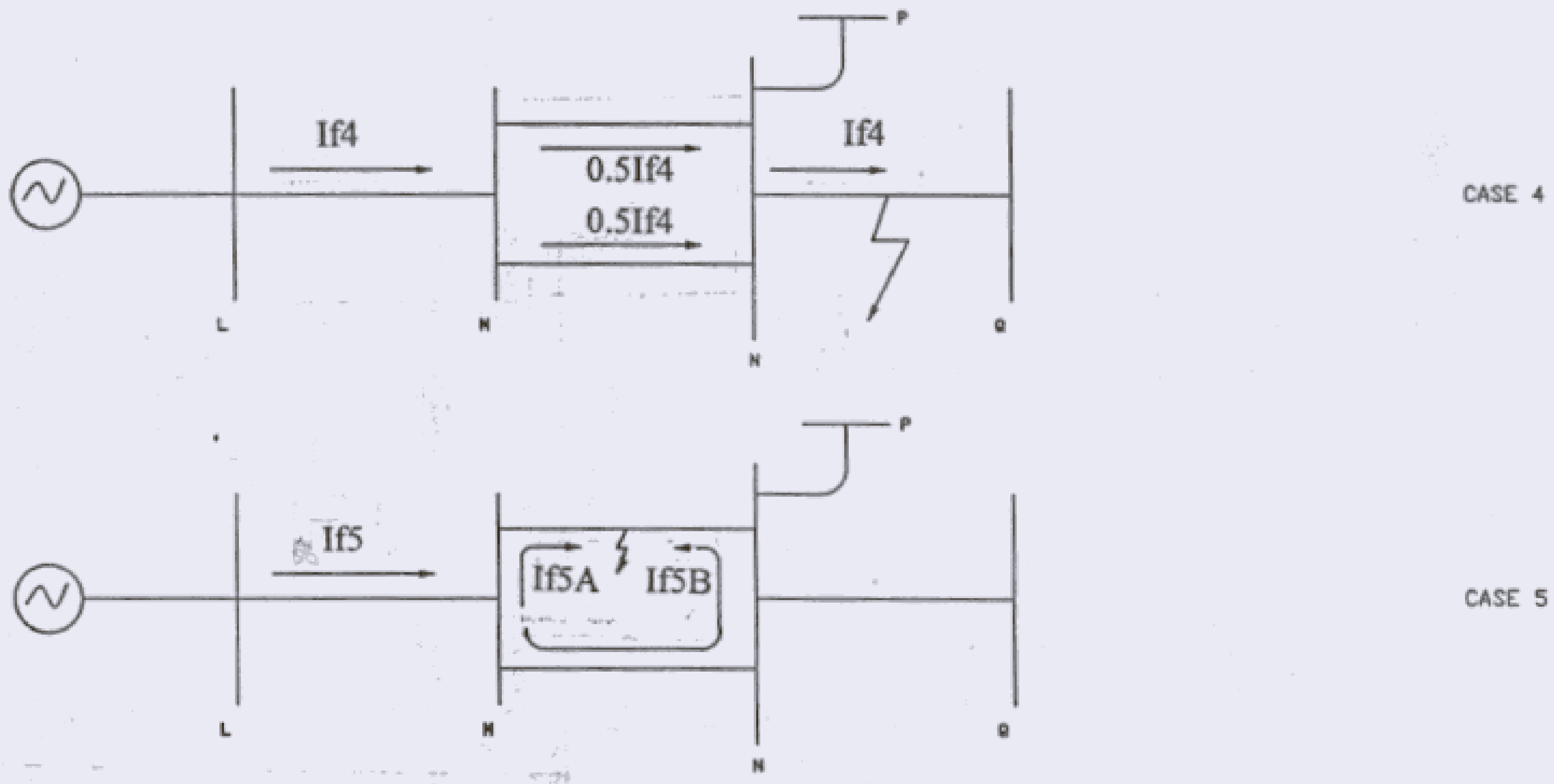
- PARALLEL CIRCUITS

(1) FAULT CURRENT THROUGH PARALLEL CIRCUITS DEPENDS ON FAULT LOCATION.

(2) FOR EXTERNAL FAULTS, EQUAL CURRENTS THROUGH PARALLEL CIRCUIT.

(3) FOR INTERNAL FAULTS, TWO UNEQUAL CURRENTS.

(4) VERY COMMON FOR UTILITY TRANSFORMERS BUT NOT SO WIDELY USED IN INDUSTRIAL SYSTEM.



(1) PARALLEL CIRCUIT

FAULT CURRENT FLOW IN POWER SYSTEMS

Part 2

Current Transformer

Demo Cable Spike

Current Transformer

Definition:

CT is a device that transforms a high primary current to low secondary current

Functions:

To reduce the primary current to secondary value in the proportion to the secondary value

To insulate the relays & instrument metering from high voltage

Reserve for CT Photo if available

Metering CT v/s Protection CT

Metering CT accuracy shall be in the region of 10% to 120% of their rated.

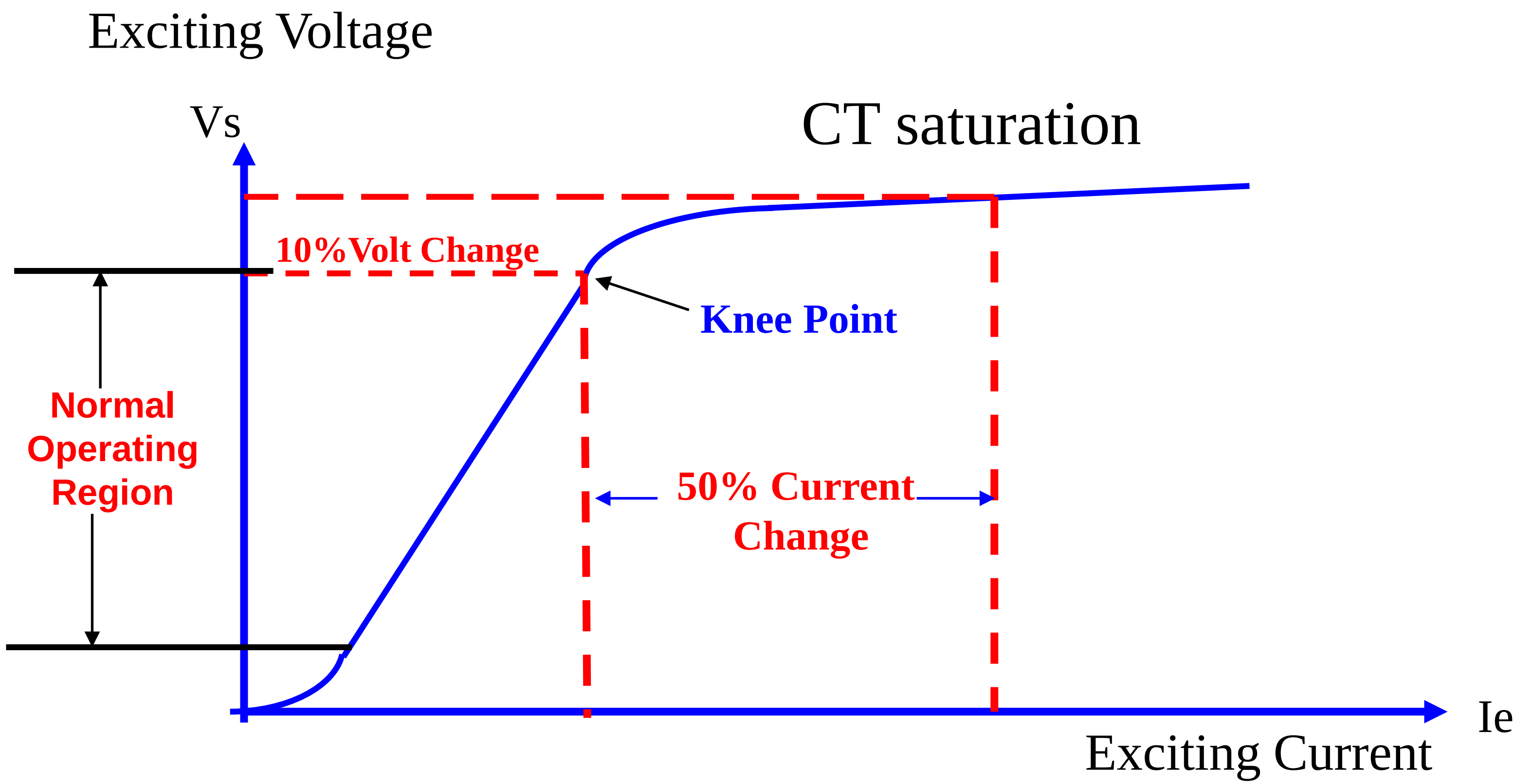
Protection CT accuracy shall be in excess their rated current i.e. approx 10 times.

Protective CT always lager than metering CT.

To provide accuracy required, the CT shall operate in liner motion to their magnetizing curve – knee point.

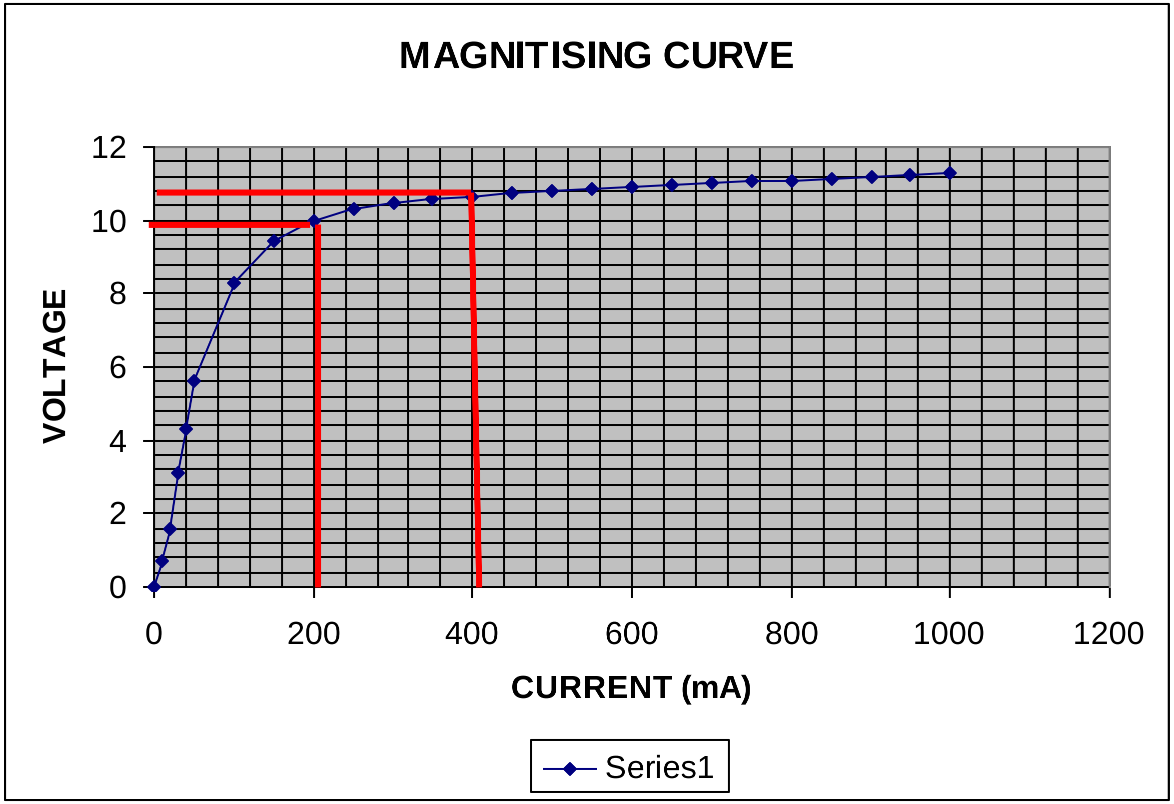
Knee point is defined as when ***secondary voltage increase 10% for a 50% Increase in exciting current . This is also called CT saturation***

Knee Point Magnetizing Curve



In the event of short circuit, the secondary current of the measuring CT will be restricted to a very small increase.

Date: 26/03/2008 - INSTEP



CT RATIO 60/1 A

VA 5

CLASS 2.5

COMMON RATINGS – Protective CT

PRIMARY CURRENT : As specified by manufacture

SECONDARY CURRENT : 1A or 5A
(5A used for indoor, 1A used for outdoor or long distance installation)

RATIO:
Transformation ratio = Rated Pri. Current / Rated Sec. Current
Example: 250/5, 400/5, 1500/5, 2500/5

VA OUTPUT (burden): Typically 15VA or higher

Note: Burden is express in impedance (ohm) of the circuit connected to the Secondary. Burden in VA can be calculated i.e. P (VA) = $Is^2 \times Z_b$

BURDEN:

> The load of a CT is called burden and be expressed either a VA load or as an impedance.

> VA is taken at the CT nominal secondary current.

> Example: 5 VA burden on 1 A CT would have an impedance of 5 ohm.

5 VA / 1 A = 5 volt

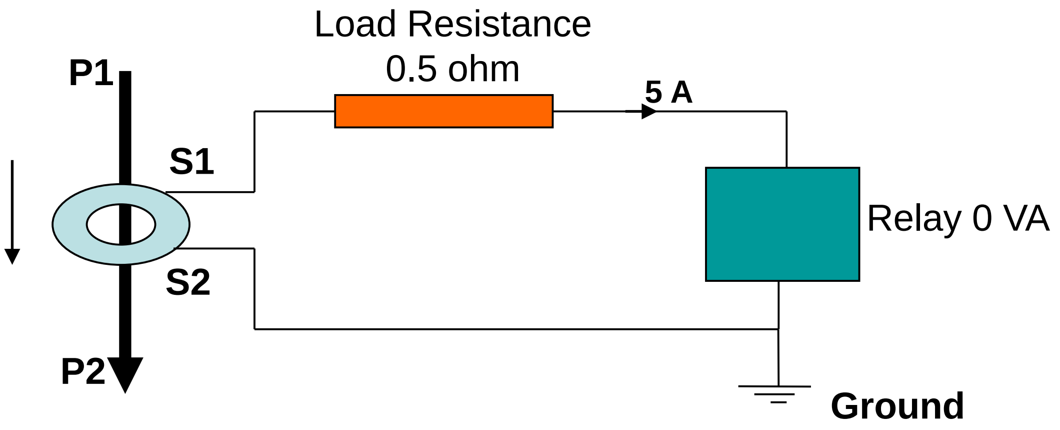
impedance = 5 volt / 1 A = 5 ohm

> All burdens are connected in series, the increase in impedance to increases the burden on the transformer.

> A *CT is unloaded when secondary of CT is short-circuited*, at this condition VA become 0 as the voltage is 0 volt.

> Standard rated burden: 2.5, 5, 7.5, 10. 15 & 30 VA

Example 1:



P (VA) $= Is^2 \times Zb$

$= 5^2 \times 0.5$

$=$ **12.5 VA**

CT Polarity
P1 & P2 = Primary Terminal
S1 & S2 = Secondary Terminal

Accuracy Limit Factor

Is the largest current value where the protection CT is still able to maintain a reasonable accuracy. It is the *ratio of the accuracy limit to the rated current of the CT* i.e.

Accuracy Limit Factor :

= Accuracy limit current primary / Rated Primary Current
= Accuracy limit current secondary / Rated Secondary Current

Accuracy Class

Two accuracy classes are: 5P & 10P which is given composite error at rated accuracy limit of 5% and 10%.

- **Standard accuracy limit factor are: 5, 10, 15, 20, & 30**
- **15VA class 5P20 meaning that: 15 VA burden, having not more than 5% error at 20 times rated current.**
-

Standard accuracy limit factor for 5, 10, 15, 20 & 30

Class	Current error at rated Primary current (%)	Phase displacement at rated current (minutes)	Composite error at rated accuracy limit primary current (%)
5P	+/- 1	+/- 1	5
10P	+/- 1	-	10

There are various class of current transformer:

*** Class 0.1 - for precision testing standard CT**
*** Class 0.2 - for precision meters and relays**
*** Class 0.5/1 - for commercial grade meters**
*** Class 1 / 3 - for general industrial application**
*** Class 5P and 10P - for protection**

- **Class X CT may be used for general protective purposes (high impedance) or metering**

Short Time Limit Factor

- When a CT is used in the system, it may be subjected to fault current that many times larger than its primary current rating.
- The CT used must be able to withstand the effect of this fault current or a period of times.
- ***This multiple current which CT can carry without mechanical and thermal damage is called "Short Time Factor"***

CT ratio:

- The most important property of CT which determine the secondary current value or the current ratio value.
- Normal secondary current CT is 1A or 5A.

- The typical CT specification is shown below;

EX: CT 500/1A, 15VA 5P 10
500/1A- Current ratio
15VA - Burden
5P - Class and error
10 - ALF (accuracy limit factor)

> Other parameter of CT which can be calculated are:

1. CT impedance, Z_{ct} = Rated Burden / (Secondary current) ^{2}
$= 15 / 1^2 = 15$ ohm

2. Maximum secondary output current within 5% error
= ALF x Rated secondary current
= 10 x 1 = 10A + 5%

3. CT operating voltage,
Vo/p = CT impedance x maximum secondary current
= 15 x 10 = 150 V

or Vo/p = $\frac{\text{Rated Burden x ALF}}{\text{Rated secondary current}}$

= (15 x 10) / 1 = 150 V

4. **Maximum load VA connected to CT**

= Maximum voltage x maximum current
= 150 x 10 = 1500 VA
or VA o/p = Rated Burden x ALF 2
= 15 x 10 2 = 1500 VA

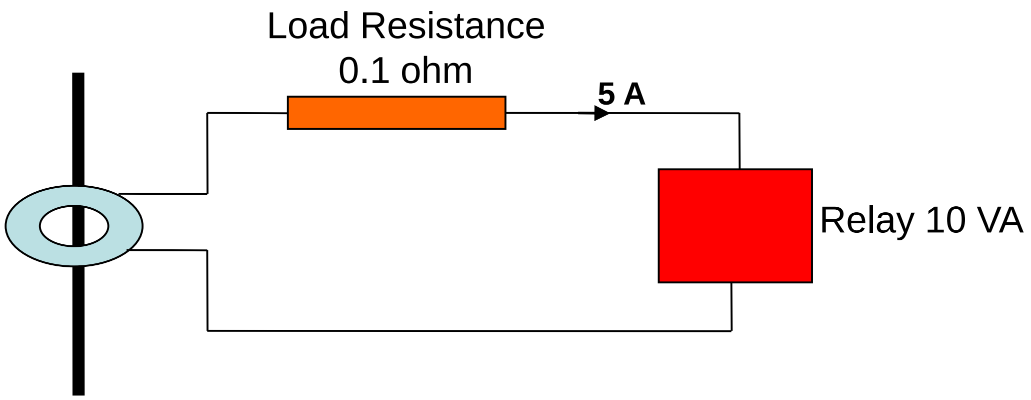
> For safety, when the meters or relays are disconnected from the circuit, CT must be discharged and shorted at secondary to prevent high voltage and spark occur between the two secondary terminals.

Lightning Power Lines

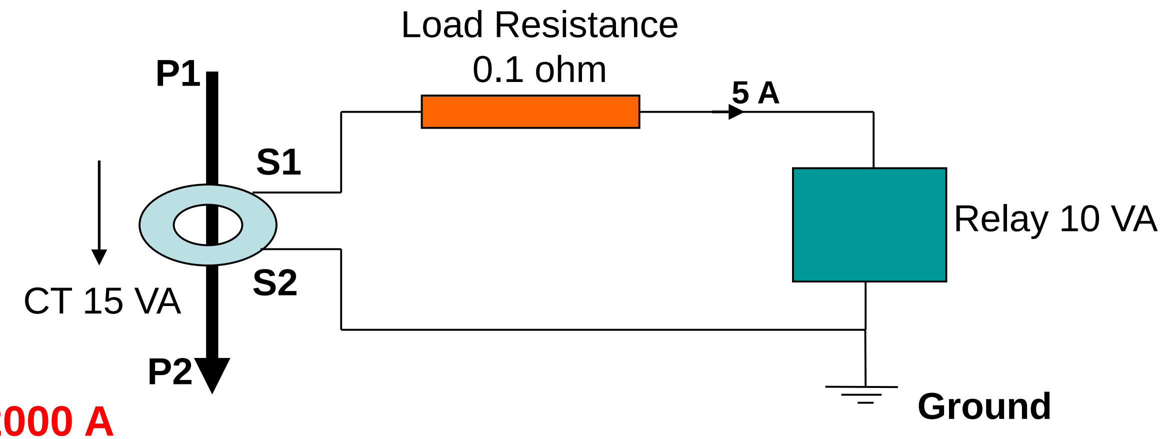
Exercise1:

Given are 2000/5 A, Class 5P10, 20 VA Current Transformer, list the value of:

- **Rated Primary Current**
- **Rated Secondary Current**
- **Rated Transformation Ratio**
- **Accuracy Class & specified composite error of the CT**
- **Accuracy Limit Factor & accuracy limit, current in primary**
- **Rated Burden at relay rating 10 VA**
- **Indicate power flow direction, Pri/Sec polarity & grounding point**



Solution Exercise1:



- **Rated Primary Current = 2000 A**
- **Rated Secondary Current = 5A**
- **Rated Transformation Ratio = 2000/5**
- **Accuracy Class = 5P**
- **Composite error of the CT = +/- 5%**
- **Accuracy Limit Factor = 5P10**
- **Accuracy limit given = 10 (Primary Accuracy limit Current is 10 times of rated primary current i.e. 10 x 2000 A = 20kA, this means the CT will have a composite error at 5% up to a maximum primary current 20 kA.)**

- **Rated Burden = $I^2 R = 5^2 \times 0.1$ = 2.5 VA. (Relay rating 10 VA), therefore total VA = 10 + 2.5 = 12.5 VA (CT Rating shall be 15 VA)**

Measuring CT

Ratings of measurement CT are terms in Burden and Class i.e. 15VA Class 0.5

For classes 0.1 to 1, the current error & phase displacement at rated frequency shall not exceed the value the value given in below table:

Class	+/- Percentage current (ratio) error at % of rated current shown below			Phase displacement at % of rated current shown in minute		
	10 up to but not incl. 20	20 up to but not incl. 100	100 up to 200	10 up to but not incl. 20	20 up to but not incl. 100	100 up to 200
0.1	0.25	0.2	0.1	10	8	5
0.2	0.5	0.35	0.2	20	15	10
0.5	1	0.75	0.5	60	25	30
1	2	1.5	1	120	90	60

Limit of error Accuracy for Class 0.1 to 1

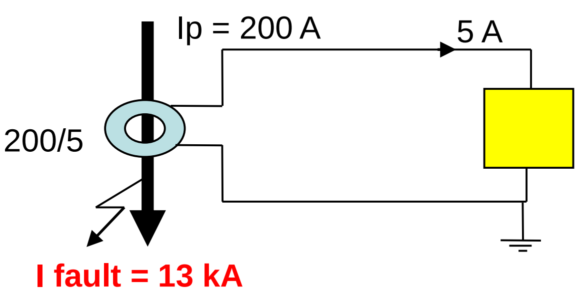
Measuring CT

For classes 3 and 5, the current error at rated frequency shall not exceed the value given as per table below when secondary burden is any value From 50% to 100% of the rated burden

Class	+/- Percentage current at percentage of rated current shown below	
	50	120
3	3	3
3	5	5

Limit of Accuracy for Class 3 and 5

Example of CT Calculation



i. Normal Condition:
Ip = 200 amp
Is = 5 amp

ii. During fault condition:

Isc = IP = 13,000 amp

Isc of CT = $\frac{13,000}{200/5}$ = $\frac{13,000}{40}$ = **325 amp** (65 times then Ip)

iii. Short Time Factor:

Is = $\frac{325A}{5A}$ = **65 A** (65 times then Is)

Solution

Normal CT up 20 times accuray;

= $\frac{13000}{CTR}$ (20 x 5 A)

CTR = $\frac{13000}{100}$ = 130

Ip = Isec x 130
5 A x 130 = 650 amp

CTR = 650 / 5 A

Cross Check

$\frac{13000}{650/5A}$ = 100

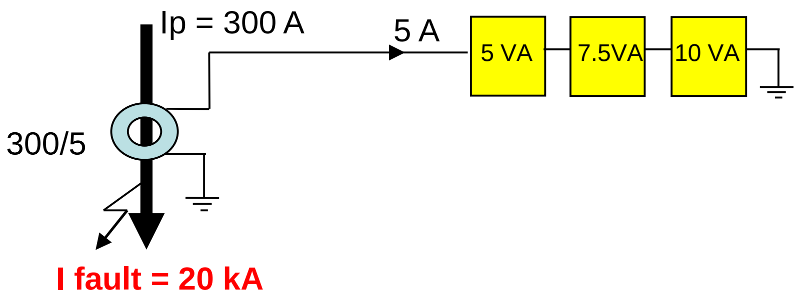
= 100 / 5 A = **20 times**

CT Isc max.

