Chapter 1

Electrical power system and protection system

Electrical power system

Generation

Generators :- **3.3 , 6.6 ,11 , 20 kv**

-step-up transformers:-

11/132kv , 20 /220kv

Transmission

- OHL:- **132 , 220 , 400kv**
- Step Dawn Transformer :-

132/33 kv , 400/220kv , 220/132 kv

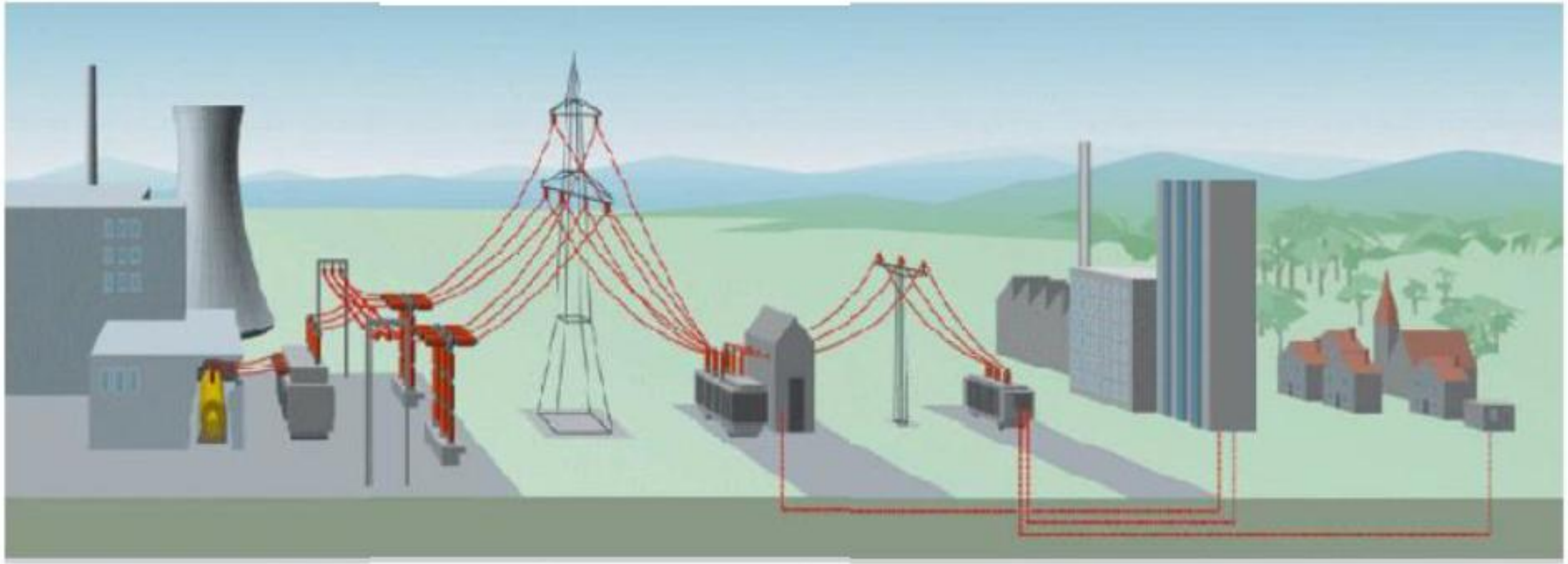
Distribution

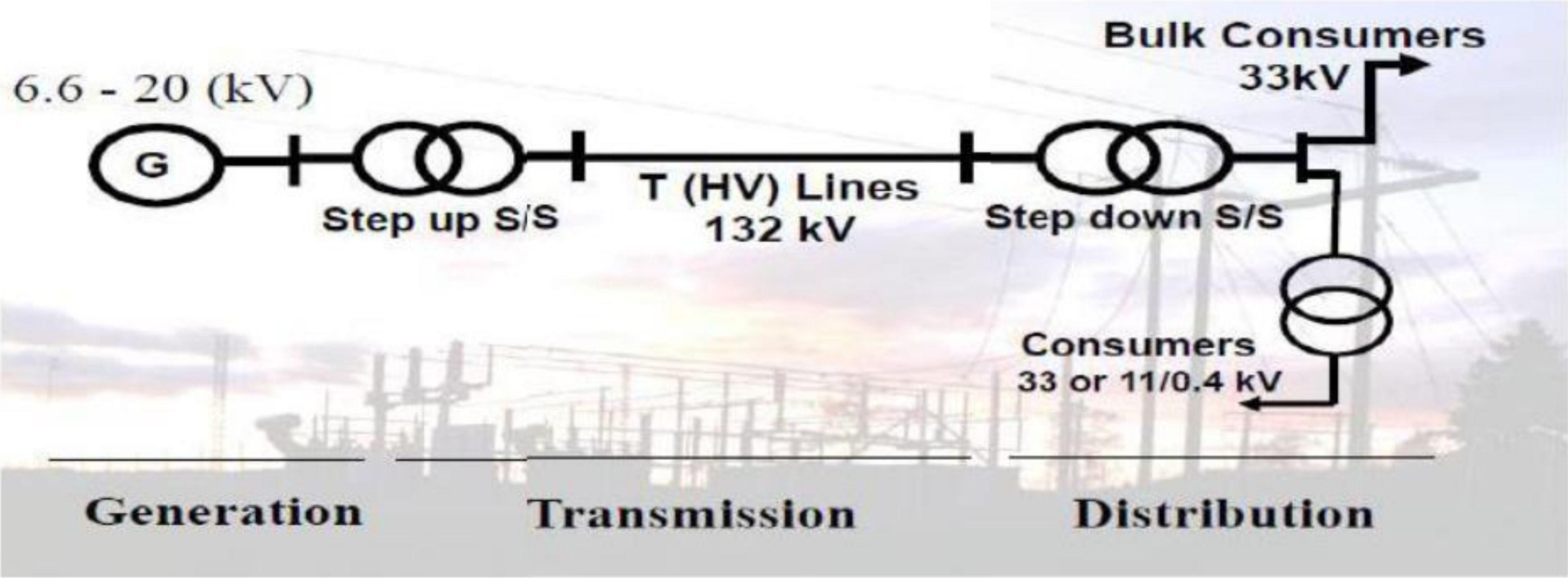
Step Dawn Transformer :-

33/11 kv , 11/0 .45kv ,

Distribution OHL & cables :-

33 kv , 22kv ,11 kv





6.6 - 20 (kV)
G
Step up S/S
T (HV) Lines
132 kV
Step down S/S
Bulk Consumers
33kV
Consumers
33 or 11/0.4 kV
Generation
Transmission
Distribution







What is the fault ? { nature and causes of faults}

- Fault is abnormal case operation for electrical power system .
  Faults are caused either by insulation failures or by conductingpath failures.
- The failure of insulation results in short circuits which are very harmful as they may damage some equipment of the power system .
- Most of the faults on transmission and distribution lines and cables are caused by the followings :-

1- Birds, aircraft, tree branches, snakes and creepers may cause faults on over head lines.

2- If the conductor are broken .and if it falls to the ground.

3- Joint failures on cables or over head lines are also cause faults.

4- Opining of one or two of the three phase makes the system unbalanced.
(this type of fault is caused by:
   - break in the conductor.
   - break in joint for cables and overhead lines.
   - C.B or isolators fail to close one or two phases .

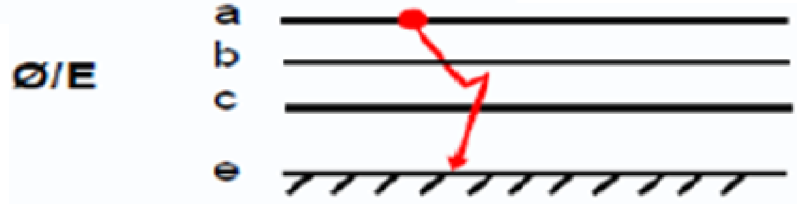
5- Direct lighting strokes, storms, earthquakes are also cause faults.

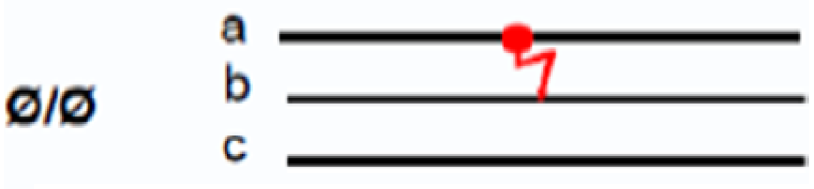
6- Most of the faults on transmission and distribution lines are caused by overvoltage due to lightning or switching surges.

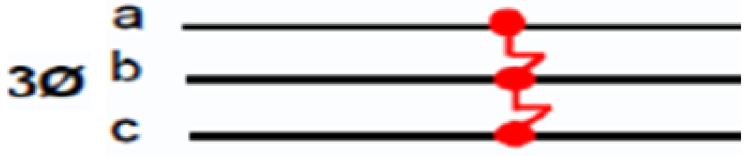
7- During switching on for lines or transformers with forgettingportable earth.