= 20 times accuracy x 5 A
= 100 Amp

Ip = 100 x CTR
100 x 200 / 5 = 4000 Amp (Isc)

Exercise 2:

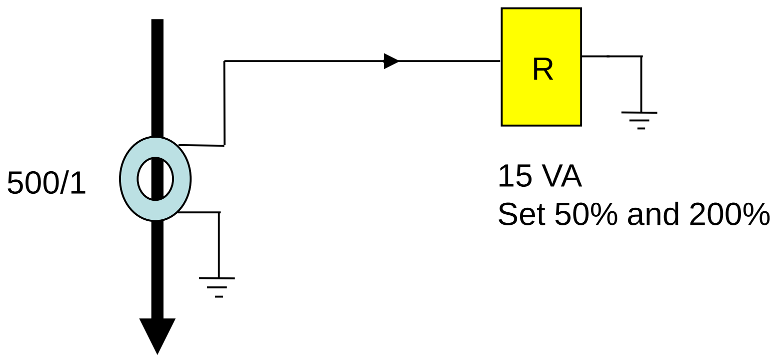


Calculate:

- **Isc during fault for Primary & Secondary**
- **Short Time Factor Current**
- **CT sizing i.e. ratio and burden at accuracy up to 20 times**
- **Propose class of CT**

15 minute

Exercise 3:

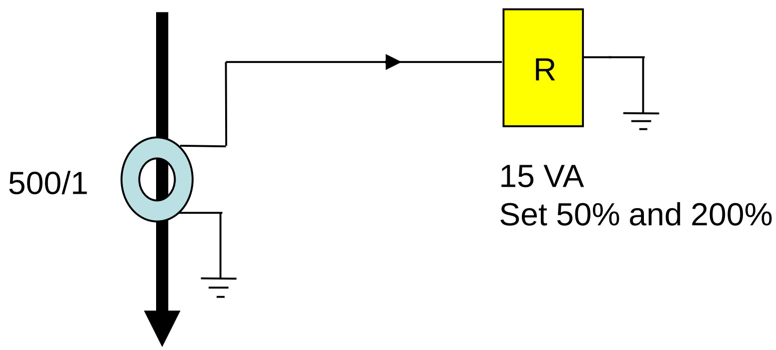


Calculate:

- Voltage across the CT at given setting
- Impedance
- Knee point voltage if relay to be maintained at 20 times of setting

10 minute

Exercise 3:



Solution:

- **Voltage across CT at given setting:** **At 50% V = 15 VA / 0.5 A = 30 Volt**
  200% V = 15 VA / 2 A = 7.5 Volt

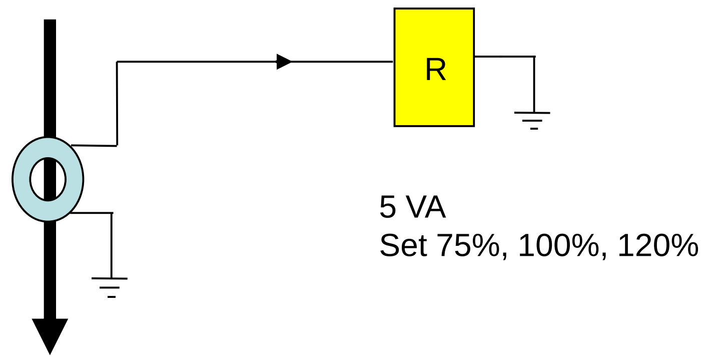
- **Impedance at 50% = 30 V / 0.5 A = 60 ohmn**
  at 200% = 7.5 V / 2 A = 3.75 ohm

- **Knee point Voltage at 50% = 20 x 30 V = 600 Volt**
  at 200% = 20 x 7.5 V = 150 Volt

Exercise 4:

1. **I pri. 750A**
2. **I pri. 900 A**

800/5



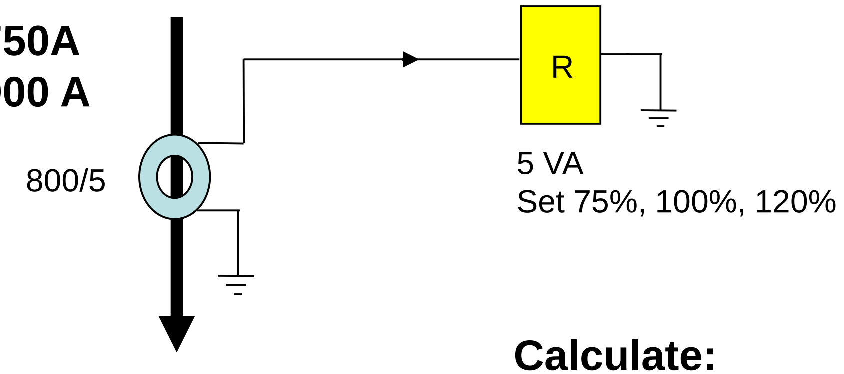
Calculate:

- **I Secondary at given Primary current**
- **Relay current to operate at given setting**

10 minute

Exercise 4:

1. **I pri. 750A**
2. **I pri. 900 A**



Calculate:

- **I Secondary at given Primary current**
- **Relay current to operate at given setting**

Solution:

I secondary at I Primary 750 A = 4.68 A
I secondary at I Primary 900 A = 5.62 A
Relay to operate @ 75% = 3.75 A
@ 100% = 5 A
@ 120% = 6 A

Voltage Transformer

- **An instrument transformer used to step down the value of secondary voltage to the required low voltage value for meters and relays, usually is 110 VAC.**
- **Used also for Under Voltage Relay to detect voltage drop in the circuit.**
- **For safety reason, when meter or relay are disconnected or removed from potential transformer, the potential transformer must be rack out or a fuse connected to the potential transformer to be removed**

Part 3

Short Circuit Definitions

Circuit Breaker Rating

A mechanical device for making & interrupting an electrical circuit,
The CB are intend to operate under all conditions. Major duties are imposed on the CB when it is in services. Under fault conditions, the CB is required to perform the following three (3) duties:

- **Must be cable of opening the faulty circuit & breaking the fault current**
- **Must be capable of being closed on to fault**
- **Must be capable of carrying fault current for short time while other CB in series is clearing the fault.**

Corresponding to the above, normally the CB may have three (3) rating e.g. ***Breaking Capacity, Making Capacity & Short Time Capacity***

Breaking Capacity

Always stated at RMS value of fault current at the instant of contact separation i.e. the highest value of short-circuit which a CB is capable of breaking under specified conditions of recovery voltage and power frequency.

$MVA = \sqrt{3}\ kV \times kA$

MVA = Breaking Capacity
kV = Rated Voltage
kA = Rated Braking Current

When fault, there will be considerable asymmetry in the fault current due
To presence of d.c component (refer short circuit waveform)

Making Capacity

May happen or possibility of the CB to closing or making during short circuit conditions without hesitation as contact touch.

Rated as Peak Value during 1^{st} cycle of current wave after the closure of the CB.

The rated of making capacity shall be around 2.5 times the RMS value of rated breaking capacity.

Short Times Capacity

It is the short times period for CB can carry fault current in closed position at specific time.

The value normally in kA i.e. short circuit rating usually in 1 or 3 sec.

RATED CURRENT:

> The continuous current that CB can carry without exceeding the standard temperature rise

SHORT CIRCUIT RATING (Fault Level):

- **This the three phase MVA rating of the CB or Transformer**

MAX. SHORT-CIRCUIT INTERUPTING CURRENT RATING

> This is the maximum current of CB can interrupt at reduce voltage

OVERCURRENT:

> Any current in excess of the rated equipment or the ampicity of a conductor. It may result from a short circuit, earth fault or overload

OVERLOAD:

> Operating of equipment in excess of normal full-load rating or of a conductor in excess of rated ampicity which it persist for a sufficient length of time, would cause damage or dangerous overheating.

A fault, such a short circuit or earth fault is not an overload.

RATING : IEC specifications IEC 298, 694, 56, (IEC 62271-100& 200)

Rated Insulation level	A group of rated withstand voltages which the insulation must withstand. e.g for 12 kV breaker **power frequency withstand voltage is 28 kV and impulse voltage is 75 kV**.(pass if 2/15 fail or pass 3 shots consecutively)
Operating sequence	O- t - CO - t' - CO where **t = 3 min or 3 sec and** **t' = 3 min**
Transient Recovery	Prospective transient recovery voltage of circuit which circuit breaker shall capable to withstand. E.g. **20.6kV for 12kV rating**

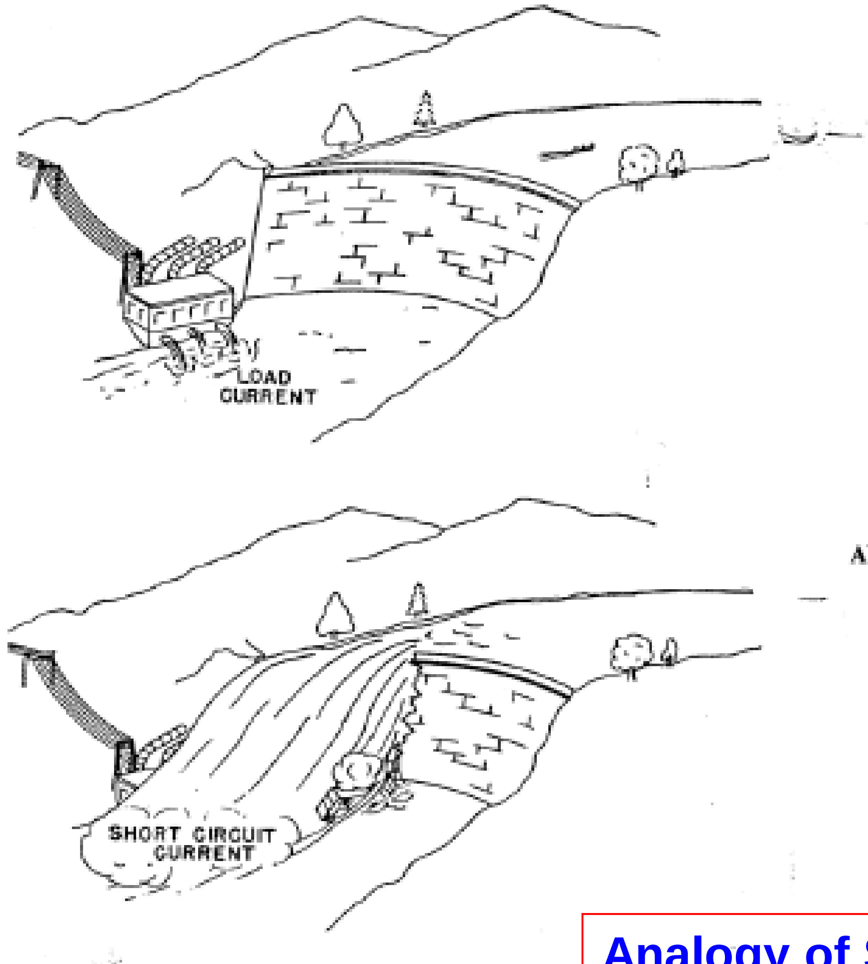
CB Operating Sequence

Category	Operating sequence for short circuit tests
P-1	*O - t - CO*
P-2	*O - t - CO - t - CO*

O - Breaking operation *t - Specific time interval*
CO - Making operation followed by breaking

P1 - Ultimate Short Circuit Breaking Capacity (Icu), require to perform reduced service. Possible to replace after short circuit operation

P2 - Service Short Circuit Breaking Capacity (Ics), require to perform normal service.



Height of dam (Pressure)	Voltage
Water flow	Current
Pipe size	Conductor size
Taps or valves	Switchgear
Burst dam	Short-circuit

ANALOGY BETWEEN WATER AND ELECTRICAL SYSTEMS

Analogy of Short Circuit

Types of short circuits

1) Symmetrical short circuit
2) Asymmetrical short circuit

3 Phase / 3 phase to ground fault is a symmetrical short circuit. All three conductors are equally involved and carry the same short circuit current.

Single phase to ground fault, phase to phase fault are some examples of *asymmetrical short circuit*. The magnitude of current varies in all the phases during an asymmetrical short circuit.

Transient

Transient means passing with time.

For example, a damped oscillator needs some time after a temporary disturbance to reach the equilibrium again, and after a permanent change in system variables, to reach the new equilibrium.

A **transient** system is a short-lived oscillation in a system caused by a sudden change of voltage, current, or load. Engineers use voltage regulators and surge suppressors to prevent transients in electricity from affecting delicate equipment.

Transient Fault

In power engineering, a **transient fault** is a fault that is no longer present if power is disconnected for a short time.

Faults in overhead power lines are often transient.

For example, if a tree contacts a line momentarily, this is a transient fault.

Similarly, if an arc is created in a line due to lightning, the arc will be fed by system power, but if the power is disconnected for a short time, the arc will disappear, and power may be reconnected, and the line will operate normally.

BEHAVIOUR OF SHORT CIRCUIT CURRENT WAVEFORMS

If envelopes of the peaks of the current waves are symmetrical about the zero axis is called ***symmetrical current.***

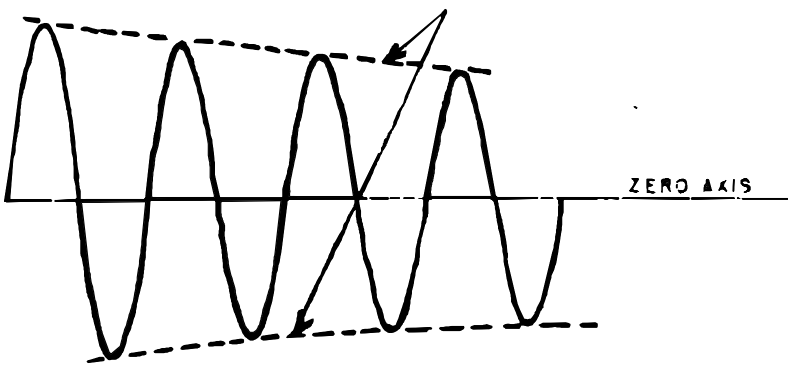


Figure 2.1 : Symmetrical alternating current from a short-circuited generator.

BEHAVIOUR OF SHORT CIRCUIT CURRENT WAVEFORMS

If envelopes of the peaks of the current waves are not symmetrical about the zero axis is called ***asymmetrical current***.

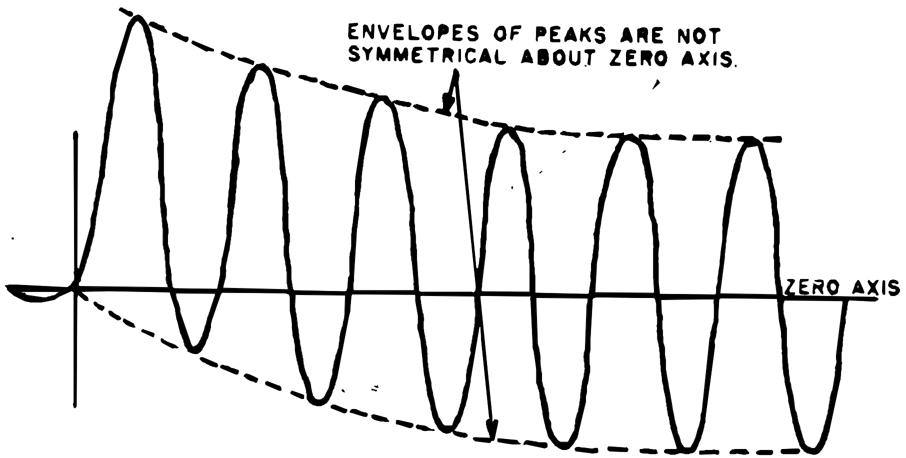


Figure 2.2: Trace of oscillograph of a typical short-circuit current.

WHY SHORT CIRCUIT ARE ASYMMETRICAL

Short circuits can happen anytime in the voltage wave depending on the system impedance to cause some offset of the current wave.

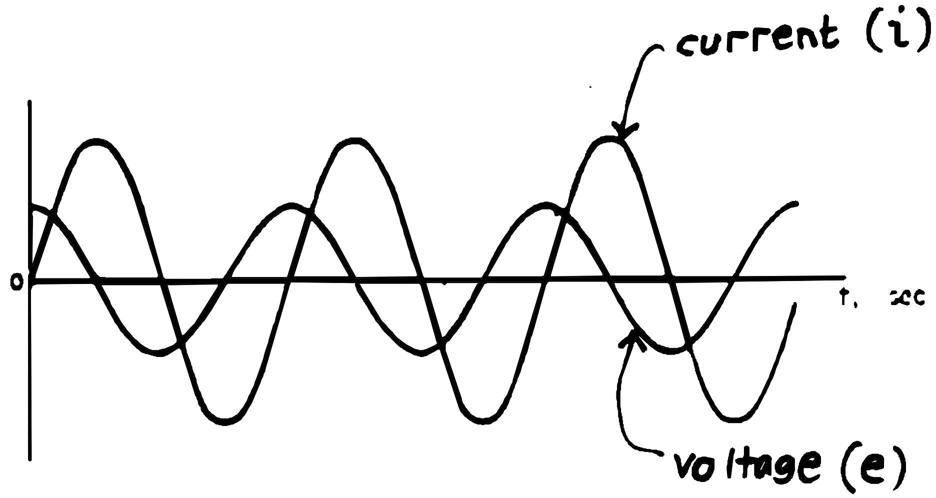


Figure 2.3 : Asymmetrical current showing the offset of the current wave with respect to the voltage wave.

ASYMMETRICAL CURRENT WAVEFORMS

The point on the voltage wave at w/c the SC must occur to produce max. asymmetry depends on the ratio of reactance to resistance (X/R) of the circuit.

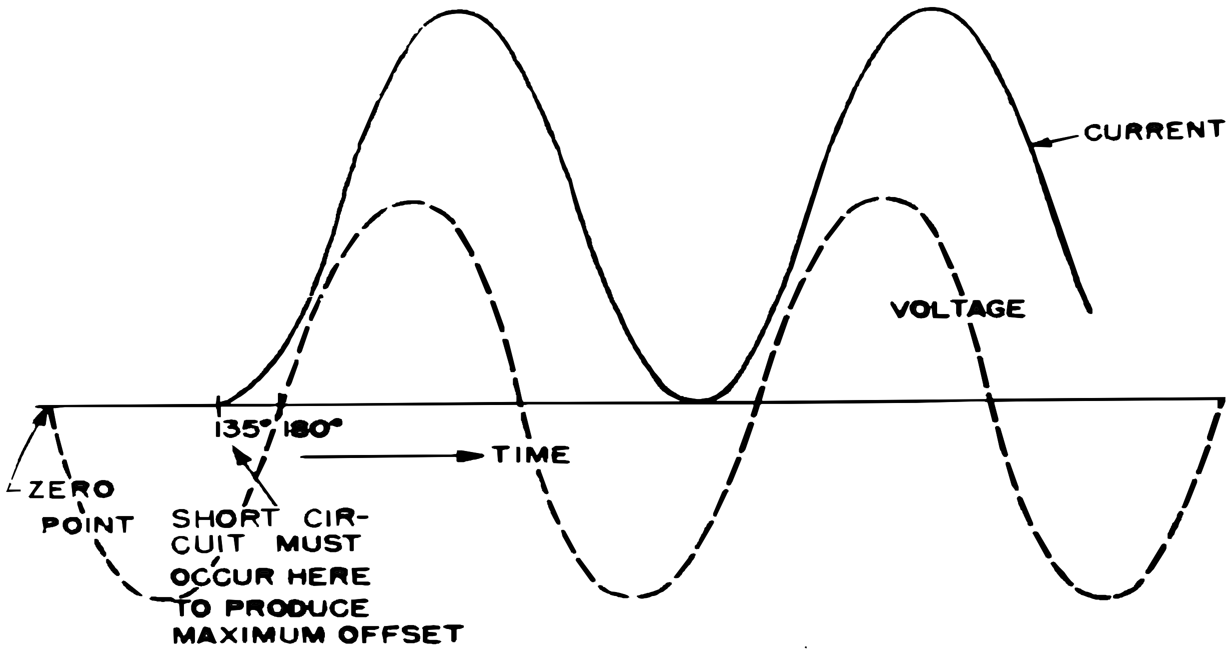
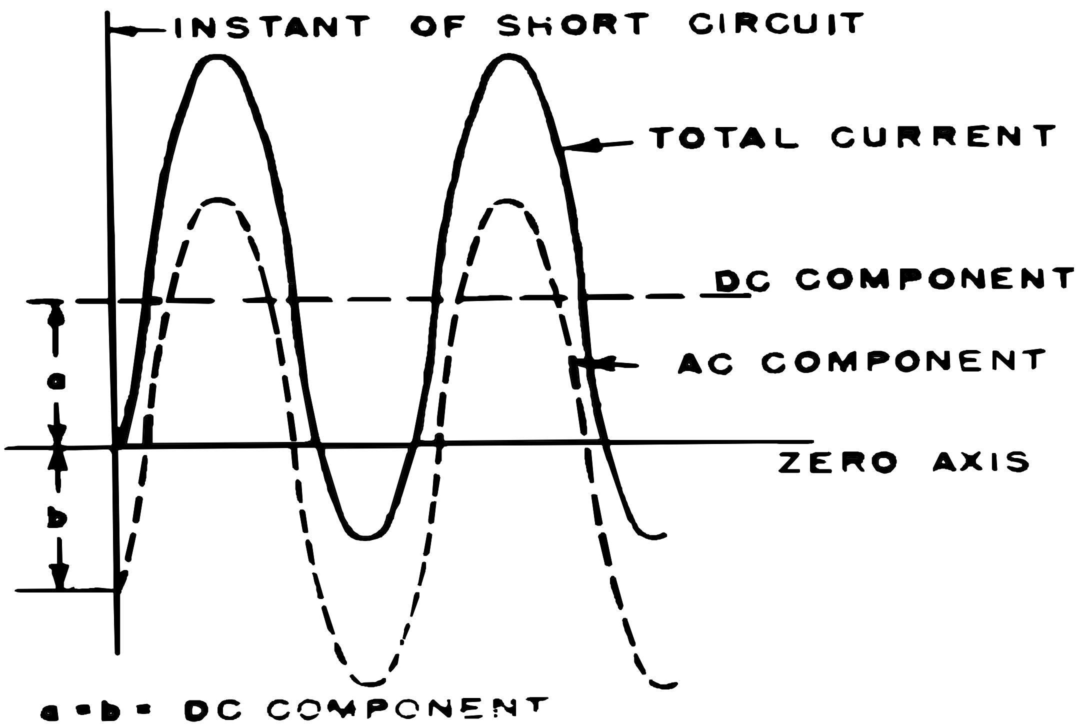


Figure 2.4 : Short-circuit current and generated voltage in a circuit with equal reactance and resistance.

COMPONENTS OF ASYMMETRICAL CURRENTS

Asymmetrical current are difficult to interpret for CB and relay setting and some complicated formulas to calculate magnitude unless resolved into components.

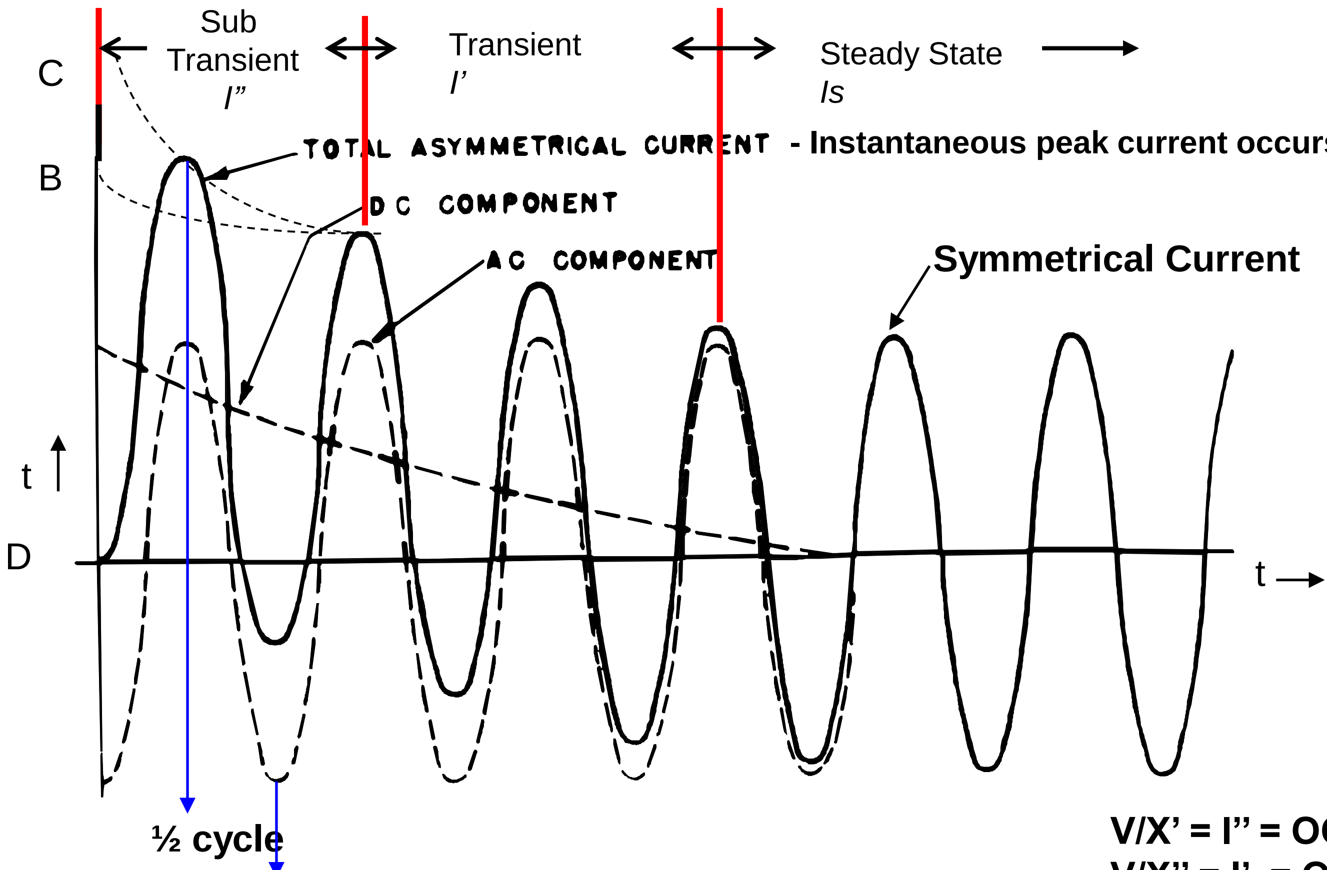
Asymmetrical AC behaves exactly as there were 2 components current flowing simultaneously with AC and DC component & the sum is equal to the magnitude.



CHARACTERISTICS OF THE DC COMPONENT

The DC component does not continue to flow at a constant value unless there is zero resistance in the circuit.

Refer to next slide



V/X' = I" = OC/ √2
V/X" = I' = OB/ √2
V/Xs = Is = OC/ √2

X" = Sub Transient Reactance
X' = Transient Reactance

Decaying dc component asymmetrical current gradually becomes symmetrical when dc component disappears.

Part 3

Structure of Protection System

Structure of Protection System

Zone Protection - **A protection zone is part of a system which fault is detected and subsequent isolation is restricted to the part of the system only.**

Each zone is independent of each other, this is normally bound by current transformers connected to the relays.

Unit Zone Protection - **A protection is considered to be a unit in which a protective system detects fault in that unit only.**

Example of a unit : alternator, power transformer, & big HV motor.

Non-unit Zone Protection - **involves detection of faults anywhere beyond the relaying point. As such, back-up protection, time graded or discrimination protection relays.**

Primary Back-up and Duplicate Protection - **Primary protection is that which firstly detects the faults and issues a command to isolate the faulted section.**

In the event of a failure of the primary protection, the back-up protection would operate to isolate the faulted section.

Part 4

Principles and Operation of Relays

Overcurrent Protection

Definition:

Any circuit in excess of the rated equipment or the ampacity of a conductor
It may result from a fault current (short circuit, earth fault) or overload.

Or

A value of current flow in a circuit or installation is higher than design
Current or higher than full load current (FL).

Fault Current:

Current flow in a circuit due to short circuit faults:

- Phase to Phase short
- Phase to neutral short
- Phase to earth short (earth fault)

Effects:

- Overloads Current: Value of current flow may be 2 0r 3 times than the FL current. The cable insulation become hot and shorten a life span of cable insulation, may produce fire or other damage to the insulation.
  A fault, such as short circuit or earth fault is not an overload.

Fault Current: Value of fault current may reach hundred or thousand times than FL current.
Fire or damage may occurs instantaneously or in short time due to burnt of cable insulation or equipment / winding insulation.
A maximum value of fault current in circuit is called Prospective Short Circuit Current and it is due to short circuit occurs at supply / source of point.

Overcurrent Protection Devices

Overcurrent can be protected by using any one of the following:

- Fuse - HRC / HBC
- Circuit Breaker - ACB, VCB, MCCB & MCB
- Relay - Instantaneous / Inverse (Time Delay)

FUSE:

A device in series with load to protect circuit. When fault occurs, fuse is designed to break the circuit automatically without any assistance by melting it's weak element.

CIRCUIT BREAKER:

A device designed to open ands close a circuit by non-automatic means and to open the circuit automatically on a predetermined overcurrent without injury to itself when properly applied within it rating.

RELAY:

- Instantaneous Relay: A which operates and reset with NO intentional time delay.
- Inverse Relay: A relay which operates and reset with time setting

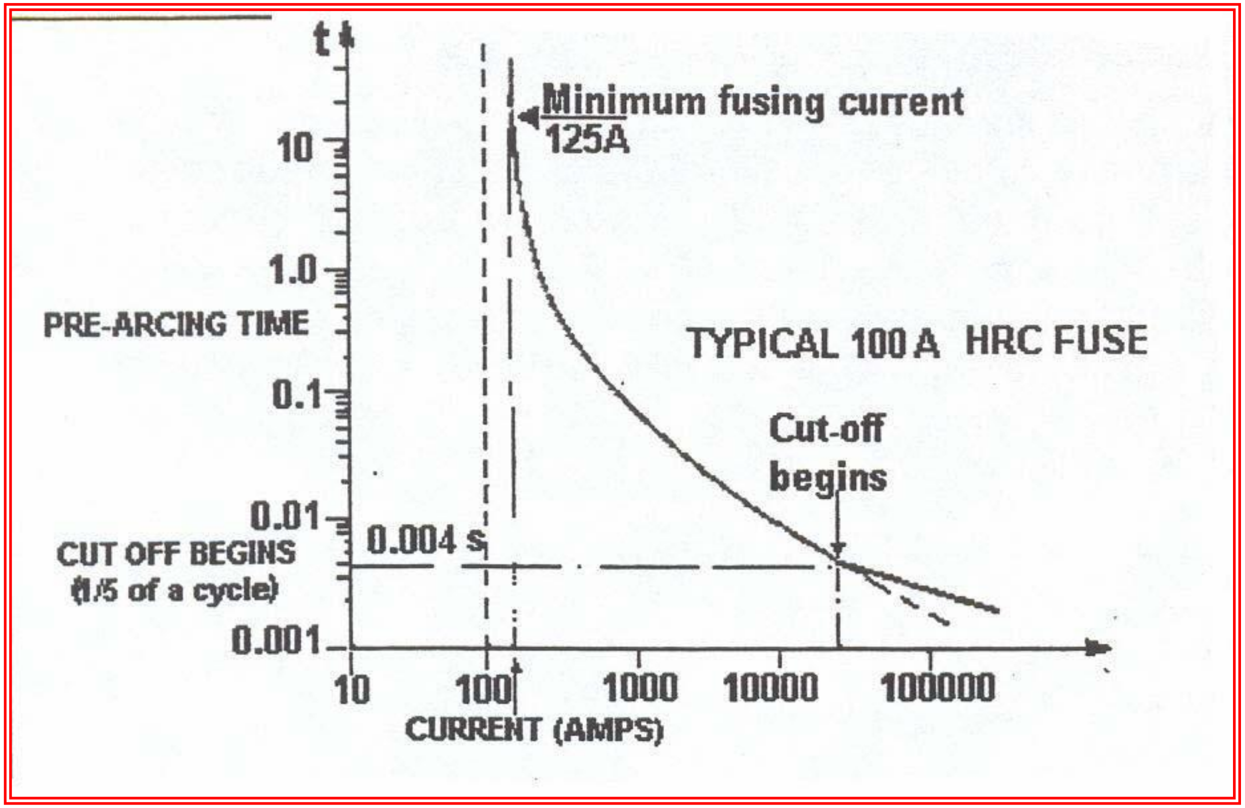
FUSE

Fuse:
A fuse is a short piece of metal inserted in the circuit, which melts when Excessive current flows through it and thus breaks the circuit.

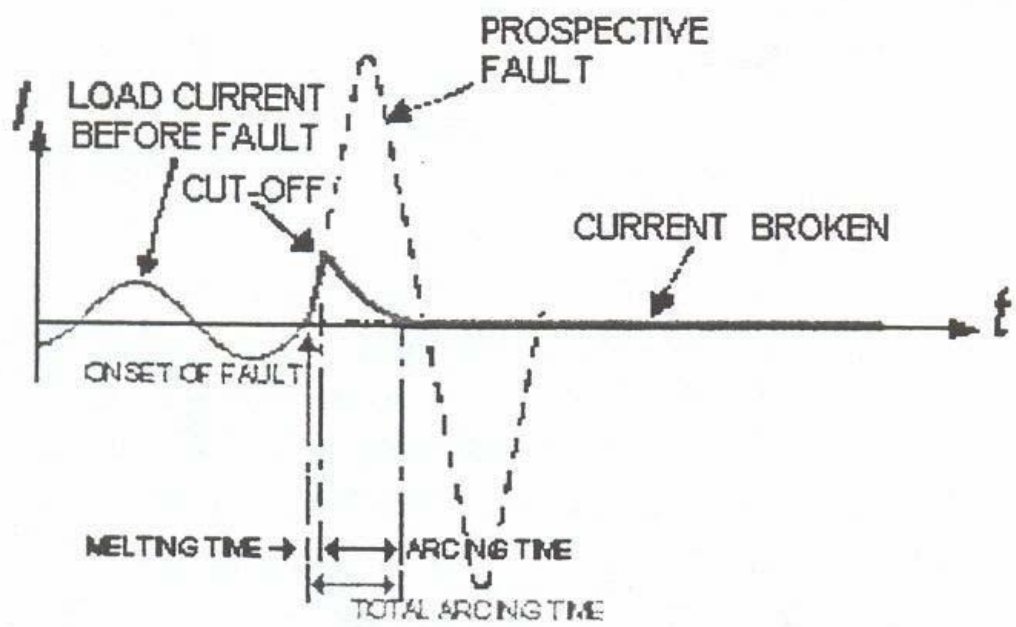
Fuse Element; Made of low melting point, high conductivity and least deterioration due to oxidation e.g Silver, Copper etc.

Suitable for overcurrent (short circuit) of overload protection for small installation.

The time required to blow out the fuse depends upon the magnitude of excessive current. The greater the current, the smaller is the time taken by the fuse to blow out, it normally having inverse time-current characteristic.



inverse time-current characteristic



FAULT CURRENT IN HRC FUSE

Important Terms:

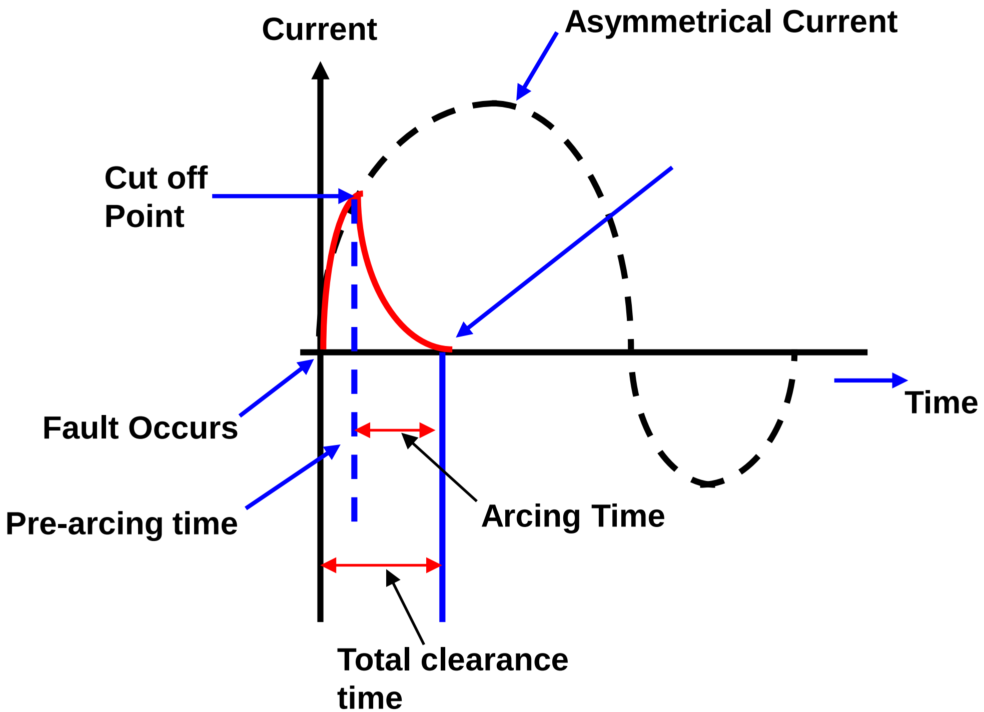
- **Current Rating**: Normal current which fuse element can carry without overheating & melting.
- **Fusing Current**: Minimum current at which fuse element to melt, obviously its value will be higher than current rating.
- **Fusing Factor**: The ratio of minimum fusing current to the current rating of the fuse element.

FF = Minimum Fusing Current / Current Rating of Fuse

(normally higher than 1)

□ **Class Q 2 Fusing factor greater than 2.0**
Class Q 1 Fusing factor between 1.5 and 2.0
Class P Fusing factor between 1.2 and 1.5

(Detail please refer to manufacture)



Fusing Current Wave

Cut Off point : Maximum fault current reached before fuse melt
Pre-arcing Time: Time between commencement of fault & the instant when cut off occurs
Arcing Time: The time between end of pre-arcing time & the instant when arc is extinguished
Total Opt Time: The sum of pre-arcing and arcing time (fast acting i.e. 0.002 sec, CB 0.2 sec)

Fusing Curve

Fusing Current

Moulded Case Circuit Breaker
MCCB

MCCB

> Used in industrial installation where high load current & high short circuit breaking capacity are required normally for low voltage system.

- Automatic protective devices assembles in a moulded plastic housing.

- Available rating ranging from 10 A to 1200 A or more with fixed trip element for low rating and adjustable for high rating.

- MCCBs having short circuit breaking capacity from 10 to 50 kA.

Time Current Characteristic

BS EN60947 or IEC947-2
The time-current characteristic of the over-current element at reference Temperature of 30^{o}C +/- 2^{o}C

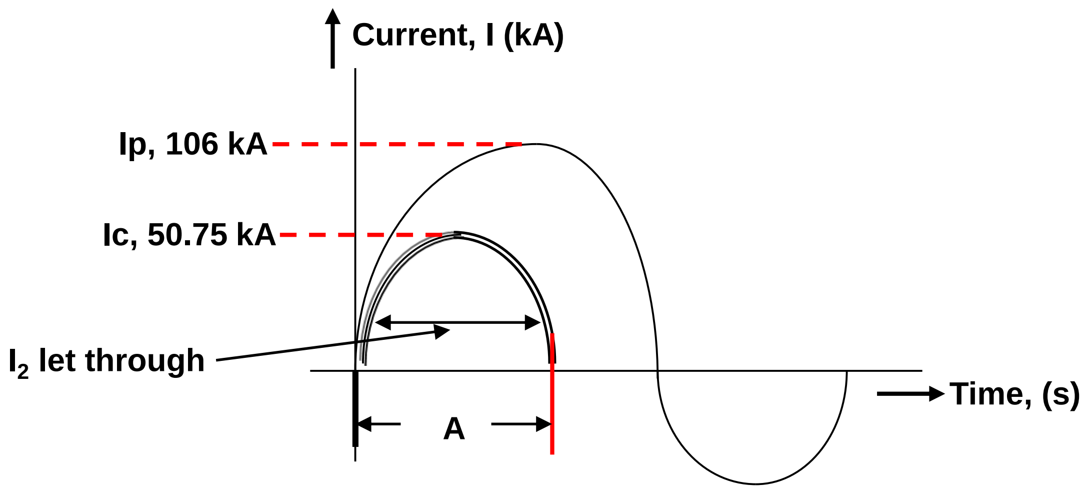
> At 1.05 times of current rating for 2 hrs, tripping shall not occurs

> At the end of 2 hrs., the value of current immediately raised to 1.3 times the current setting, tripping shall occurs less than 2 hrs. For breaker less than 63A, the duration of 2 hrs. should be reduced to 1 hour.

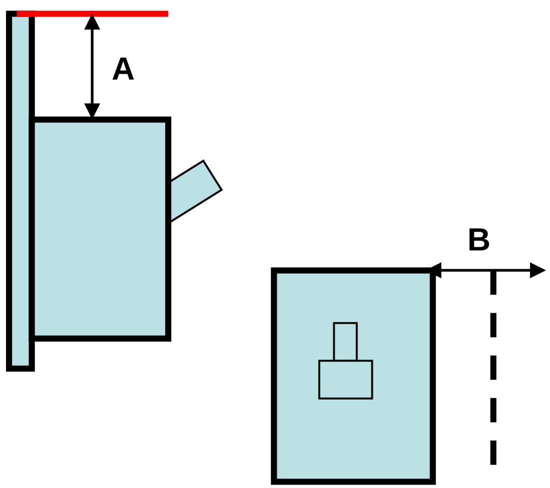
Current Limiting Performance

Some model of MCCBs has exceptional characteristics at the breaking current Of 50 kA. This includes:

- **Limiting short-circuit current, Ip, to 106 kA (max. peak let through current)**
- **Interrupting fault current. Ic, 50.7 kA at 436 volt.**
- **Breaking time at approx. 000949 seconds**
- **Arc-quenching time at approx. 0.0066 seconds.**



A – Total break time, approx. 0.00949 second



A/B: Arc-quenching level

Frame Size Designation:

For automatically tripping MCCBs, two (2) component shall be considered:

- The frame.
- The trip unit.