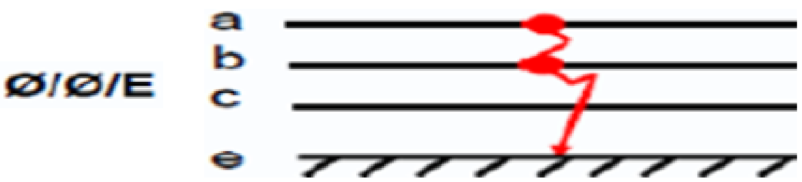
8- in addition. to short circuits between turns of the same winding.

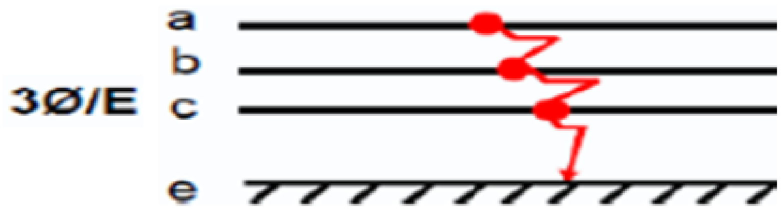
Types of Fault











Type of fault	Fault symbol	Percentage of occurrence
Line to ground fault	L- G	85 %
Double line to ground fault	2L- G	5 %
Line to line fault	L-L	8 %
Three phase fault	3- Φ	2 %

Fault Statistics

Element	% of total fault	Cause of fault
Overhead lines	50 %	1- Birds, aircraft, tree branches, snakes and creepers. 2- Direct lighting strokes, storms, earthquakes. 3- Internal over-voltage.
Underground cables	10 %	1- Damage during digging. 2- Failure of joints. 3- Insulation failure due to temperature rise.
transformers	10 %	1- Insulation failure. 2- Fault in tap changer. 3- Fault in bushing. 4- Over loading , over voltage . and over flux. 5- Fault in protection system.
Generators	6 %	1- Stator fault. 2- Rotor fault. 3- Abnormal condition. 4- Fault in associated equipment. 5- Fault in protection system.

Element	% of total fault	Cause of fault
Switchgears	12 %	1- Insulation failure. 2- Leakage of air/oil/gas. 3- Mechanical defect. 4- Lack of maintenance.
CTs , VTs	3 %	1- Insulation failure. 2- Breaking of conductor. 3- over -voltage. 4- Wrong connections.
Control - circuits equipment	3 %	1- Insulation failure of leads for DC and AC circuits. 2- Damage for control circuits and equipment. 3- Wrong connections.
miscellaneous	6 %	1- Insulation failure.


DANGER
HIGH
VOLTAGE


SF-A4
OMR

Effects Of Faults

The most dangerous type the fault is a short circuit as it may have the following effects on a power system:- **{ if it remains uncleared }**

(I) Heavy short circuit current may cause damage to equipment or any other element of system due to overheating and high mechanical forces.

(II) Arcs associated with short circuits may cause fire hazards.

(III) There may be a loss of system stability.

(IV) The above faults may be cause interruption of supply to consumers. (loss of revenue) .

(V) An unlearned heavy short circuit may cause the total failure of the system.

need for protective system

Now, the main question

Why we need the protection system?

the basic requirments of protective system   4 S – R - C

- Speed   (Fast operation) .
- Stability.
- Selectivity or discrimination.
- Sensitivity.
- Reliability.

❖ **Speed   (Fast Operation):-**

- A protective system should be ***fast*** enough to isolate the faulty element of the system as quickly as possible to minimize damage to the equipment and to maintain the system stability.
  (To operate within acceptable system security limits (1- 3 cycles).

❖ **Stability:-**

- A protective system should be remain ***stable*** even when any a large current is flowing through its protective zone due to an ***external fault*** .

- **Selectivity or discrimination:-** - A protective system is able to ***discriminate between:-***

  Fault and the normal operation in its protective zone .

  Fault in its protective zone and a fault outside protective zone .

  To isolate only the effected power system zone (s)

- **Sensitivity:-** - A protective relay should be ***sensitive*** to operate when operating current just exceeds its pick – up value.

- **Reliability:-** - A protective system (protective relay , C.B , CT , VT , Battery , wiring, etc ...) is a high degree of ***Reliability*** to operate reliably when a fault occurs in its protection zone. The Failure of any protective element cause Failure for protective system. (A typical value of ***Reliability*** of protective scheme is 95%). To respond when reqired.