Frame Size:

The frame size are set to the following electrical characteristic:

- **Maximum continuous voltage rating (insulation level)**
- **Maximum continuous current rating**
- **Maximum interrupting rating**
- **Maximum permissible of trip unit**

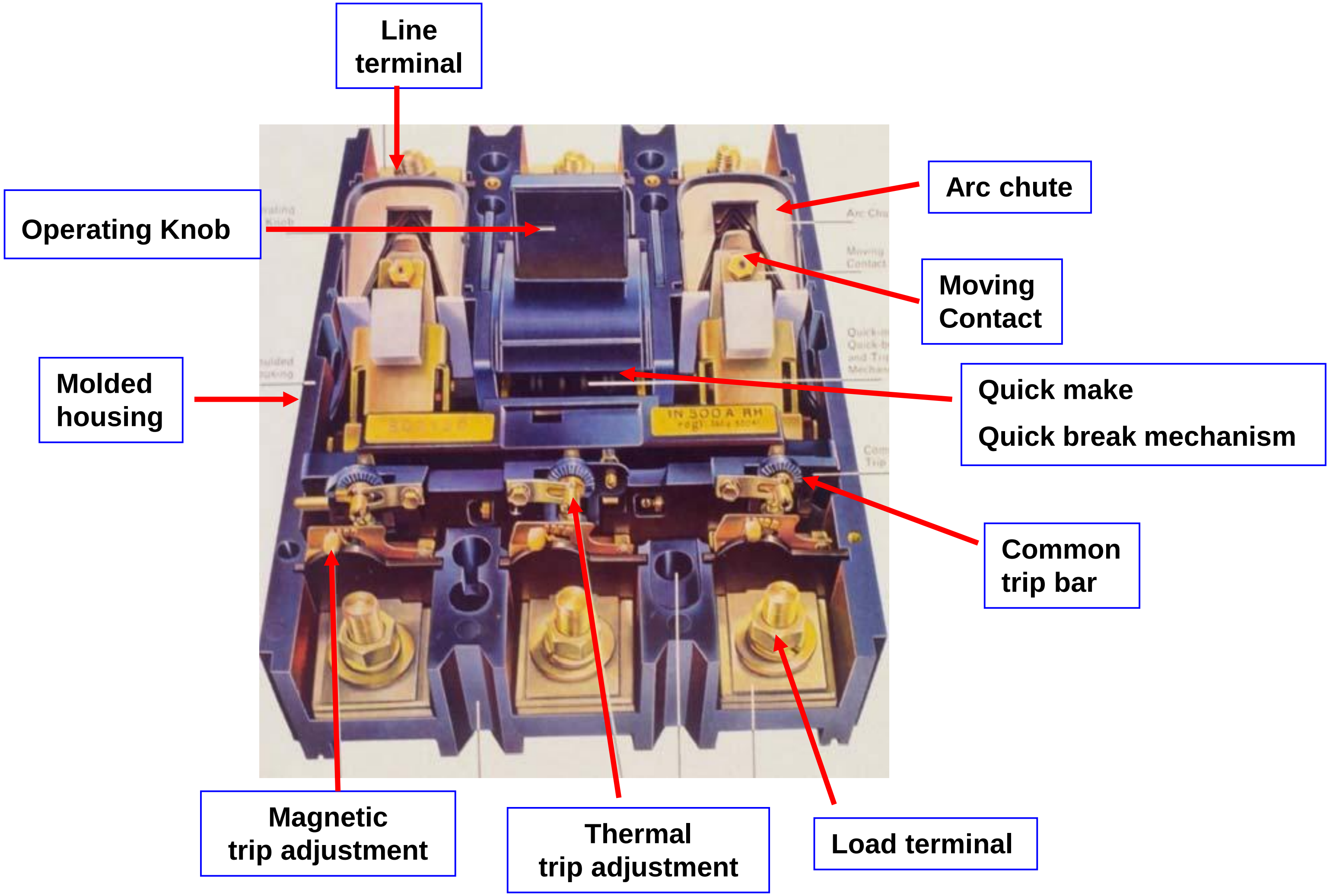
Frame Size & Trip Rating (AF & AT):

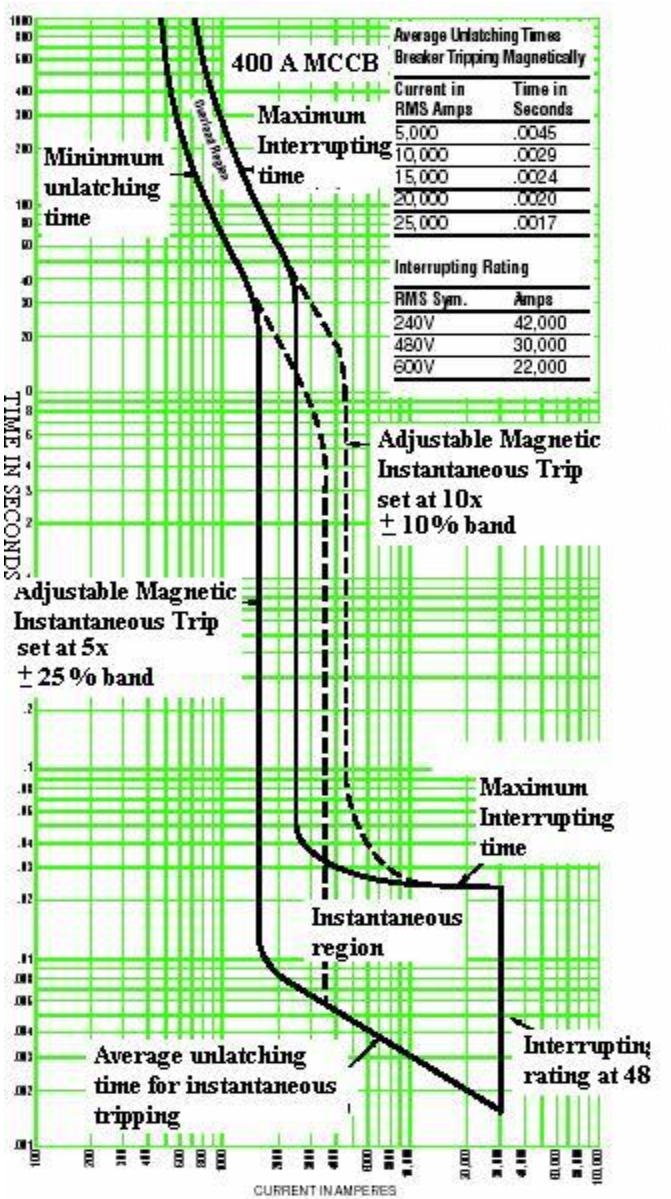
- AT or trip rating to indicated tripping current of the MCCB i.e 70A
- AF or Frame Size rating to indicated interrupting capacity i.e. 225A
- Normally the rating shall be indicated as 225AF/70AT

Selection of MCCBs

The following shall be the criteria of the selection of the MCCBs:

- **Long lasting & trouble free**
- **Nominal current rating of the MCCB, depending on full load**
- **Fault current – Icu, Ics, depending on fault level point in power system**
- **Number of poles**
- **Other accessories if required – shunt trip release, UV release, trip alarm etc**


Line terminal
Arc chute
Operating Knob
Moving Contact
Molded housing
Quick make
Quick break mechanism
Common trip bar
Magnetic trip adjustment
Thermal trip adjustment
Load terminal



Operating characteristic curve of MCCB

Relays

Nasib Janda TNB

Test Helmet

Relay Definition:

A device which makes a measurement or receives a signal which causes to operate and to effect the operation of other equipment.

A protection relay is a device which responds to abnormal condition the In an electrical installation system to operate a CB to disconnect faulty section of the system with minimum interruption of supply.

The type of relays are :

A. According to it construction and operation are:

*** Attracted armature Relay**
*** Moving Coil Relay**
*** Induction Relay**
*** Solenoid**
*** Oil Dash-pot Relay**
*** Thermal Relay**
*** Static Relay or Microprocessor base Relay**

B. According to its function or application.

* Over Current relay (OC)
* Earth Fault relay (EFR)
* Earth Leakage relay (ELR)
* Under Voltage relay (UV)
* Over Voltage relay (OV)
* Under Frequency relay (Uhz)

C. According to the operation scheme or curve

*** Inverse Definite Mean Time (IDMT) relay**
- Normal Inverse, Extremely Inverse and Very Inverse
*** Definite Time relay**
*** Instantaneous relay**
*** Combination of IDMT, Definite time and Instantaneous relay**

Relay Protection

> OC and EF protection system for LV system, four (4) CTs normally used to detect circuit secondary current to relay. Only 3CTs require for HV system.

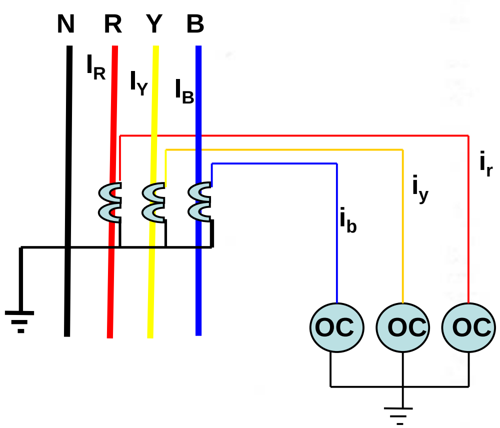
- The CTs are couple to R. Y, B lines and Neutral line

- OC relay are connected in series with the CTs, when primary current I_R, I_Y, I_B and I_N flow in each phase and neutral line, a replica secondary current at reduced level i_r, i_y, i_b and in will flow in each CT in opposite direction i.e.

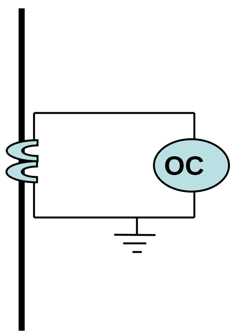
$$i_r = I_R / \text{CT ratio},\ i_y = I_Y / \text{CT ratio},\ i_b = I_B / \text{CT ratio}$$

- The OC relay can be set to operate at any desired level. The relay can cater for overcurrent and over load protection.

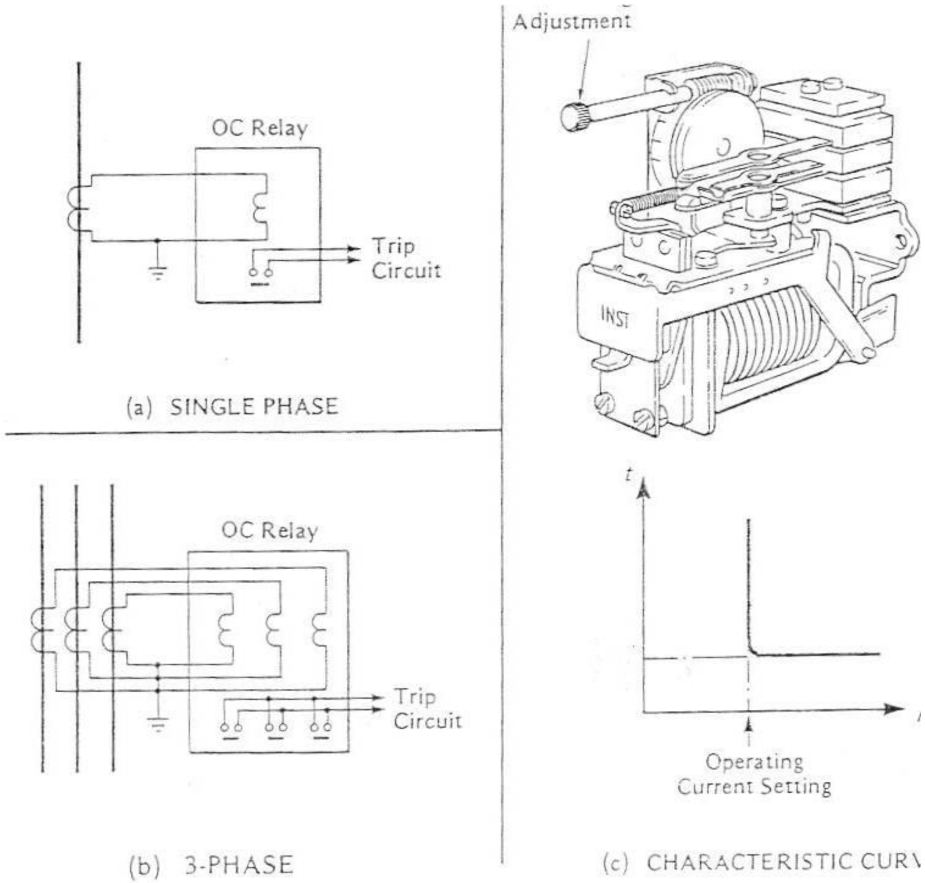
Relay Connection



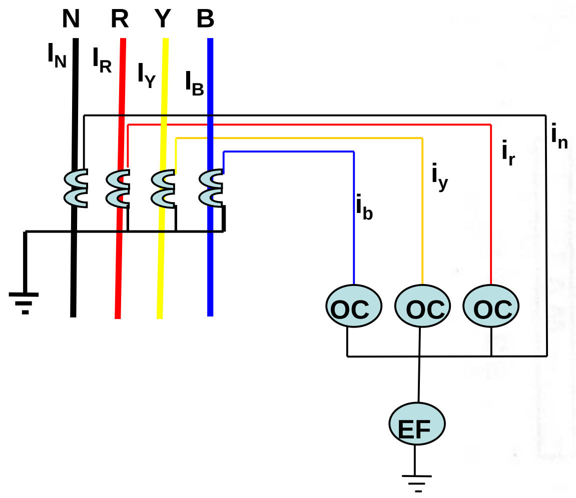
Three Phase 4 wire



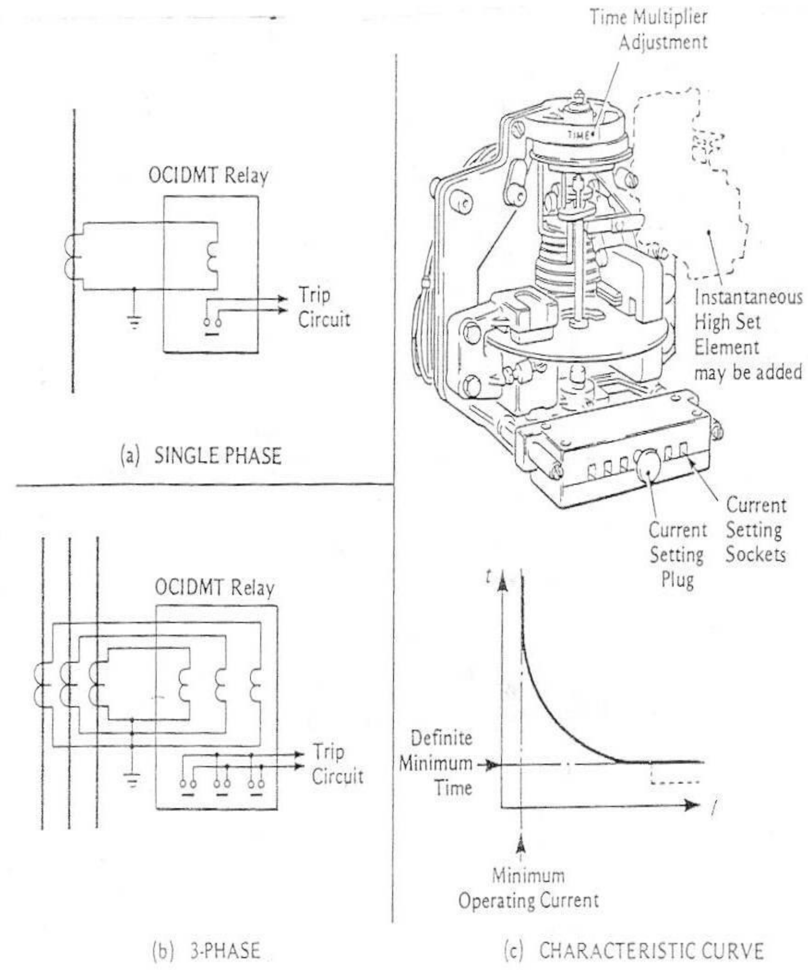
Single Phase



TYPICAL INSTANTANEOUS OVERCURRENT RELAY



Three Phase 4 Wire With Earth Fault



TYPICAL INVERSE AND DEFINITE MINIMUM TIME OVERCURRENT RELAY

12B

Relay Connection Pg 323

EARTH FAULT RELAYS

- PROTECTS AGAINST INSULATION FAILURE TO EARTH. USES RELAY THAT MEASURES EARTH FAULT CURRENT.
- UNDER NORMAL CONDITIONS, RELAY CURRENT IS ZERO. CAN THEN BE SET TO VERY SENSITIVE LEVEL, INDEPENDENT OF LOAD CURRENT.
- EARTH FAULT RELAY SHOULD NOT OPERATE UNDER FAULT CONDITIONS NOT INVOLVING EARTH, SUCH AS PHASE FAULTS.

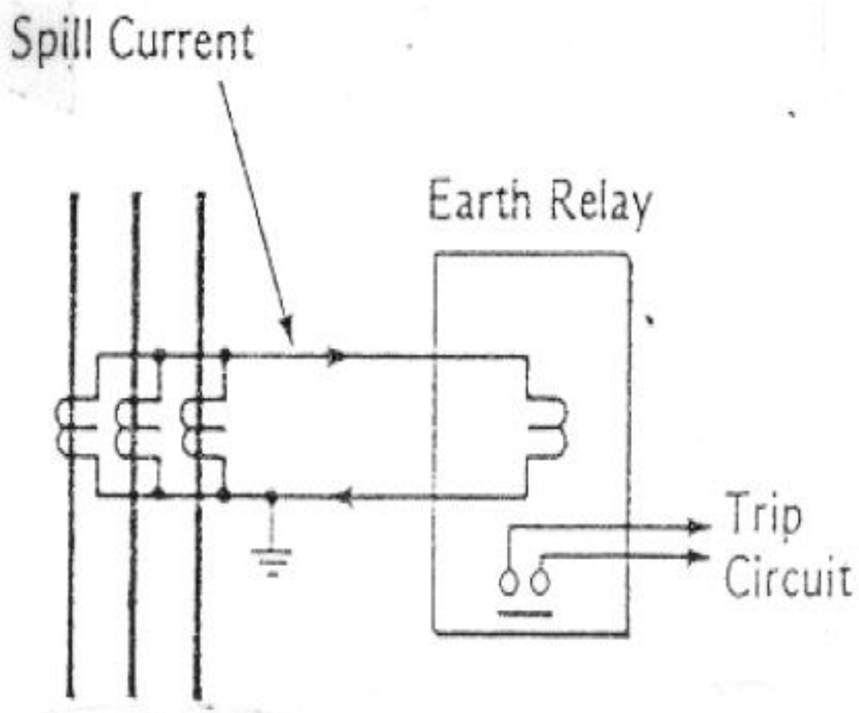
EARTH FAULT RELAY CONNECTION

- *RESIDUAL CONNECTION*

(1) MOST COMMON TYPE. USES THE SAME CTS FOR BOTH OVERCURRENT AND EARTH FAULT PROTECTION.

(2) CHEAPEST BECAUSE NO NEED FOR ADDITIONAL CTS. POSSIBLE MALOPERATION OF INSTANTANEOUS EF RELAY DURING MAGNETISING INRUSH OR MOTOR STARTING BECAUSE OF CT SATURATION. SOLUTION WILL BE DISCUSSED IN MOTORS.

(3) SUMS UP THE CURRENTS IN THE CURRENT CARRYING CONDUCTORS, INCLUDING THE NEUTRAL WIRE.



(a) Residual Connection

(4) 3-PHASE 3-WIRE SYSTEMS (R, Y AND B WITHOUT NEUTRAL WIRE. FOR MV SYSTEMS).

$$I_{EF} = I_A + I_B + I_C$$

(5) FOR NORMAL 3-PHASE LOAD OR BALANCE 3-PHASE FAULT

$$I_{EF} = I_A + I_B + I_C = 0$$

(6) FOR PHASE FAULT, $I_A = 0$; $I_B = -I_C$; $I_{EF} = 0$

(7) I_{EF} IS THE ZERO SEQUENCE CURRENT

$$I_A = I_1 + I_2 + I_0$$

$$I_b = a^2 I_1 + a I_2 + I_0$$

$$I_C = A I_1 + A^2 I_2 + I_0$$

$$I_{EF} = 3I_0 = 0$$

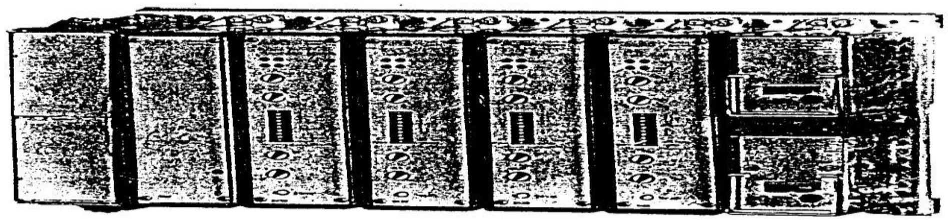
I_1, I_2 AND I_0 ARE THE POSITIVE, NEGATIVE AND ZERO SEQUENCE CURRENTS

a operator: $a = 1\angle 120^\circ$ $a^2 = 1\angle 240^\circ$ $1 + a + a^2 = 0$

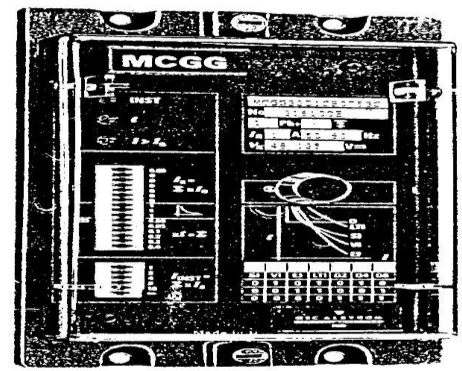
Neutral Connection

Page 107

RXIDK 2H



STATIC RELAYS WITH DIP SWITCHES



Type MCGG 22 nameplate

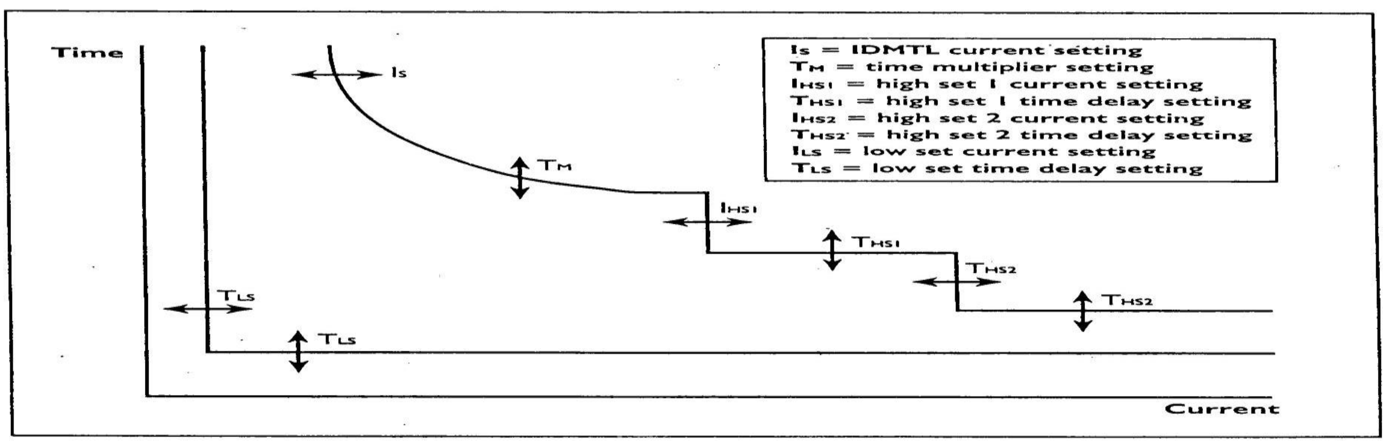
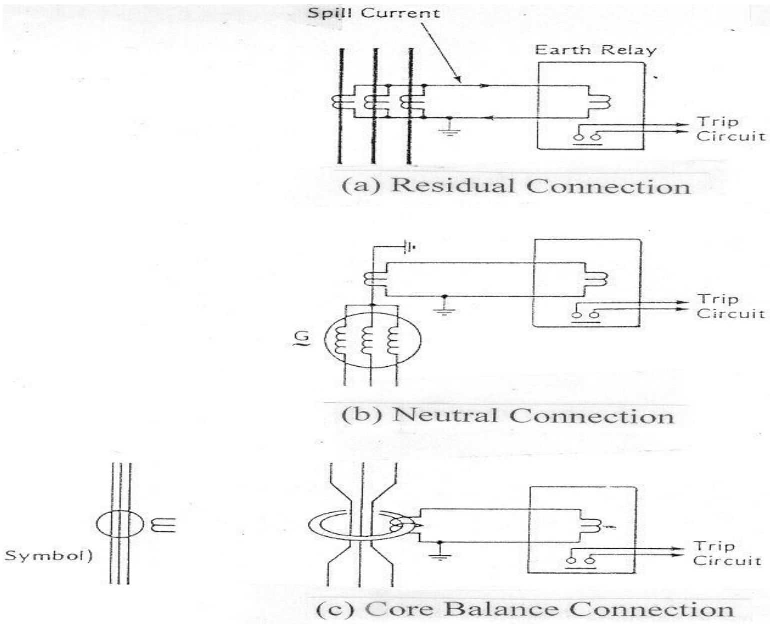