- **Cost**:- Maximum/Adequate protection with minimum cost in the same time.

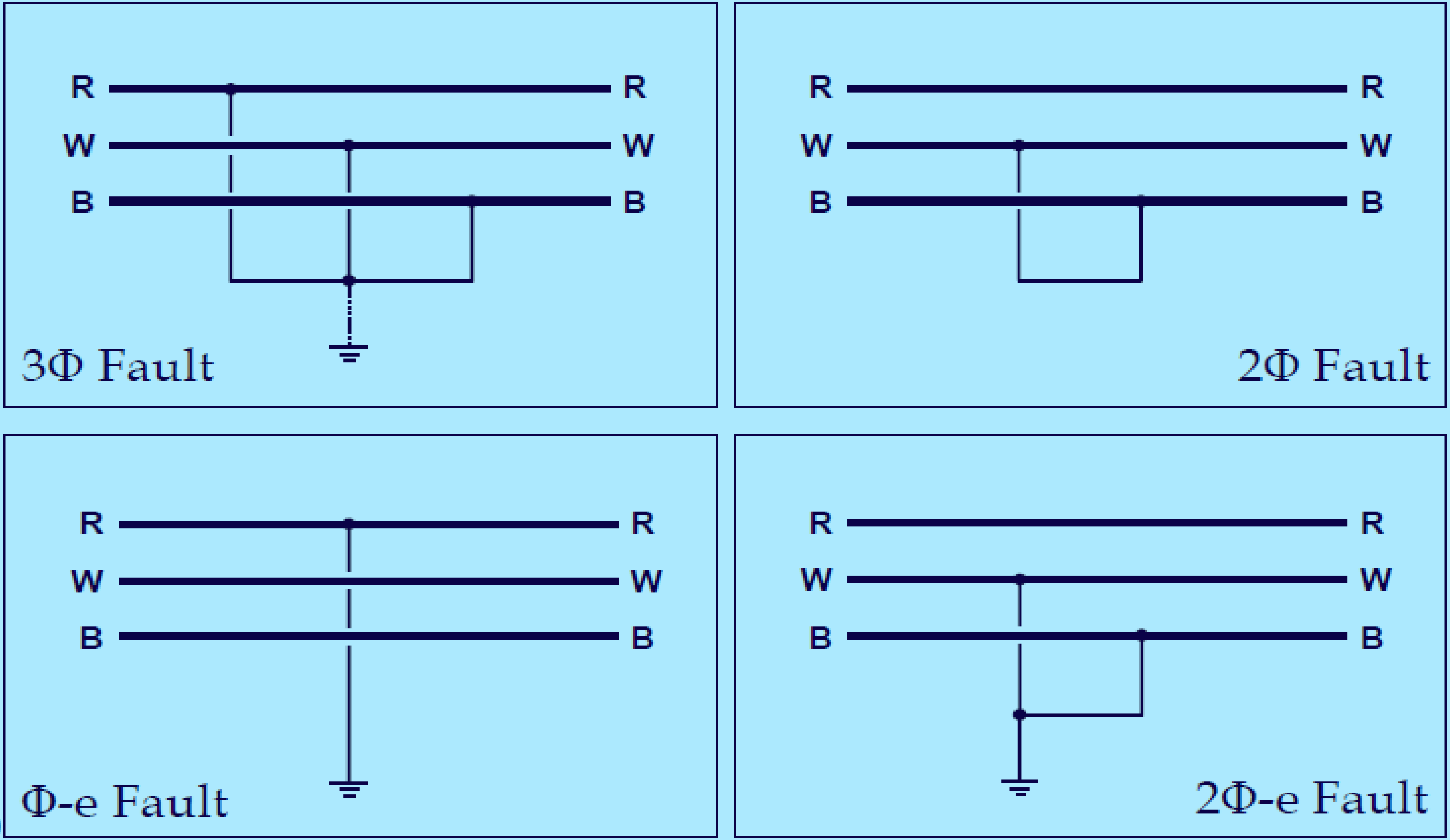
  Simplicity :- minimum equipment and circuity.

  Operability:- Flexibilty of protection system for maintenance purpses with adequqte test facilties.

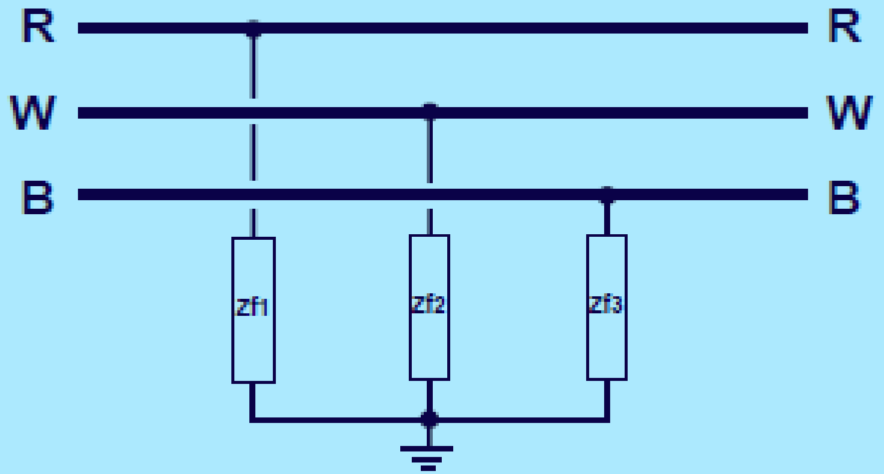
Purpose of Protection

- Detect all electrical faults and some abnormal operating conditions
- Protect human beings and properties around the power network
- The operation must be selective
  - disconnect minimum possible part of the power network
- The operation must be fast and sensitive
  - danger of life, damages and disturbances have to be minimized
  - the stability of the network has to be ensured in all conditions
- Protection must cover 100% of the protected network
- Protection should be reliable and simple
- Commissioning tests of the protection should be possible to perform in a place of installation

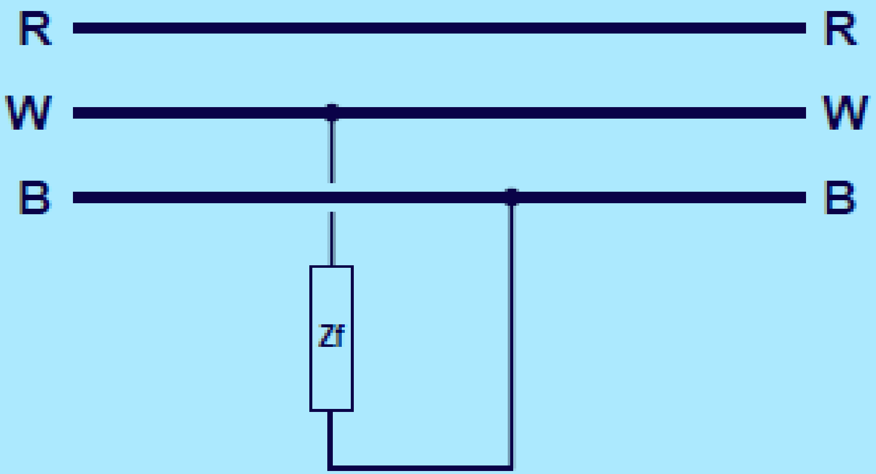
Short-circuit Type Faults



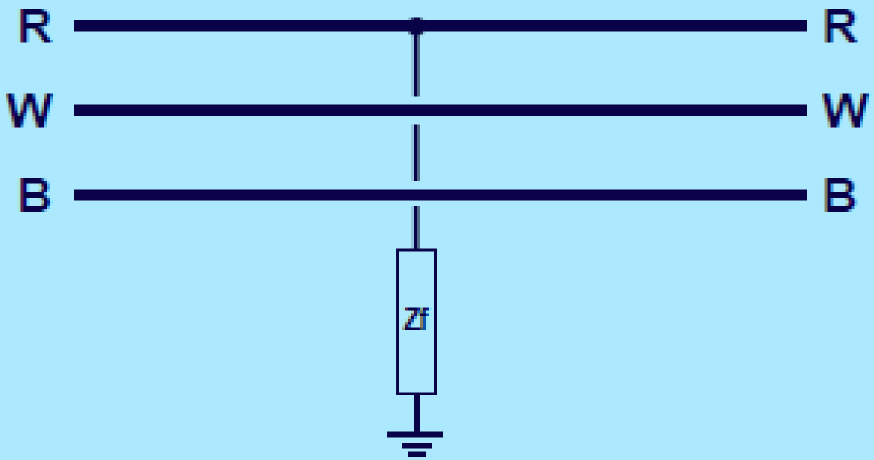
Short-circuit Type Faults with Fault Impedance