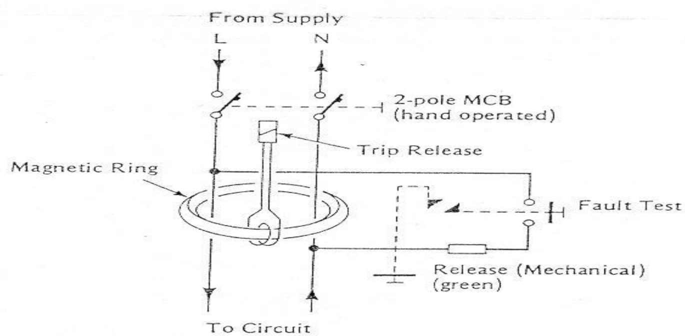
Illustration of Protection Functions

MULTIPLE PROTECTIONS OF NUMERICAL OVERCURRENT RELAY

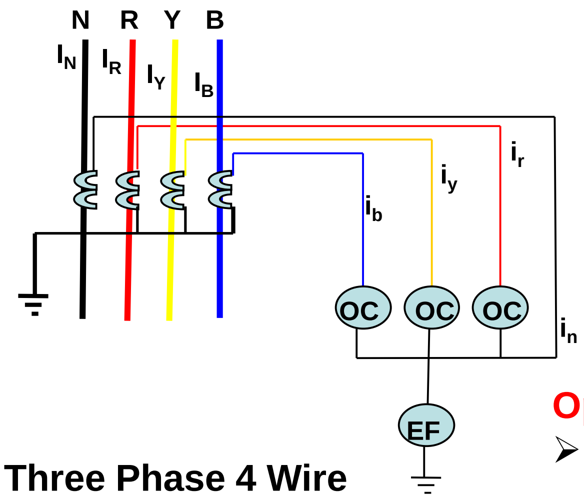
Electrical Protection - INSTEP 08



UNRESTRICTED EARTH FAULT RELAY CONNECTIONS



TYPICAL EARTH LEAKAGE CIRCUIT BREAKER (rcd TYPE)



Three Phase 4 Wire
With Earth Fault

Relay Setting:

> For OC Relay normally set to 100% of approved load

- For EF Relay normally set to 10 – 20% of rated load current subjected to maximum of 120 A

Operation of EF Relay:

- In healthy situation, the summation vector quantities of phase – neutral current must equal to zero.

$$\vec{IR} + \vec{IY} + \vec{IB} + \vec{IN} = 0 \quad \text{-------------} \quad 1$$

- At secondary circuit

$$\vec{ir} + \vec{iy} + \vec{ib} + \vec{in} = 0 \quad \text{-------------} \quad 2$$

- At Neutral point N, the current following Kirchhoff's Law $\sum I = 0$:

$$\vec{ir} + \vec{iy} + \vec{ib} + \vec{in} + \vec{ie/f} = 0 \quad \ldots\ldots\ldots \quad 3$$

- Comparing equation 2 & 3, at neutral point N, ie/f = 0

- Relay not to operate on healthy condition, also EF relay shall not operate under balance 3 phase & 2 phase short circuit.

Ω

Earth Fault Condition

- When Fault, the leakage current to flow from Red phase to ground
- At neutral point N, following Kirchhoff's Law:

$\vec{ir} + \vec{i\,e/f} = 0$

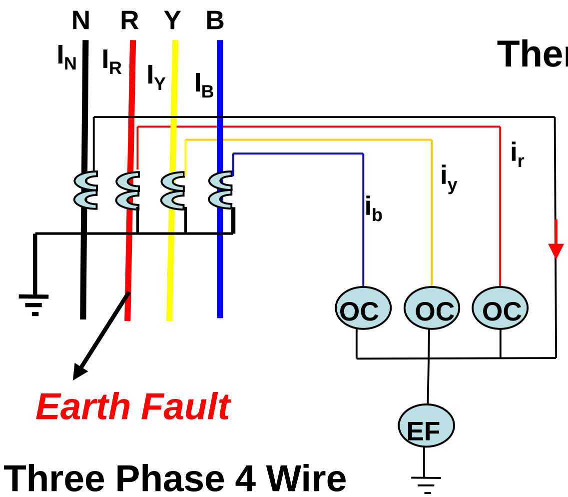
or $\vec{ir} + \vec{ib} + \vec{Ic} = 0$

Therefore:

$\vec{i\,e/f} = -\vec{ir}$

or $\vec{ir} + \vec{ib} + \vec{ic} \neq 0$

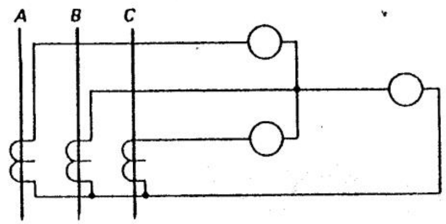
(the current flow into EF Relay to operate)

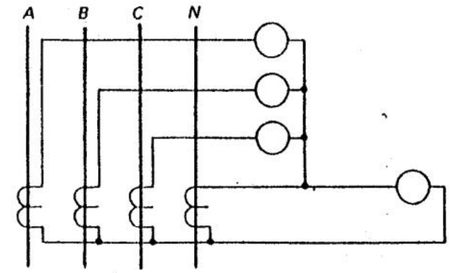


Three Phase 4 Wire
With Earth Fault

The value of Earth Fault Current is depending on System impedance, higher the impedance the Fault current can be quit small.

Relay normally set from 10 – 20% or max of 120 A

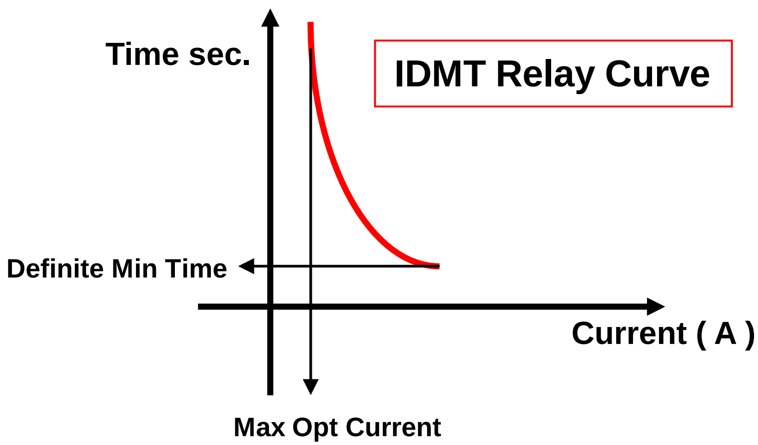


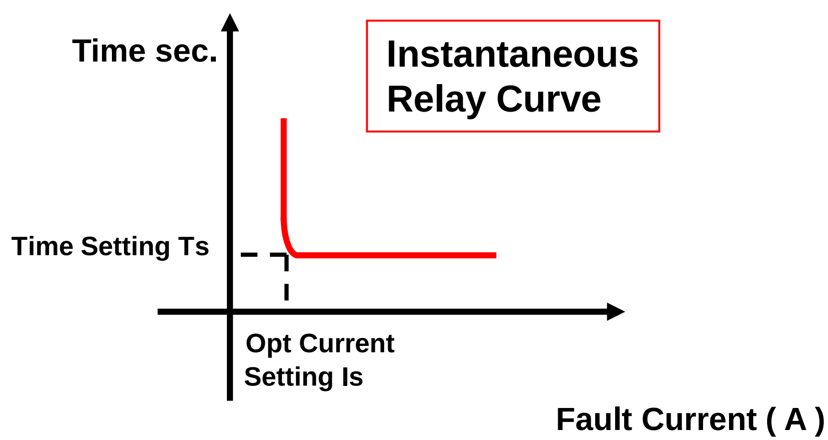


FAULTED PHASE	High Voltage System			LOW VOLTAGE SYSTEM			
	R	E/F	B	R	Y	B	E/F
R-E		✔					✔
Y-E		✔					✔
B-E		✔					✔
R-Y	✔			✔	✔		
Y-B			✔		✔	✔	
B-R	✔		✔	✔		✔	
R-N	NOT APPLICABLE			✔			
Y-N					✔		
B-N						✔	

TABLE OF TRIPPING OF OVERCURRENT-EARTH FAULT RELAYS

Relay Curve

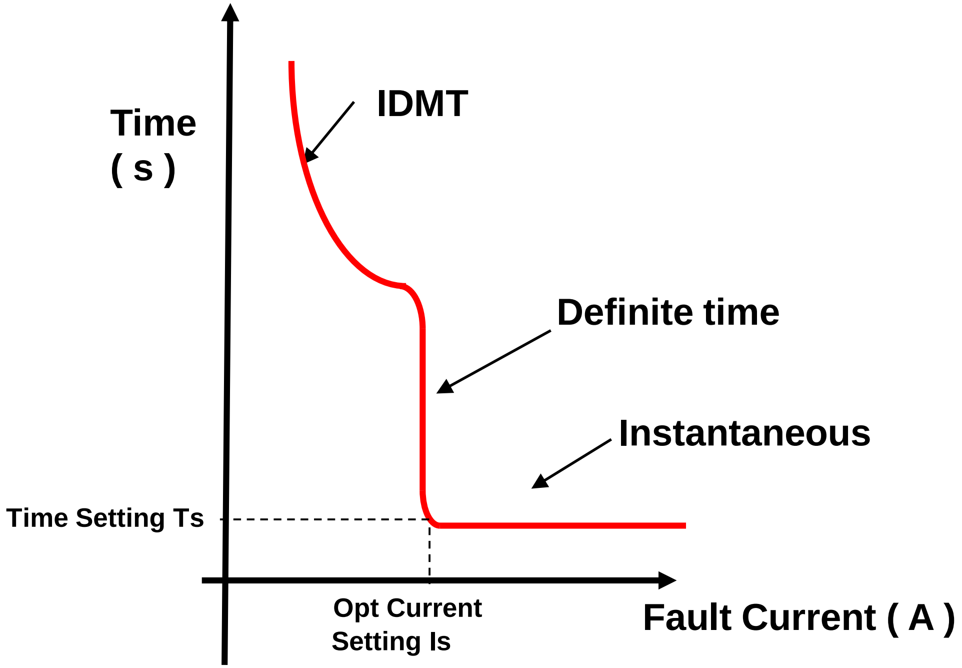




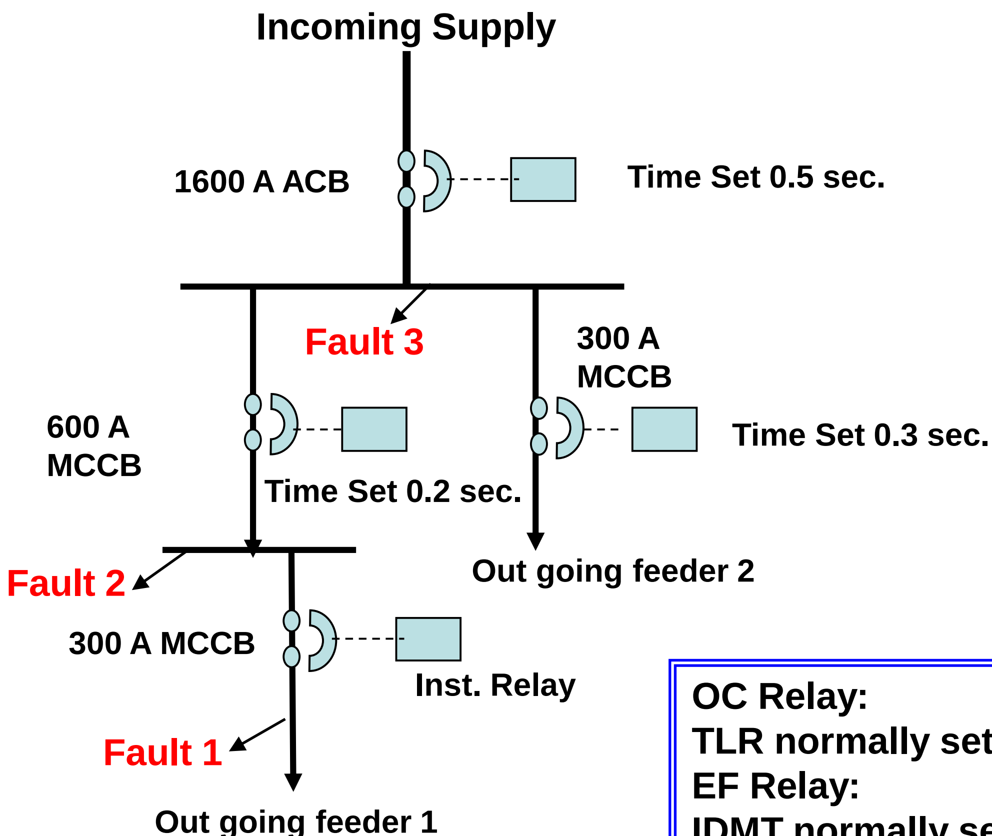
IDMT Relay Curve

Time Graded & Instantaneous Coordination

- Time Graded or IDMT relay normally is combination with instantaneous relay
- The operating current of the IDMT relay can be set at time element
- When heave fault detected, normally the instantaneous relay to operate to isolate the system.



Relay Application



OC Relay:
TLR normally set at 100% of approved load at Ts = 0.5 sec
EF Relay:
IDMT normally set at not more than 20% of approved load At Ts = 0.5 sec
Inst Relay:
For high fault current Ts = 0.04 sec or less

Direct Acting Trip

> Main Incoming ACB using shunt trip shall be provided with series with trip (direct acting) devices that operates with no time lag under short circuit condition. Direct acting trip usually from magnetic trip.

- The maximum direct acting trip setting as recommended for various load as shown in Table below 01:

Range of Approved Load	Max Allowable Direct Trip Setting
200 A & below	1200 A
200 A to 260 A	2000 A
260 A to 400 A	2400 A
400 A – 1500 A	3200 A
Above 1500 A	4500 A

CLASSIFICATION OF RELAYS

Exercise Example

Light industry feeder taking 3 phase power supply through 2000A ACB, 415 volt is provided with Time Lag Relay (TL) OC & EF relay.

The particular of the protection system as follows:

- **CT** — **Ratio 2000/5, Class 5p10, Burden 20 VA**
- **OC Relay** — **Adjustable setting 2A – 7A, Time setting: 0 -1 sec.**
- **EF Relay** — **Adjustable setting 0.1A – 2A, Time setting: 0 – 1 sec**

- **If approved load 1800 A 3 phase at 415 volt, determine the setting of OC and EF relay according to authority requirement.**

Solution

OC Setting:

- **Requirement of OC set at 100% of at approved load at 1800 A**
- **Therefore, primary trip current = 1800 A**
- **OC relay setting = 1800 / CT Ratio = 1800 / 2000/5 = 4.5 A**
- **Set OC relay to trip:**

  Ip = 1800 A
  Is = 4.5 A (set to 5A)
  Time = 0.5 sec (Max)

EF Setting:

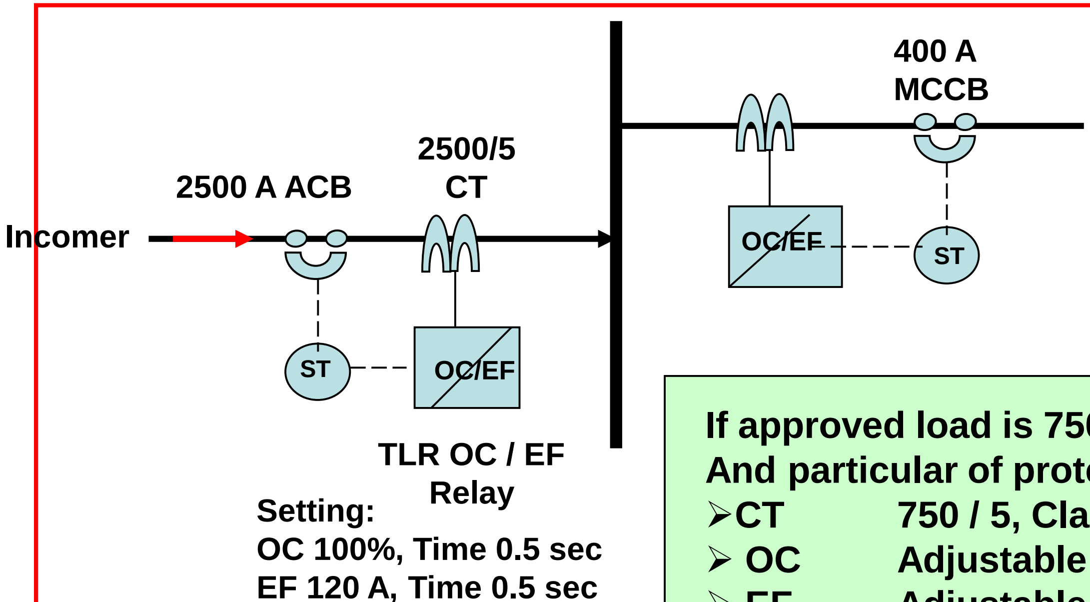
- **Requirement of setting is 10 – 20% of max 120 A**
- **20% x 2000A = 20 / 100 x 2000 = 400 A (higher than permissible of 120 A)**
- **Corresponding to Is = 120A / CT Ratio = 120/ 2000/5 = 0.3 A**
- **Set EF relay to trip:**

  Ip = 120 A
  Is = 0.3 A
  Time = 0.5 sec (max)

- **Therefore direct acting trip element or HRC fuse must be fitted to operate with no time lag under severe short circuit condition.**
- **From Table 01, for approved load 1800 A, the max allowable direst acting trip setting 4500 A.**

Exercise 5

The power supply to customer of multi story building is taken from 2500 A 3 phase, 415 volt via main switch board as shown below:



If approved load is 750 A, 3 phase, 415 volt,,
And particular of protection as follows:

- **CT** 750 / 5, Class 5p10, Burden 15 VA
- **OC** Adjustable 2A – 7A, Time 0 – 1 sec
- **EF** Adjustable 0.1 A – 2 A, Time 0.1 sec

- **Calculate:**
  - OC setting for incomer& sub-main
  - OC Time grading margin if sub-main set to 0.2 sec
  - EF setting for incomer & sub-main
  - Propose EF Time grading margin at sub-main

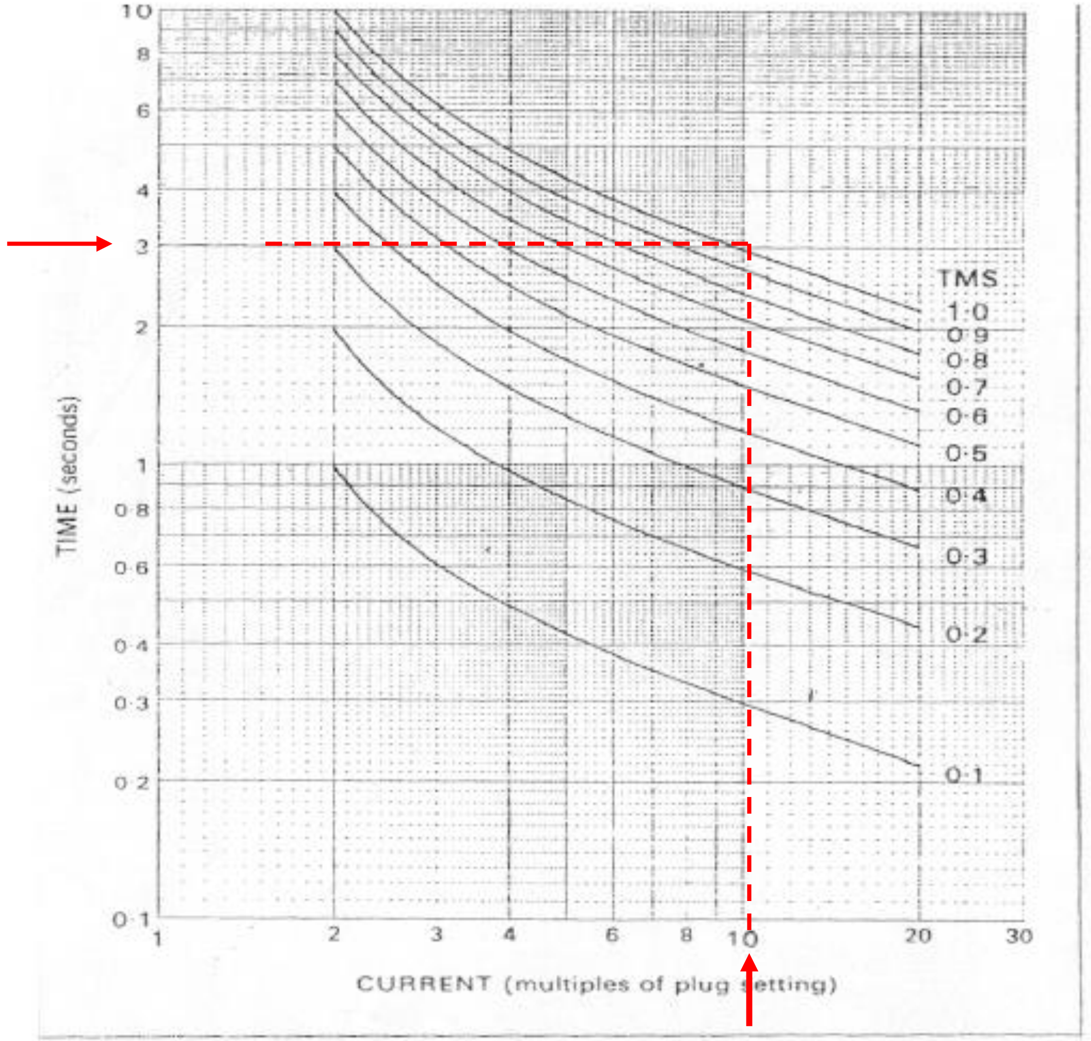
NO SOLUTION PROVIDED

IDMT Relay

- IDMT relay used to discriminated the protection system both by current & time
- The characteristic of the relay to provide inversely proportional to the the fault current level.
- Typical IDMT curve of a 3s/10x and 1.3s/10x IDMT relay are shown in the next slide.

Type of IDMT Relay

- For the purpose of this class, the reference to CDG11 time setting 3s/10x is selected and it conform to BS142.
- At ten time (10x) plug setting current & TMS of one (1), the relay will operate in 3 sec.
- The relay can be from single disc or double disc for trip and alarm contacts.
- The Plug Setting (PS) are in fixed discrete percentage at 25%, 50%, 75%, 100% 125%, 150% and 175%.



Typical time/current characteristics of 3 seconds standard electromechanical I.D.M.T. relay.

Time Multiplier Setting (TMS)

- The adjustment in setting dial (back stop) of the relay is known Time Multiplier Setting which scale from 0.05 to 1.0
- For example at TMS = 1, if time taken to operate the relay is S second (10 sec), then for TMS = 0.1, the relay will operate in 0.1 x S seconds .
  For TMS = 0.8 the operating time shall be 0.8 x S seconds
  e.g. 0.8 x 10 = 8 sec.
- TMS does not present actual operating time, but a multiplier used to convert the time known from the relay/current characteristic.
- As such TMS for IDMT relay is defined as:

  TMS = T / TM
  T: The require time for operation
  TM : The time obtained from the relay curve at TMS = 1.0

curve

- CURRENT SETTING

ELECTROMECHANICAL IDMT RELAY HAS SEVEN SETTINGS. SELECTION BY A PLUG TAP.

RANGE FROM 50% TO 200% OF RELAY RATING (1A OR 5A) IN STEPS OF 25%.

PERCENTAGE SETTING	50%	75%	100%	125%	150%	175%	200%
CURRENT SETTING (1A RELAY)	0.5A	0.7A	1.0A	1.25A	1.5A	1.75A	2.0A
CURRENT SETTING (5A RELAY)	2.5A	3.75A	5A	6.25A	7.5A	8.75A	10A

ABOVE TAP SETTINGS APPLY TO ELECTRO-MECHANICAL RELAY.

Plug Setting (PS)

- **The relay coil is connected to the secondary of CT, and provided with tapping.**
- **These current tapping are connected to a PS bridge and given 7 selections of tapping in % value of the current rating of the relay.**
- **Relay can be set to operate at 5A = 100% or 2.5A = 50%.**
- **Pick-up error are allowable error in the current value for disc starts to move, and overshoot is time allowed for relay disc to continue to travel after the fault has been cleared and before its closes its contact.**

- **IDMT Relays are rated at 5A, will need to use CT secondary current value of 5A (e.g. 500/5 or 250/5 CT ratio).**
- **Relay Current Setting = Plug Setting (PS) % x 5A**
- **PS % = Relay Current Setting / 5A**

Pick-up Current

- **Pick-up current = Rated secondary current of CT x Current setting**
- **Example:**

  For OC relay set at 125% connected to circuit with CT 400/5. If rated of secondary current is 5A, Therefore, pick-up current will be 25% more than 5A i.e. 5A x 1.25 = 6.25A. This means the relay will operates at current equal to or more than 6.25A.

Example

- If PS = 50%, Relay Current Setting = 50 / 100 x 5A = 2.5A
- If PS = 200 %, Relay Current Setting = 200 / 100 x 5A = 10A

Plug Multiplier Setting (PMS)

- PMS is a multiple plug setting current, normally appears on the X axis of IDMT characteristic curve, it represent the actual secondary fault current flow in the relay against the relay current setting.
- PMS = Actual Is flow in the relay / Relay Current Setting or
- PMS = Fault current in relay coil / Is of CT x Current Setting

curve

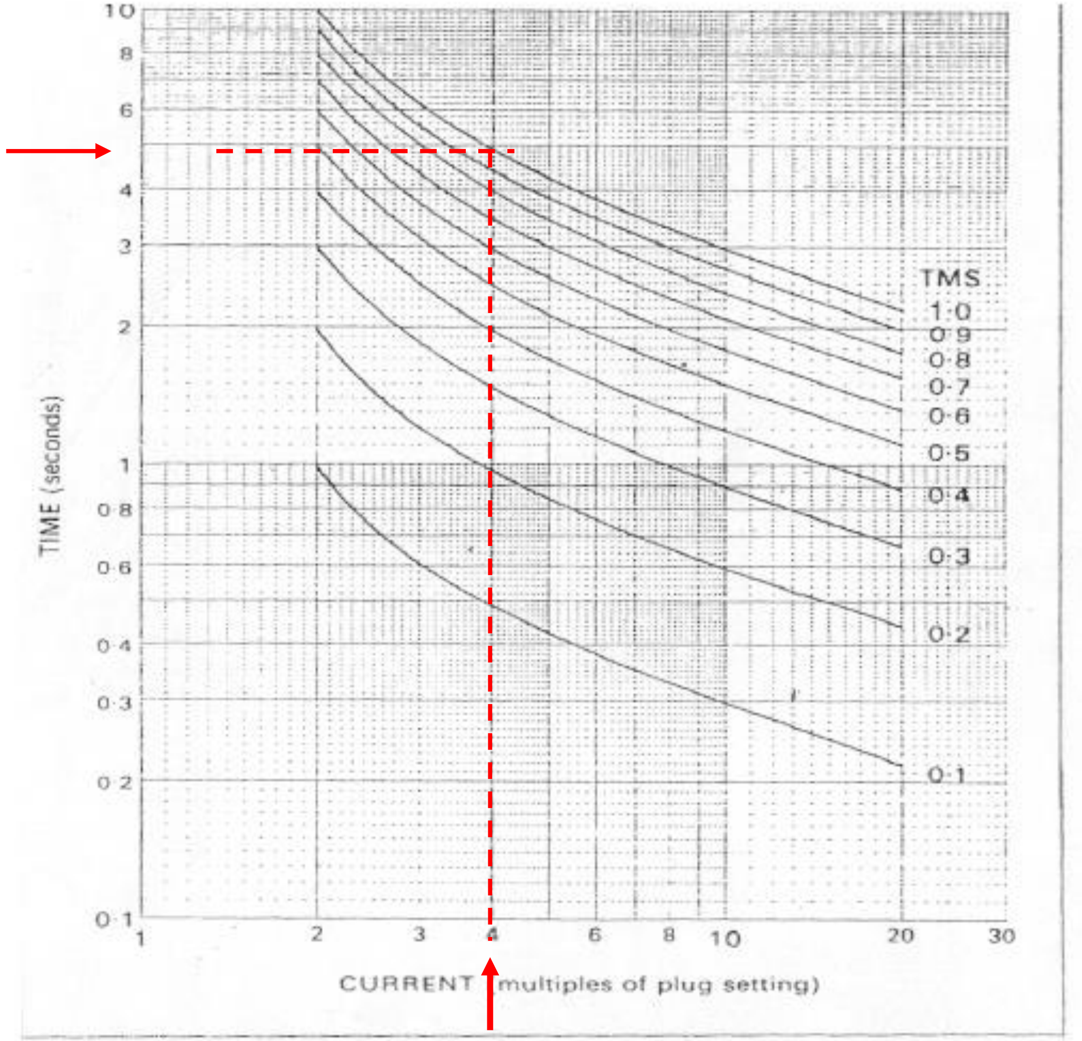
Example

Fault Current is 2400A, if CT ratio is 400/5 and relay TMS is 1, PS is 150% of 5A. What is the PSM?

Solution:

- **Relay Current Setting = 150% x 5A = 7.5A**
- **Actual Isc flow into the relay = 2400 / CTR (400/5) = 30A**
- **Therefore PSM = 30A / 7.5A = 4 times.**
- **Relay operating time = 4.9 sec (from curve & calculation)**

$$t = \frac{0.14}{\left(\frac{I\ fault}{CTRS \times PS}\right)^{0.02} - 1} \times TMS$$



Typical time/current characteristics of 3 seconds standard electromechanical I.D.M.T. relay.

Exercise 5

1400A incomer feeder cable fed to 415 volt MSB is protected by IDMT Overcurrent relay with 3s/10x characteristic and DTL EF Relay. The Setting as follows:

➢ **IDMT OC Relay:**	**PS = 100% (5A)**
	TMS = 0.05
DTL EF Relay:	**Current Setting = 120A**
	Tripping Time = 0.5 sec
CT Ratio:	**1400/5A**

- **Determine:**
  - **Tripping Time of the OC if a 2800A fault current passes through the incoming feeder cable.**
  - **The max. earth loop impedance value allowable for this system**

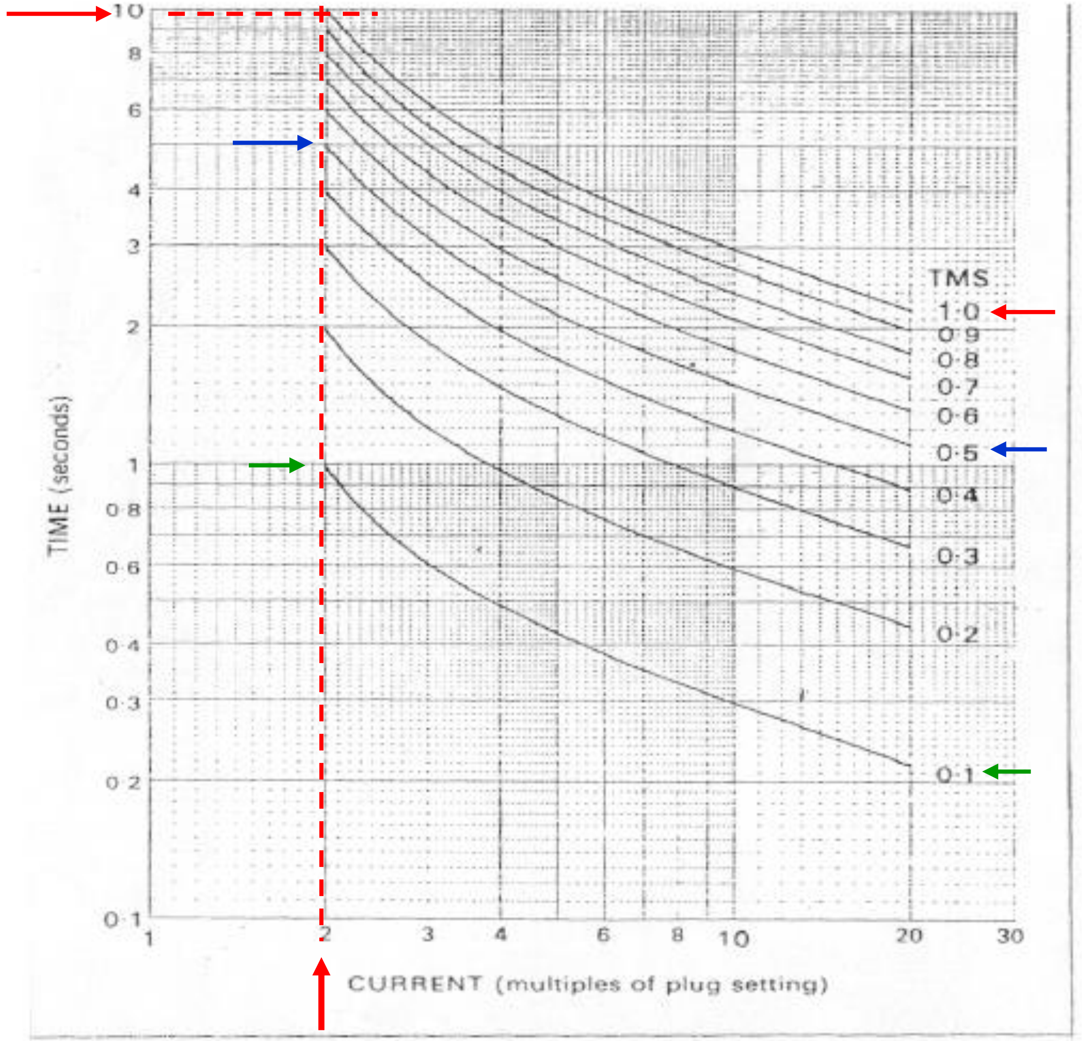
10 minutes

Solution

- Relay Current Setting (PS) = 100% x 5A = 5A
- Isc in relay = 2800A / 1400 x 5 = 10
- Therefore PSM = 10A / 5A = 2 times.
- At TMS = 1, Tripping Time = 10 seconds (calculated)
- At TMS = 0.5, Tripping Time = 5 sec (calculated)
- AT TMS = 0.1, Tripping time = 1 sec (calculated)

- EF Relay Setting: = 120A
- Safe touch voltage: = 50 volt
- Tripping Time = 0.5 sec

Therefore the EF loop impedance = 50V / 120A = 0.42 Ω



Typical time/current characteristics of 3 seconds standard electromechanical I.D.M.T. relay.

Grading & Margin

- The time interval between the operation of the relay depends to several factors:

- The fault current interrupting time of the circuit breaker.
- The overshoot time of time of the relay.
- Errors
- Final margin on completion operation – safety margin.
- 0.5 sec is normally acceptable for the grading margin for coordination of the relay
- A high set instantaneous ocvercurrent tripping element operate at reduced the operating time for high fault level.

OVER CURRENT AND EARTH FAULT (OCEF) RELAY SETTING

Discrimination IDMT

A.

Let say a balanced 3-phase load connected to Switchboard A =730kW
Receiving end 3-phase voltage = 415Vac 50Hz
Power factor = 0.85 lagging
3-phase load current = 730kW/[1.732 x 415V x 0.85] = 1194.8 A
Circuit breaker : 1200A 43kA 4-pole Air Circuit Breaker (ACB)
Current transformer: 1200/5 A 15VA CT
For relay setting, let us set continuous current to carry (100%) = 1200 A
Current to trip in 5 minutes (120%) = 1.2 x 1200A = 1440 A
Current to trip in 1 second (150%) = 1.5 x 1200A = 1800 A
Earth Fault (10%) = 0.1 x 1200 A = 120A

B.

Let us now find Time Multiplier Setting (TMS)
Assume, from calculation of fault above, 3-phase symmetrical fault = 20.3kA
Multiple pickup, m = symmetrical fault /setting current = 20.3kA/1200A = 16.9

Now, let us find operating time of the OCEF relay
There are 3 types of time-current characteristic curves –
Normal inverse, Very inverse and Extremely inverse

The formula of operating time at TMS 1 can be given = $a / [m^b - 1]$
where a and b are given in the table below

Type of curve	a	b
Normal inverse	0.14	0.02
Very inverse	13.5	1
Extremely inverse	80	2

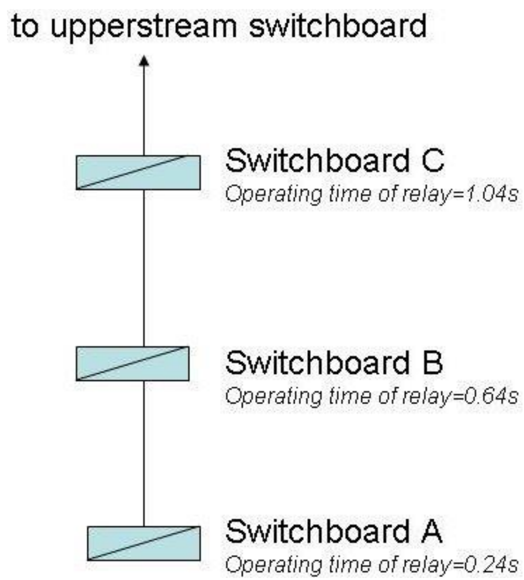
C.

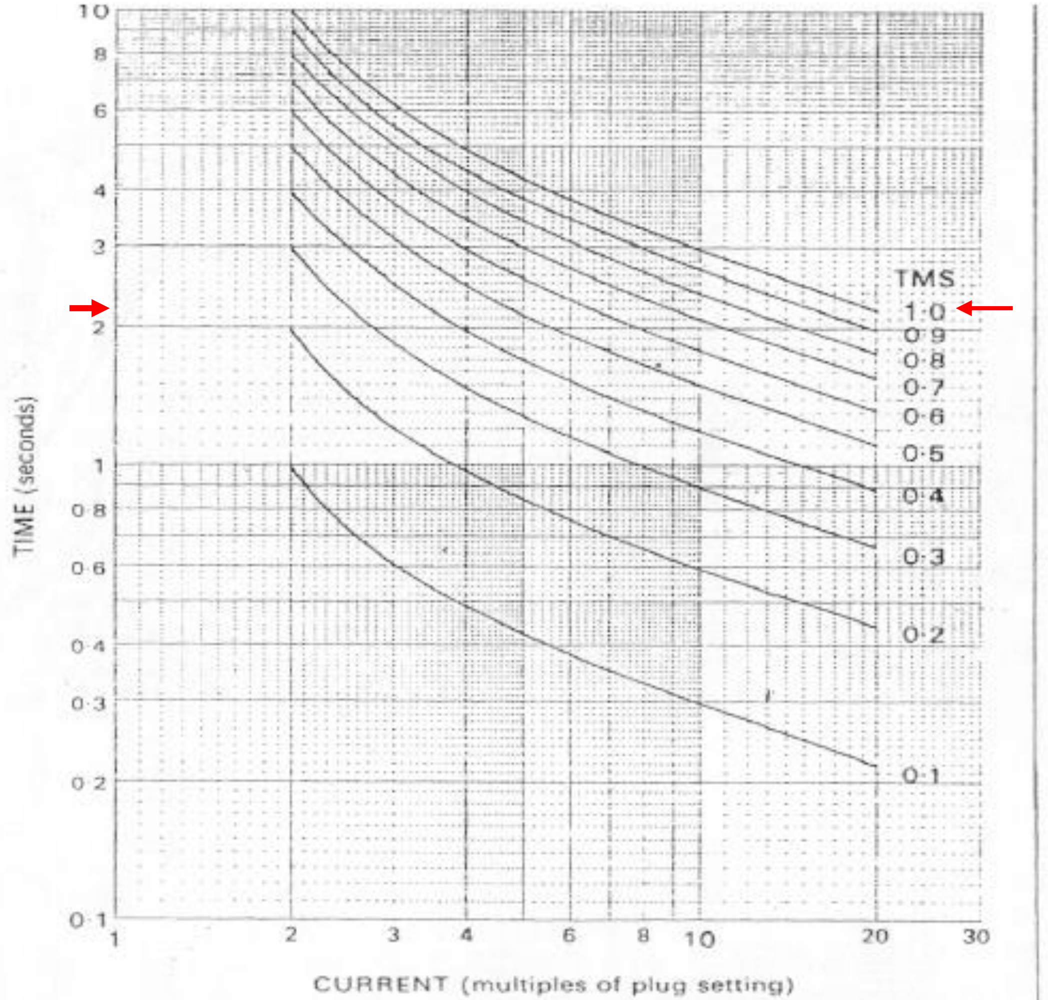
Let us choose normal inverse curve
From the table, a = 0.14 and b = 0.02
Operating time at TMS 1 = $0.14/[16.9^{0.02} -1]$ = 2.4 second

Hence, operating time of the relay at TMS 0.1 = 0.1 x 2.4 s = 0.24 second.
If there is another switchboard named Switchborad B in the upstream of the line, its relay operation should have time discrimination of 0.4s or 0.5s

Therefore, OCEF relay of this Switchboard shall have operating time of
= 0.4s + 0.24s = 0.64s

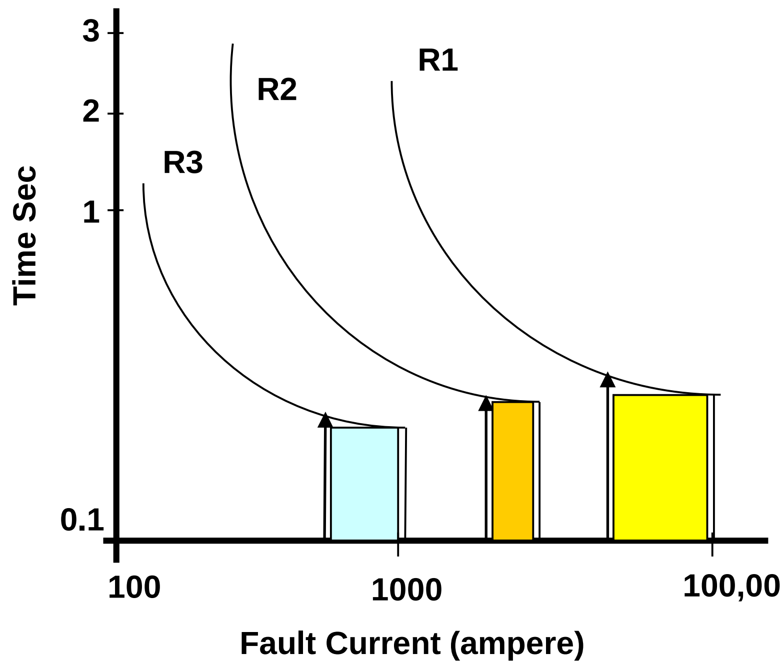
And so on for the next Switchborad C which is in the upstream of Switchborad B, its relay operating time will be set at :
= 0.4s + 0.64s = 1.04second



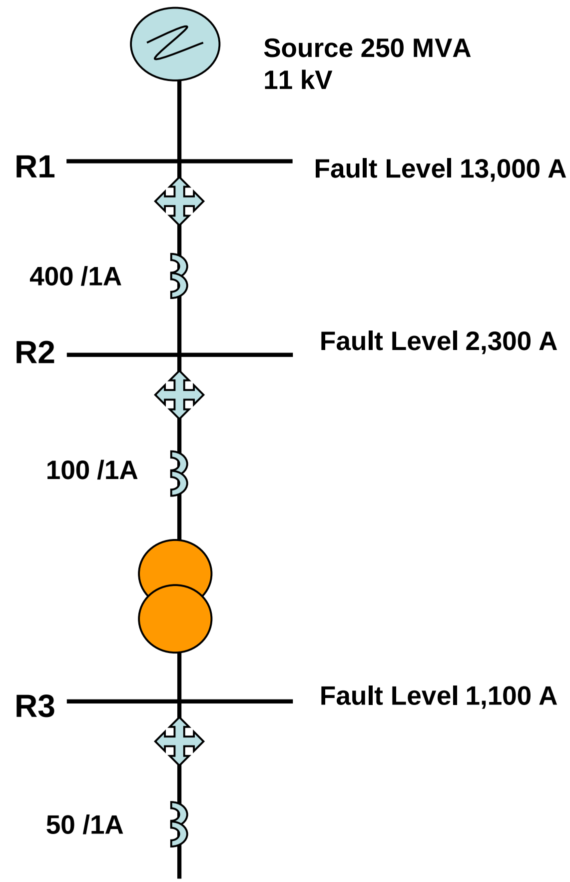


Typical time/current characteristics of 3 seconds standard electromechanical I.D.M.T. relay.

Example



IDMTL Curve with High Set



IDMTL Relays with High Set OC

Example Curve

CAG14

CDG11
CDG16

KCEG

Part 5

Short Circuit & Fault Calculation

FAULT CALCULATIONS

To predict the performance of the protection scheme as it is necessary to know what the fault conditions will be.

Some relays will be required to deal with overloads, under voltages and etc., but majority will be concerned with the detection of the ***short-circuit*** condition.

To determine the fault level when a short-circuit occurs requires a knowledge of the ***impedance*** of the various components in the system.

IMPEDANCE

An impedance consist of a resistance and reactance, it usually sufficient to consider on reactance for the purpose of fault calculations.

In most cases the exclusion of resistance is justified in that the resistance is only small fraction of the impedance and even if it were as high as 20% it would only change the impedance by a bout 2%.

The exception is in the cables where, if the CSA is small, the resistance is of the same order as the reactance,

However, as the cable have a very low impedance compared to the transformers and generators the overall effect of ignoring resistance is small

SOURCE IMPEDENCE

> THIS IS THE VALUE WHICH REPRESENTS THE IMPEDENCE BETWEEN THE SYSTEM UNDER CONSIDERATION AND THE SOURCE.

> THE VALUE IS DETERMINED BY THE FAULT LEVEL AT THE INCOMING BUSBAR

> IF THE ACTUAL FAULT LEVEL IS NOT KNOWN, THEN A VALUE BASED ON THE SWITCHGEAR RUPTURING CAPACITY IS USED.

> FOR EXAMPLE, IF THE FAULT LEVEL OR RUPTURING CAPACITY IS 250 MVA, THEN THE SOURCE IMPEDENCE ON A 10 MVA BASE IS:

$$\frac{10}{250} = 0.04\text{p.u}$$

FAULT LEVEL

When evaluating relay performance, it is usual to use ***three phase fault level*** and, if earth-fault relay are involved, the ***earth-fault level.***

It is appreciated that a ***phase-phase fault*** is far more likely than a three-phase fault, however, the three-phase value is used on the basis that it is the most onerous condition.

Calculation of a three-phase fault is fairly straightforward as it is a ***balanced fault.*** That is the current in each of the three-phase has the same magnitude and they are 120º apart.

Therefore all that is required is to calculate the current in ***one phase*** using the ***phase-neutral voltage*** and the ***impedance per phase***.

For example, an 11 kV generator has an impedance of 1.61 Ω / phase:

Phase voltage: $\frac{11,000}{\sqrt{3}}$ = 6350 volt

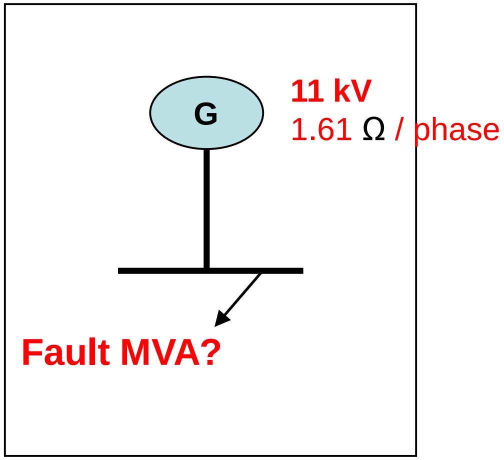
Fault current: $\frac{6350}{1.61}$ = 3944 A / phase

Although current is used in determining relay setting, it is more usual to perform fault calculations in MVA as this avoids complications when there is a ***change in voltage*** i.e. when transformer are involved.

Therefore the fault level:

= 6350 x 3944 x 10^{-6} = 25 MVA

or $\sqrt{3}$ x 11 kV x 3.944 kA = 75 MVA



A quicker way would be to perform the calculation in one operation:

viz. $3 \times 11{,}000 \times \dfrac{11{,}000}{3 \times 1.61} \times 10^{-6}$ = **75 MVA**

or in symbol $\dfrac{V^2}{Z} \times 10^{-6}$ = **MVA**

or if V in kV: Fault MVA = $\dfrac{kV^2}{Z}$

If the generator was rated as 15 MW, 0.8 p.f then the rating would be:
15 / 0.8 = **18.75 MVA**

The rating as a fraction of fault level would be:

$$\frac{\text{Rating}}{\text{Fault Level}} \quad \frac{18.75 \text{ MVA}}{75 \text{ MVA}} = \tfrac{1}{4} \textbf{ or 25\%.}$$

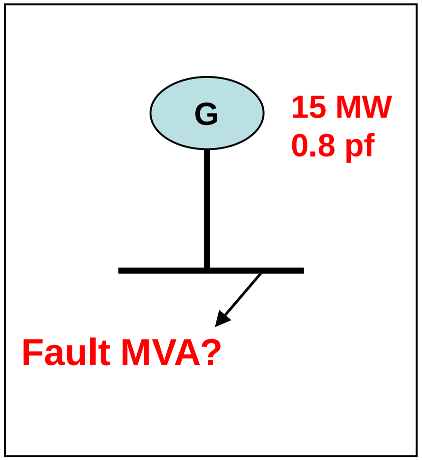
This ratio is known as the *percentage impedance or Z%.* Generator and transformer impedance are generally express in this way.

$$Z\% = \frac{\text{MVA rating}}{\text{Fault level}} \times 100\% = \frac{\text{MVA rating}}{kV^2} \times Z \times 100\%$$

Check:

$$Z\% = \frac{18.75}{11^2} \times 1.61 \times 100\% = 25\%$$

$$\text{Fault Level:} = \frac{18.75}{25\%} \times 100\% = 75 \text{ MVA}$$



Example

Generator Fault level 12.5 MVA, 20%, to avoid multiply by 100% every time, convert Z% into *p.u* i.e. 0.2 meaning that every 20 in 100. Therefore, for the generator Z p.u = 0.2

Three-phase fault level = 12.5 / 0.2 = 62.5 MVA

or on previous generator = Z p.u = 0.25

Three-phase fault level = 18.75 / 0.25 = 75 MVA

It is also convenient to convert all per unit impedance (Z p.u) to a *common base*, say 10 MVA in the following manner:

18.75 MVA generator Z p.u $= \frac{10}{18.75} \times 0.25 = 0.133$ **p.u**

12.5 MVA generator Z p.u $= \frac{10}{12.5} \times 0.2 = 0.16$ **pu**

The reason for this is so that the relative value of impedance can be attribute to every component in the circuit and therefore allow easy calculation.

The per unit method is not much better because of the many conversions of data to the chosen base values.

The complexity is significantly increased when symmetrical component theory is used to solve single phase to earth faults, double phase to earth faults, and phase to phase faults. Most electrical engineers will blindly memorize these abstract formula and cumbersome conversions.

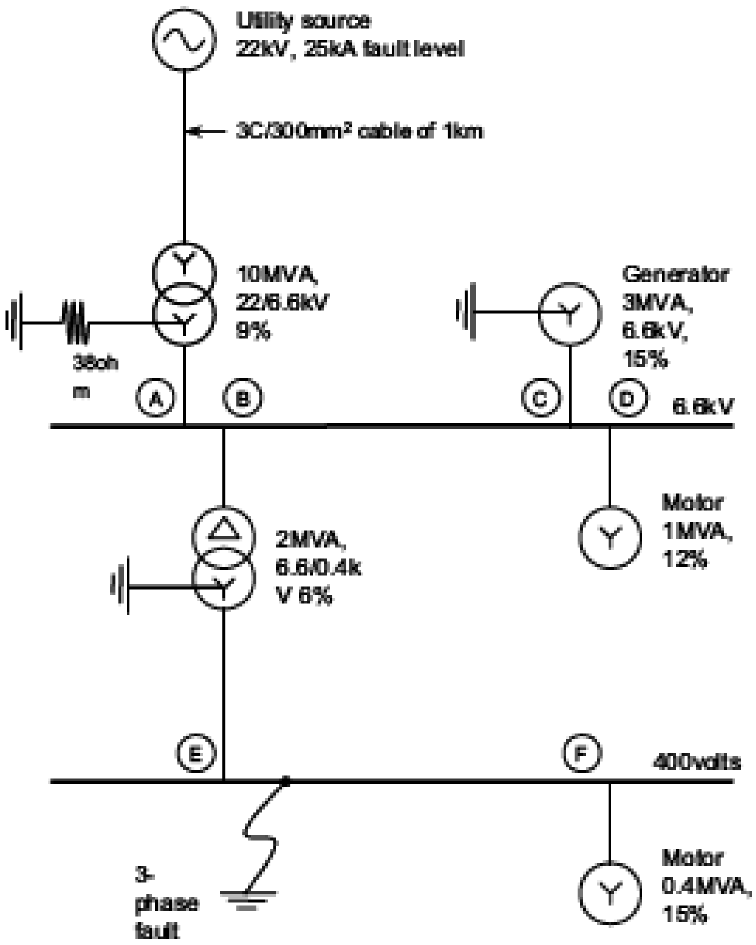
When the engineers are needed to provide on the spot estimates of fault level which are quick and reasonably accurate, they will often fail to deliver.

When software programs are used, it is not uncommon to have errors in modeling and data entry, which will produce fault level several order of magnitude in error from the correct value.

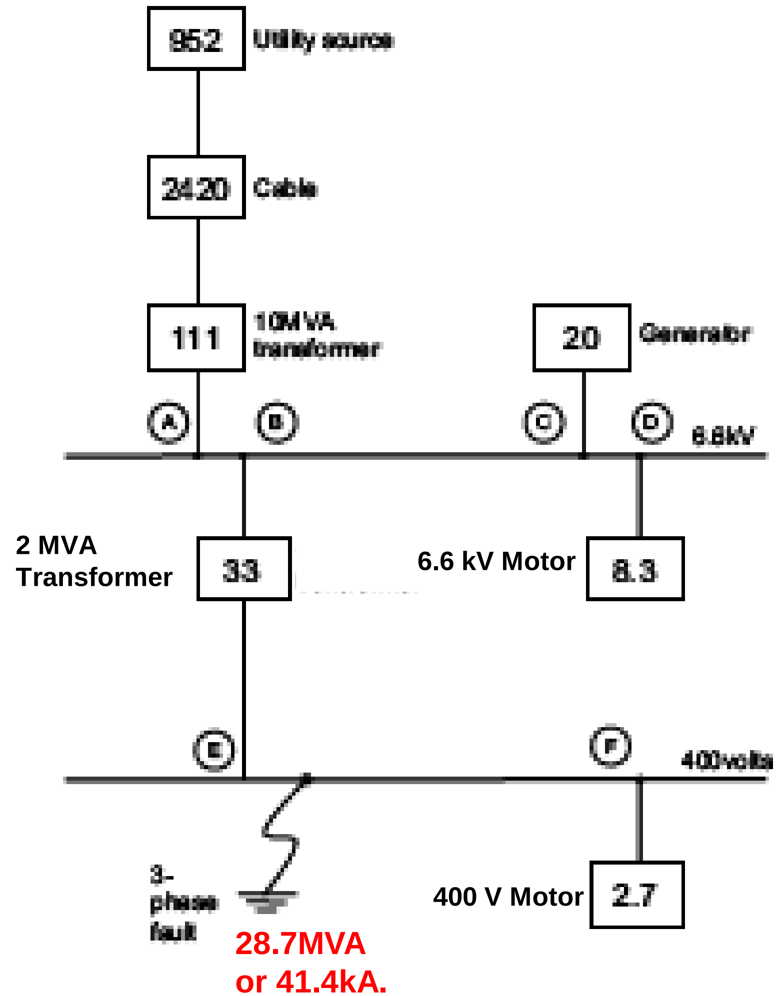
So the MVA method, a **hand calculation method** which is easy to use, easy to remember, quick and accurate.

OK, let try the following example

Other Example



The first step is to convert the typical single line diagram to the equivalent MVA single line diagram, and then to reduce the MVA single line diagram into a single MVA value at the point of fault.



MVA single line diagram

22kV Utility Source

The MVA value will be √3 x 22 x 25 = **952MVA.**

The utility source has a 25kA fault level.

10MVA Transformer

The MVA value will be $\frac{10}{0.09}$ = **111 MVA**

The transformer has 9% impedance

2MVA Transformer

The MVA value will be $\frac{2}{0.06}$ = **33 MVA**

The transformer has 6% impedance

6.6kV Motor

1The MVA value will be $\frac{1}{0.12}$ = **8.3 MVA**

The motor has a sub-transient reactance of 12% and will contribute fault current to the fault.

400 Volts Motor

0.4 The MVA value will be $\frac{0.4}{0.15}$ = **2.7 MVA**

The motor has sub-transient reactance of 15% and will contribute fault current to the fault.

Internal Generator

The MVA value will be $\frac{3}{0.15}$ = **20 MVA**

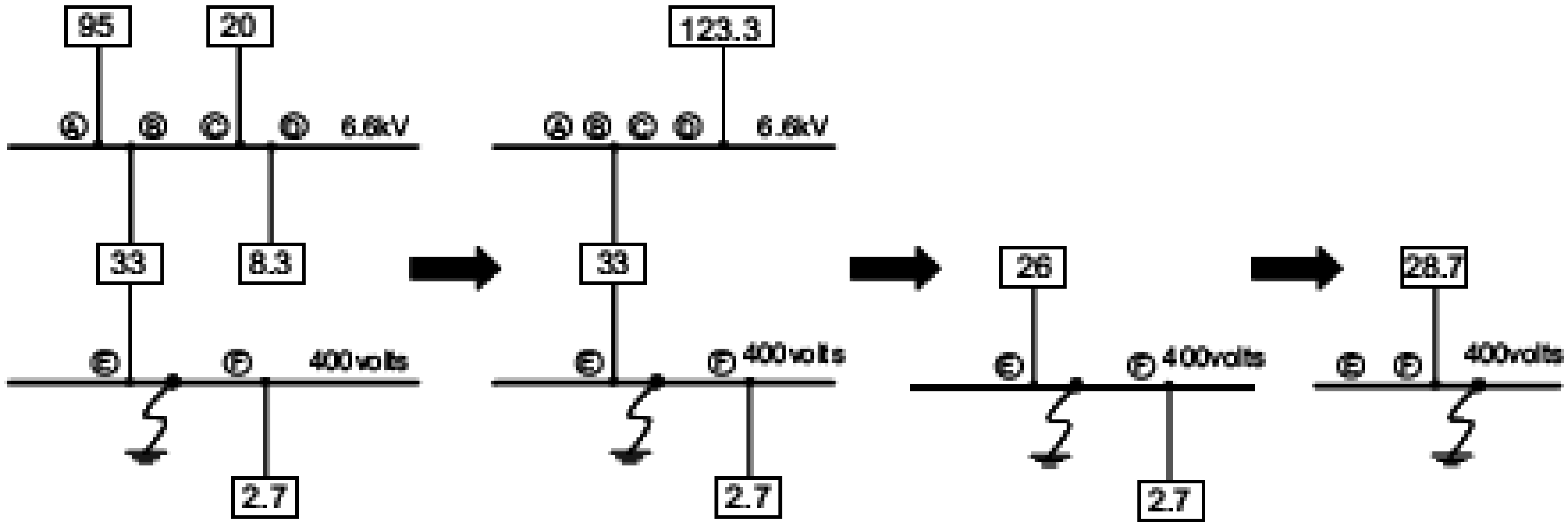
The generator is synchronized to the utility source and has a sub-transient reactance of 15%.

22kV Cable

The MVA value will be $\frac{V^2}{Z}$,

Where : V is the phase to phase voltage in kV.
Z is the per phase impedance in ohm.

The MVA value will be $\frac{22 \times 22}{0.2}$ = **2420 MVA**



$95 = \left(\frac{1}{952} + \frac{1}{2420} + \frac{1}{111}\right)^{-1}$

$123.3 = 95 + 20 + 8.3$

$26 = \left(\frac{1}{33} + \frac{1}{123.3}\right)^{-1}$

$28.7 = 26 + 2.7$

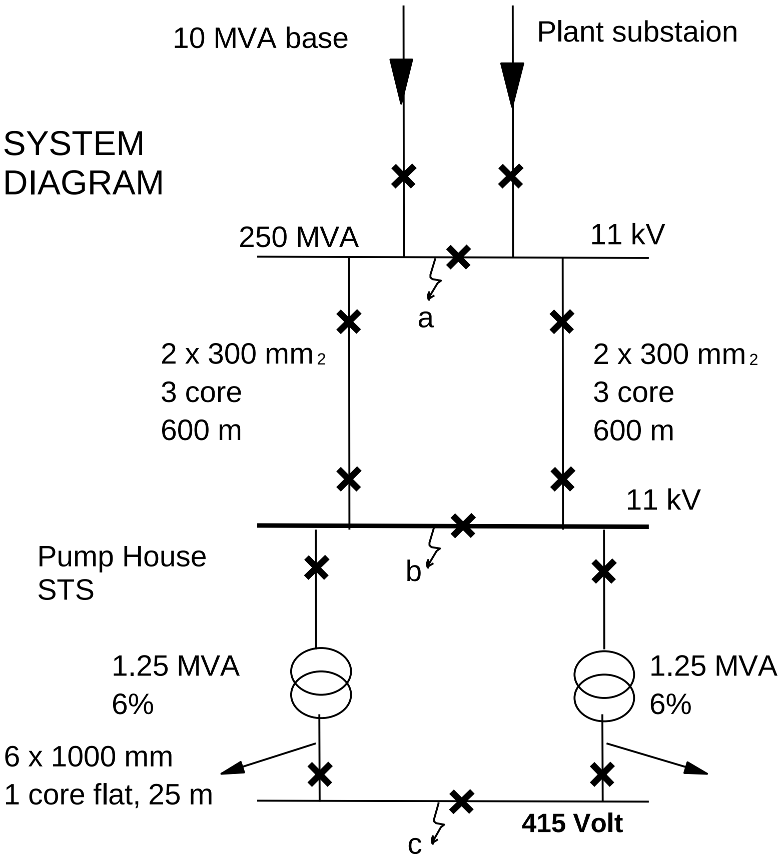
Thing to be remembered:.
In MVA series circuit, the total sum of MVA to be calculated as parallel circuit, where If MVA in parallel, total sum of MVA to be calculated as series circuit

EXERCISE (Z pu / 10 MVA base)

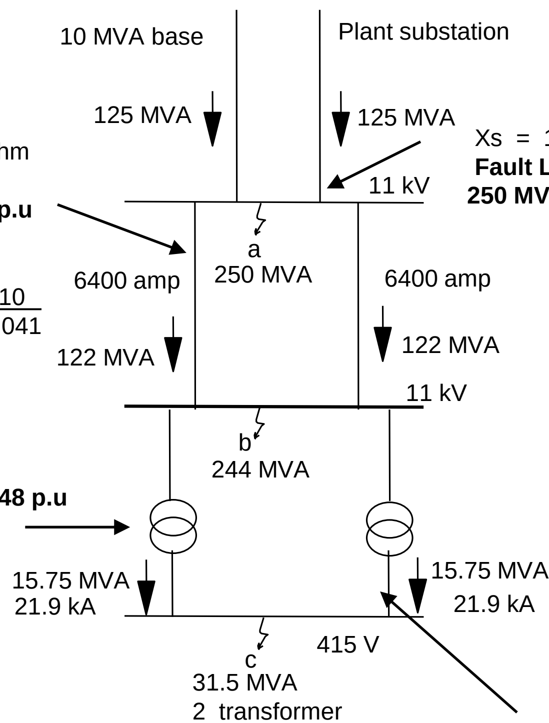
Calculates:

1. **Fault Level at a, b and c (on single and two transformer in parallel).**
2. **Calculate Short Circuit Current at every feeders**

SYSTEM DIAGRAM



MVA and Current Flow



$$Xs = 10/250 = \mathbf{0.04\ p.u}$$

Fault Level: 10 / 0.04 = 250 MVA

$$Xhtf = \frac{0.5 \times 600 \times 80}{1000000} = 0.024 \text{ ohm}$$

$$= 0.024 \times \frac{10}{11^2} = \mathbf{0.002\ p.u}$$

$$\text{Fault Level: } \frac{10}{0.04 + (0.002)\,0.5} = \frac{10}{0.041}$$

$$= 244 \text{ MVA}$$

$$Xt = \frac{10}{1.25} \times \frac{6}{100} = \mathbf{0.48\ p.u}$$

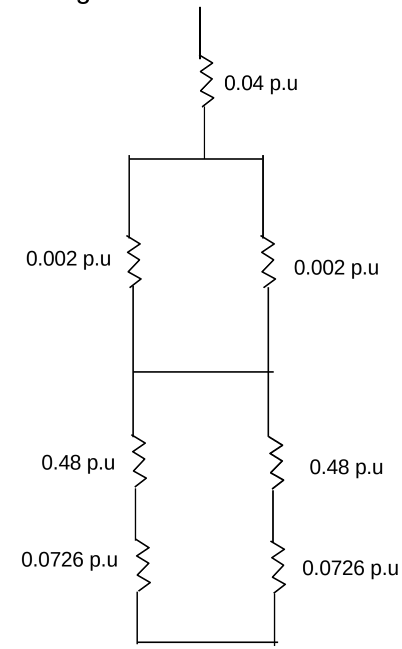
$$Xltf = 1/2 \times 25 \times 100 \times 10^{-6} = 0.00125 \text{ ohm}$$

$$= 0.00125 \times \frac{10}{0.415^2} = \mathbf{0.0726\ p.u}$$

$$\text{Fault Level: } \frac{10}{0.041 + (0.48 + 0.0726)\,0.5} = \frac{10}{0.3173}$$

= **31. 5 MVA** for 2 x'former in parallel

Impedence Diagram

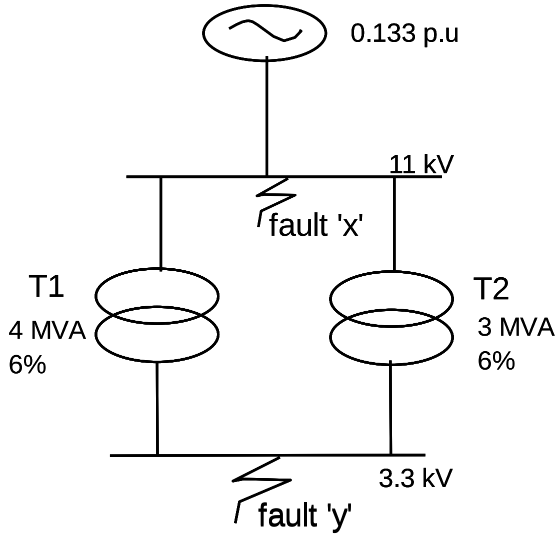


EXERCISE

If a transformer rated at 4 MVA and 3 MVA having an impedance of 6% is connected to the 18.75 MVA generator and both impedance are converted to base of 10 MVA, then the generator impedance is 0.133 p.u,

Calculates:

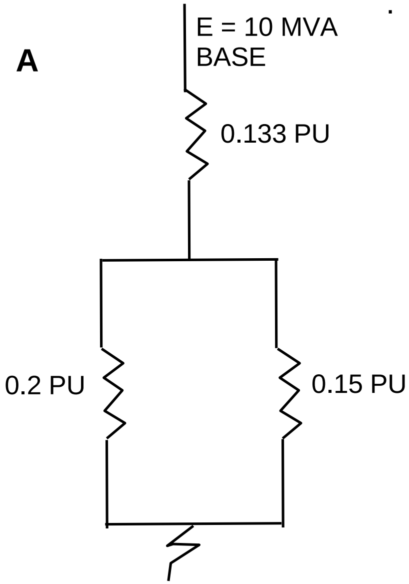
1. **Transformer impedance (p.u)**
2. **Fault Level (MVA) on generator, each transformer and total system fault level**
3. **Short-circuit current at fault 'y'**



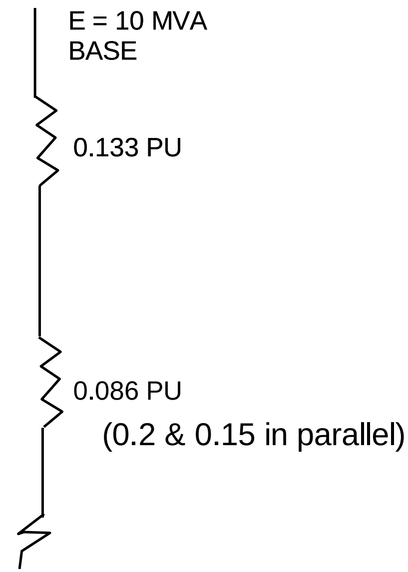
No Solution Provided

Solution

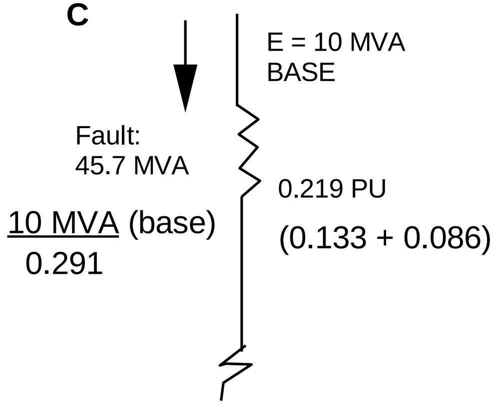
A



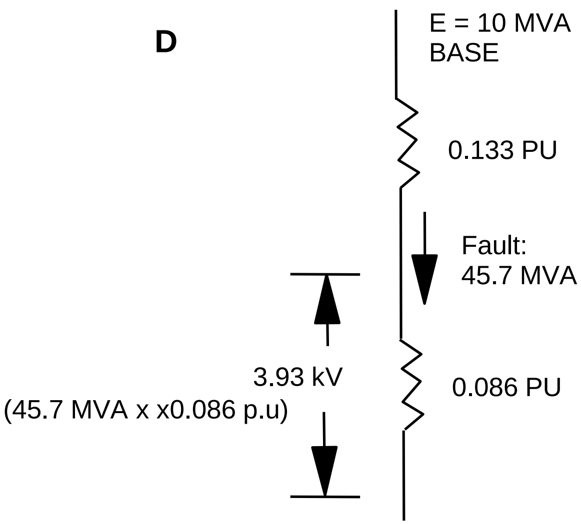
B

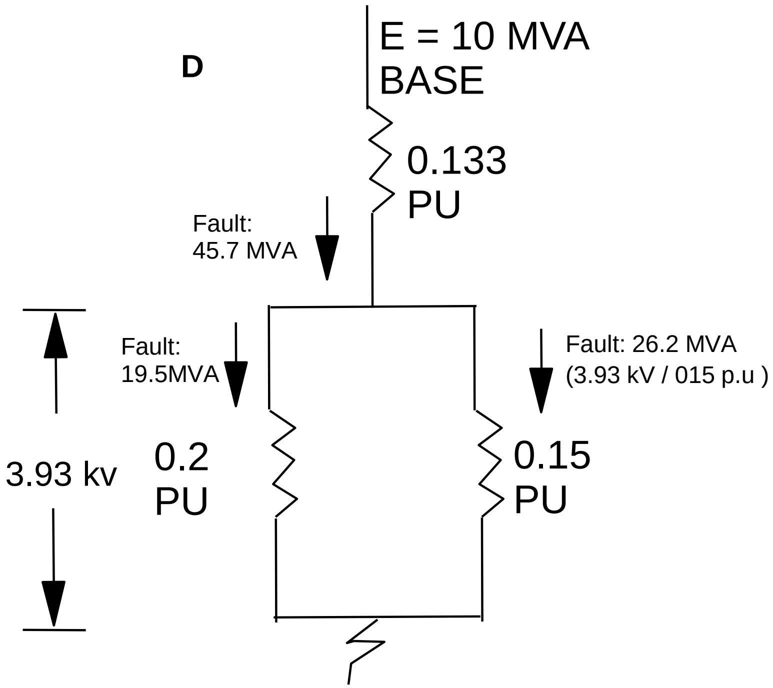


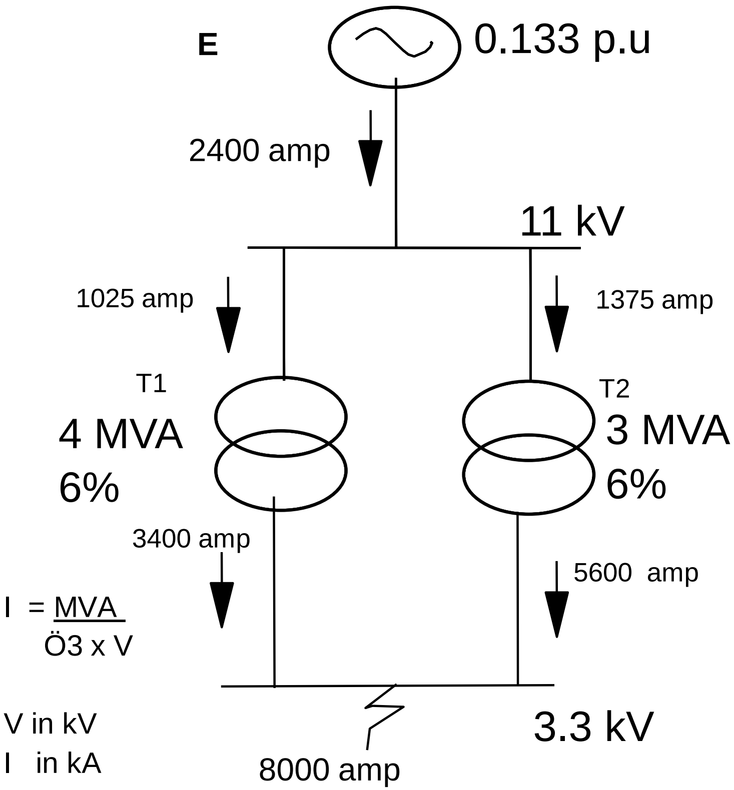
C



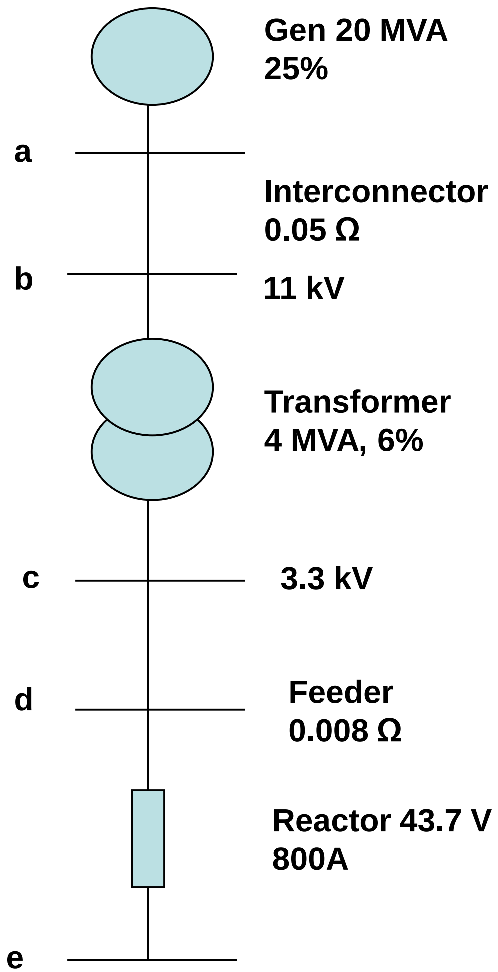
D




D
E = 10 MVA
BASE
0.133
PU
Fault:
45.7 MVA
Fault:
19.5MVA
Fault: 26.2 MVA
(3.93 kV / 015 p.u)
3.93 kv
0.2
PU
0.15
PU


E
0.133 p.u
2400 amp
11 kV
1025 amp
1375 amp
T1
T2
4 MVA
6%
3 MVA
6%
3400 amp
5600 amp
I = MVA
Ö3 x V
V in kV
I in kA
8000 amp
3.3 kV

Another Example



Tips:

- **Generator & Transformer - Z% on rating**
- **Feeder & Interconnector – actual Z per phase**
- **Reactors – Volt drop at rated current**
- **Example:**
  - $Z\ pu = \frac{Z\ \%}{100} \times \frac{MVA\ base}{MVA\ rating}$
  - $Z\ pu = Z \times \frac{MVA\ base}{kV^2}$
  - $Z\ pu = \frac{V_R}{I_R} \times \frac{MVA\ base}{kV^2}$

Exercise:
Using the fig shown and formulae given above, calculate every component pu by using 10 MVA Base. Also calculate fault level at every points.

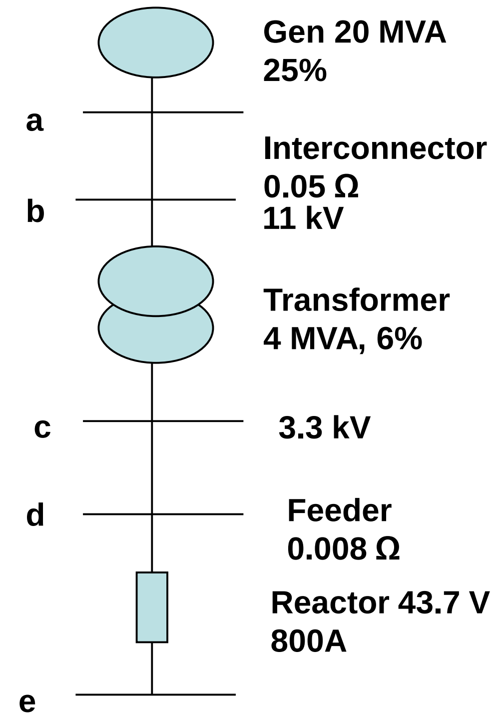
15 mins

Ω

Solution

- **Generator:** 20 MVA, 25%, $X_g = 25 / 100 \times 10 / 20 = 0.125$ pu
- **Interconnector:** 0.05 Ω, 11 kV, $X_i = 10 / 11^2 \times 0.05 = 0.004$ pu
- **Transformer:** 4 MVA, 6%, $X_t = 6 / 100 \times 10 / 4 = 0.15$ pu
- **Feeder:** 0.008 Ω, 3.3 kV, $X_f = 10 / 33^2 \times 0.008 = 0.007$ pu
- **Reactor:** 43.7 V, 800A, $X_r = 10 / 33^2 \times 43.7 / 800 = 0.05$ pu

- **Fault Level at:**
  - $a = 10 / 0.125 = 80$ MVA
  - $b = \dfrac{10}{0.125 + 0.004} = \dfrac{10}{0.129} = 77.5$MVA
  - $c = \dfrac{10}{0.129 + 0.15} = \dfrac{10}{0.279} = 35.8$ MVA
  - $d = \dfrac{10}{0.279 + 0.007} = \dfrac{10}{0.286} = 35$ MVA
  - $e = \dfrac{10}{0.286 + 0.005} = \dfrac{10}{0.336} = 29.8$ MVA



CABLES

When evaluating fault level (MVA) of cable, the Reactance in *u ohm/m* shall be taken for consideration.

VOLATGE	3 CORE	TREFOIL	FLAT
11 kV	80	95	110
414 volt	75	87	100

$$Zp.u = \frac{MVA\ base}{V^2} \times Z$$

For example: - 1 km, 11 kV, 3 core cable

$X = 1000 \times 80 \times 10^{-6} = 0.08\ \Omega$

$Xp.u = \frac{10}{11^2} \times 0.08 = 0.0066$ p.u

Fault Level: $\frac{MVA}{Xp.u} = \frac{10}{0.0066}$

$= 1515$ MVA

For example: - 15 m, 415 volt, 3 core cable

$X = 15 \times 75 \times 10^{-6} = 0.001125\ \Omega$

$Xp.u = \frac{10}{415^2} \times 0.001125$ ohm $= 0.065$ p.u

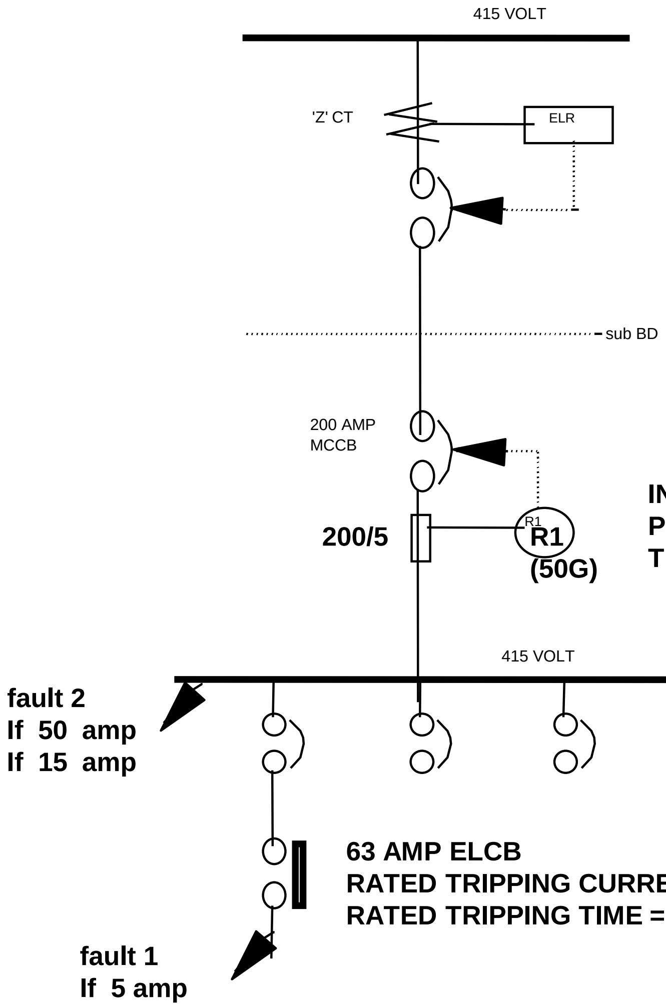
Fault Level: $\frac{MVA}{X\ pu} = \frac{10}{0.065} = 153.8$ MVA

Graph Plotting

Get ready your calculator, color pencils & flex ruler

ABC current coordination

Exercise 2



RATED TRIPPING CURRENT
= 500 mA (0.5 AMP)
RATED TRIPPING TIME
= 0.3 SEC.

INSTANTENOUES REALY
PS = 0.5 AMP
TIME = 0.03 SEC

63 AMP ELCB
RATED TRIPPING CURRENT = 300 mA
RATED TRIPPING TIME = 0.1 SEC.

Calculate Fault Current at If1 & If2
Plot the ELR & ELCB curve on the graph
(current scale x 0.01)

NOTE: FOR R1 RELAY

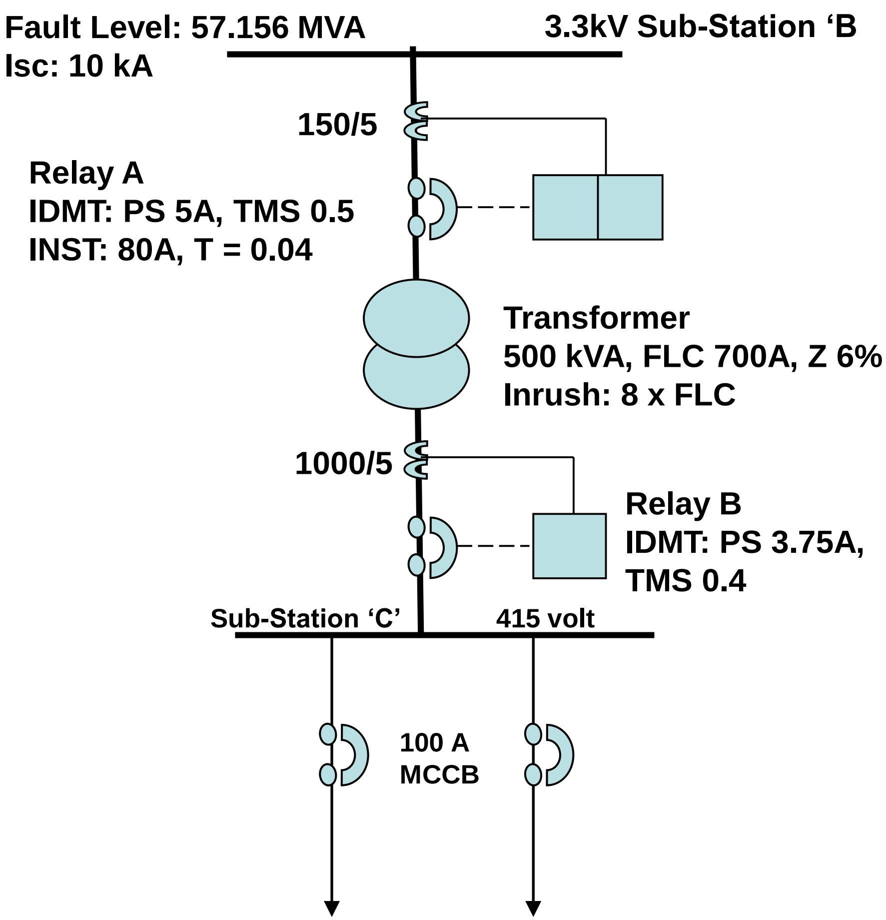
$$\% \, i \, in = \frac{If}{CTR \times PS} \times 100$$

Where: % I in = percentage of input current
If = fault current
CTR = Current Transformer Ratio
PS = Multiplier Plug Setting

EARTH FAULT / LEAKAGE COORDINATION

Plot

Exercise 3



1. Estimate the max Isc available from power transformer at SS 'C' and indicate in the graph.
   Also indicate Isc at SS 'B' on graph
2. Plot the transformer withstand limit*
3. Plot characteristic relay A/Bat given setting plot on 415 volt rating;
   - Isc of LV to HV = Isc x 415V / 3300V*
   - Isc of HV to LV = Isc x 3300V / 415V*
4. Are the transformer well protected? And is the discrimination healthy?

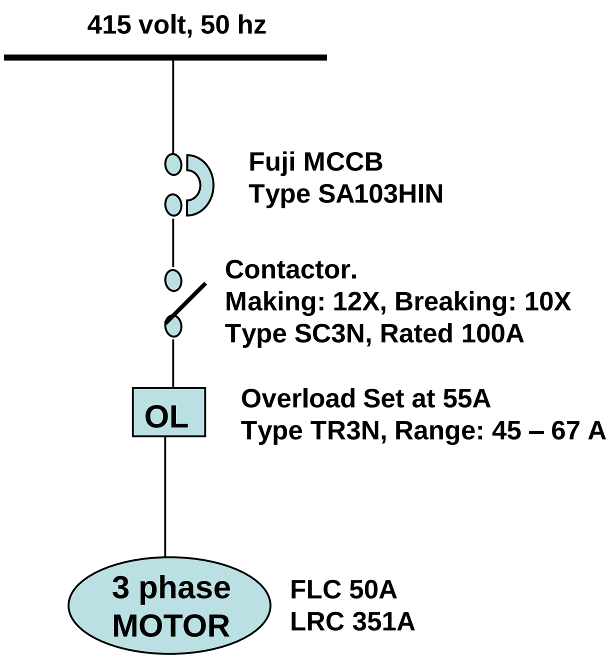
* Set table with multiple Isc*

*Formula: $Isc = \dfrac{FLC}{Z\%}$

$$t = \frac{0.14}{\left(\dfrac{I\ fault}{CTRS \times PS}\right)^{0.02} - 1} \times TMS$$

Plot

Exercise 5



Question:

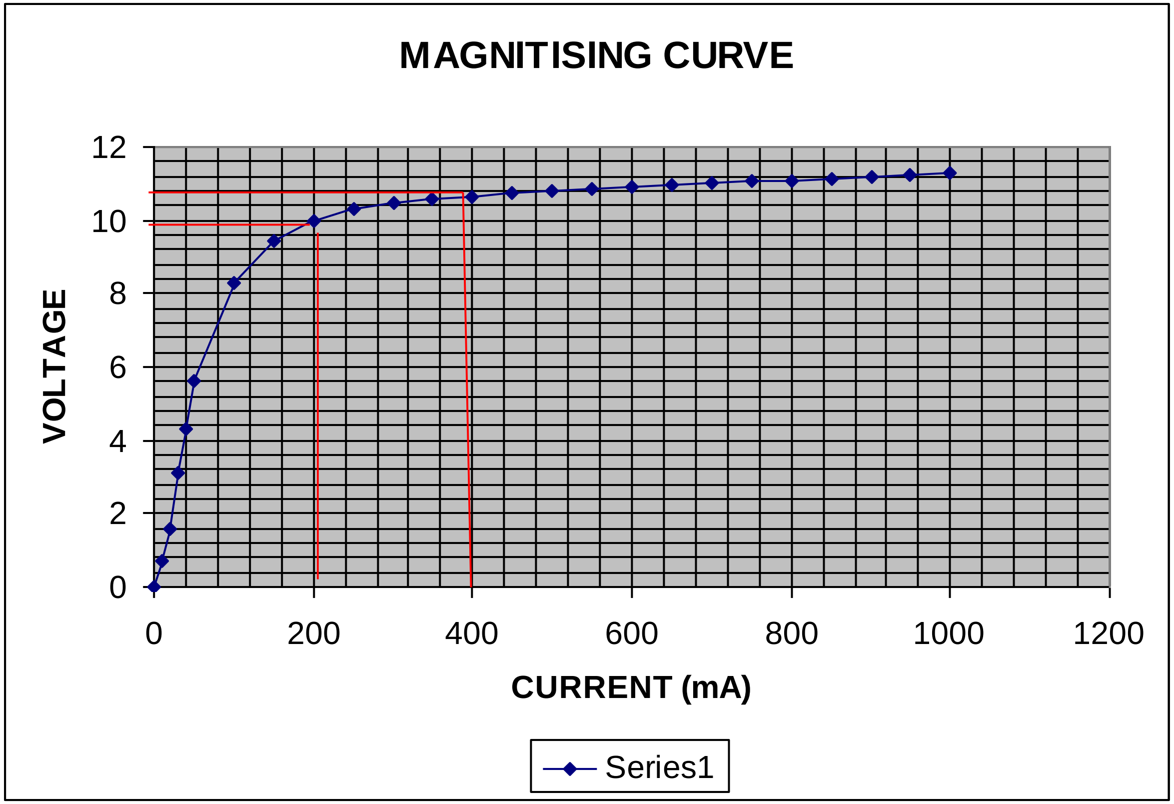
- **Plot the motor characteristric**
- **Set & plot the protective device characteristic i.e. MCCB, Overload Relay, Motor FLC/LRC Contactor rating, Breaking & Making rating**

Motor Curve ABC Pg 26

Plot

Terima Kasih

Date: 26/03/2008 - INSTEP



CT RATIO	60/1 A
VA	5
CLASS	2.5