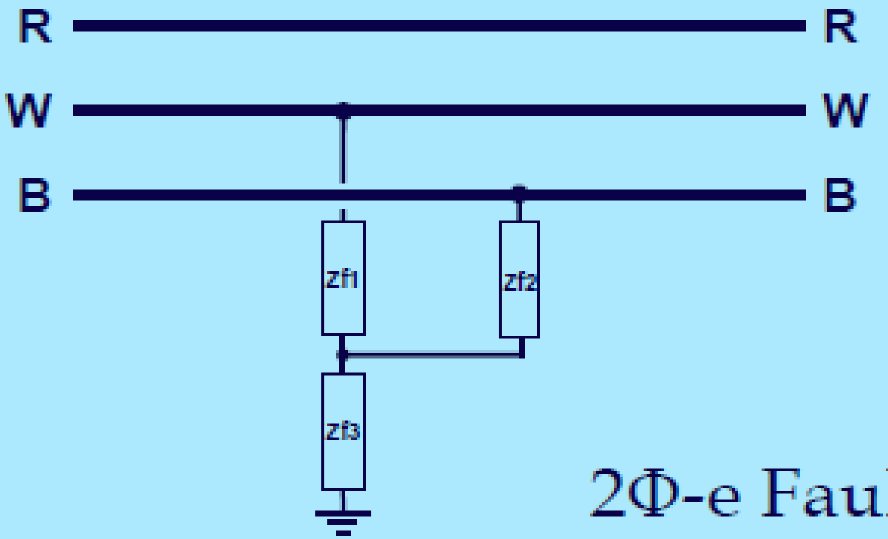
3Φ Fault



2Φ Fault

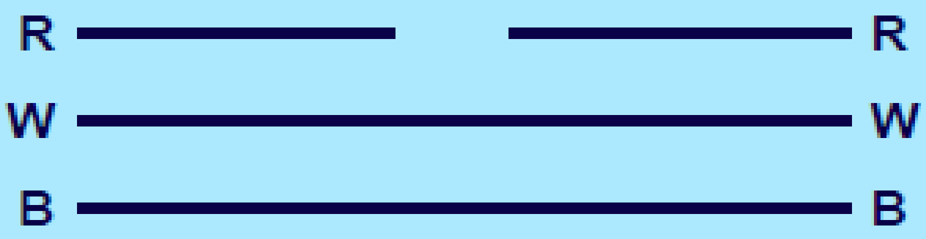


Φ-e Fault

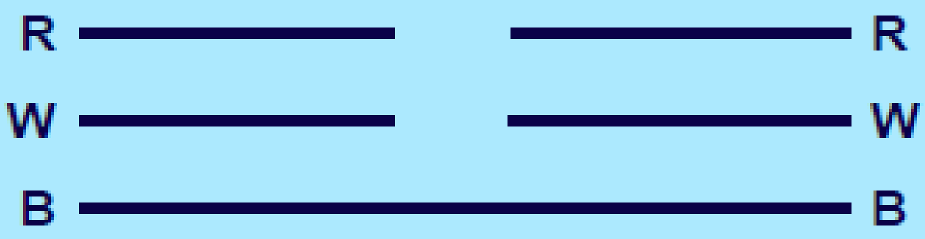


2Φ-e Fault

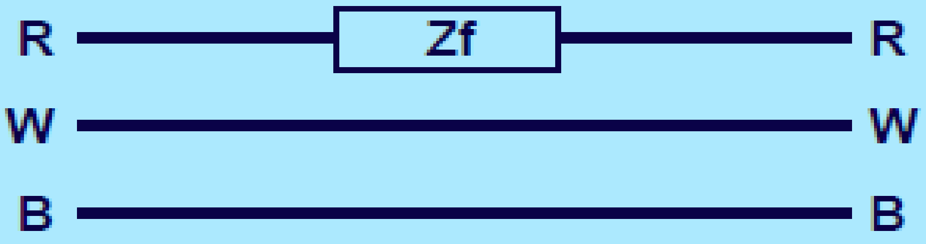
Series Type Faults



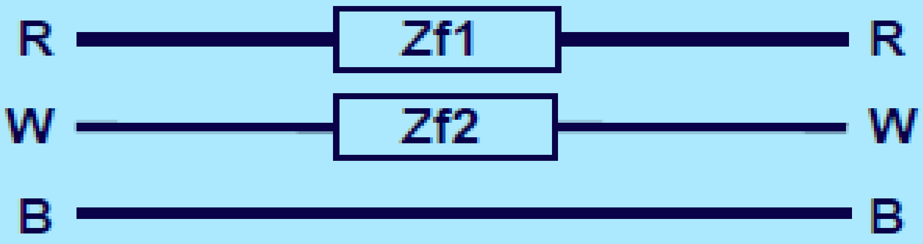
1Φ Open



2Φ Open

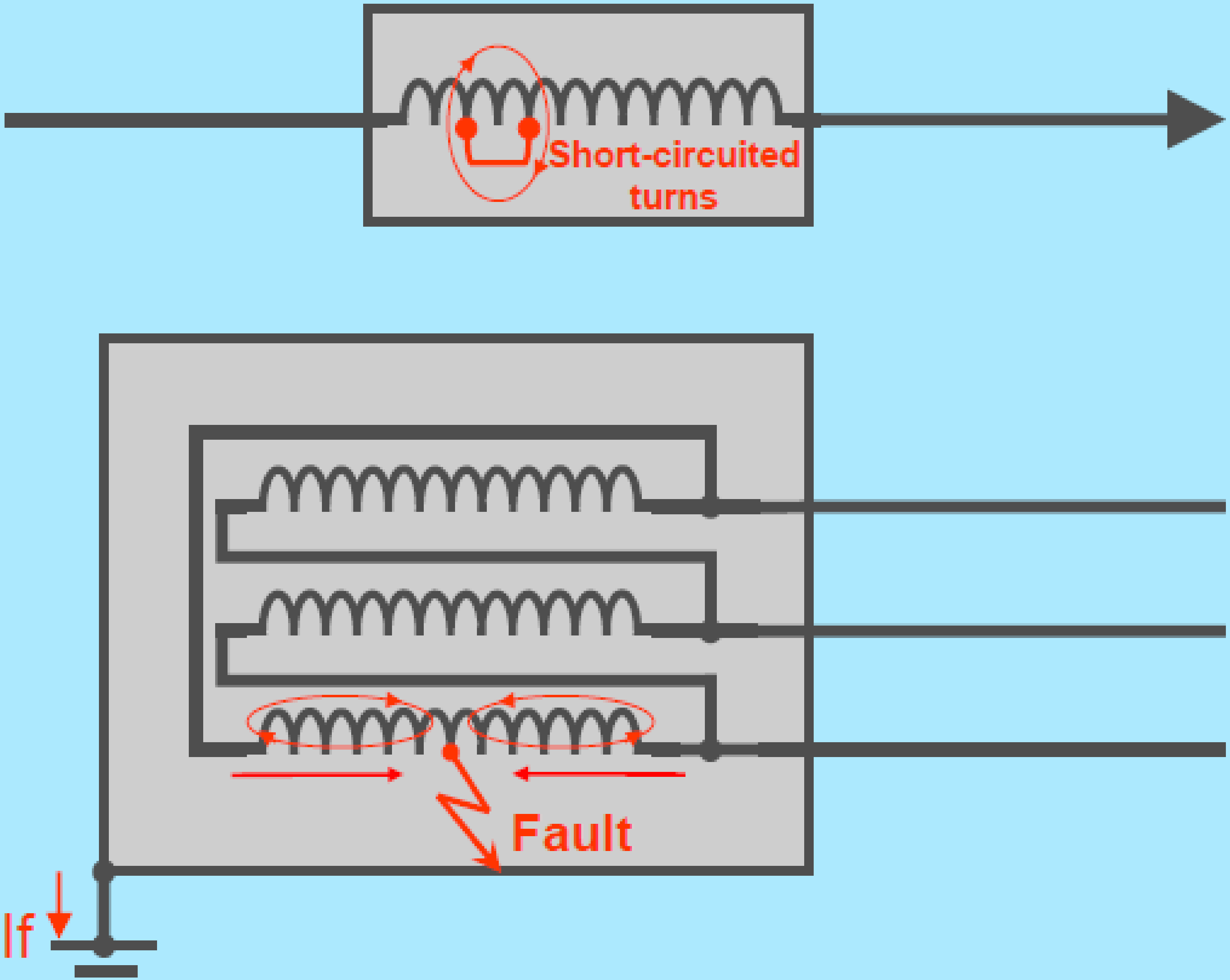


Series impedance in 1Φ



Series impedance in 2Φ's

Faults in Windings



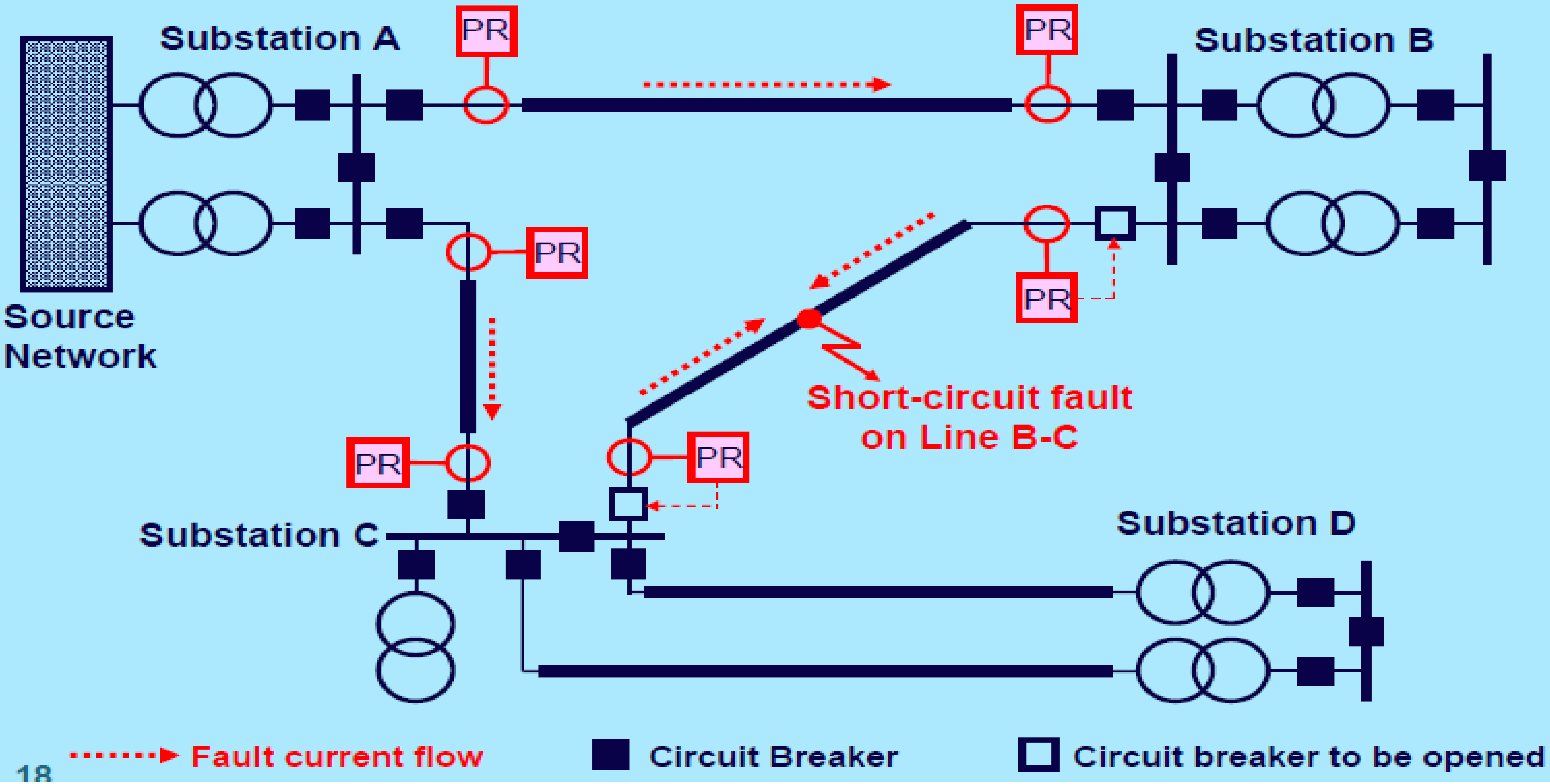
Protection Schemes – Key Factors

- Automatic and correct diagnosis of faults and abnormalities
- Quick response – measured in milliseconds to a few seconds at the most
- Must operate reliably
- Can be viewed as a form of active insurance intended to maintain high degree of service continuity and limit losses through equipment and plant damage

Basic Objectives of a Network Protection System

- Detect faults and unacceptable abnormalities and isolate faulty section of network as quickly as possible
- Minimise extent of damage at fault point
- Minimise effect fault has on rest of power system
- Minimise danger to life and property
- Minimise extent and duration of outage

Protection Application Concepts



Protection Application Concepts - continued

- Protection relays are associated with each network plant equipment item or circuit (ie line, cable, transformer, generator, busbar etc)
- Protection relays closest to the fault location should operate first
- Circuit breakers closest to fault should be opened first
- Fault current components will flow in other (unfaulted) circuits – protection relays associated with these should not operate in the first instance
- As protection relays or circuit breakers may fail to operate during a fault on occasions, back-up is necessary
- Concepts of protection function *Availability, Reliability* and *Security*

Protection system contents

- **Sensors :** **1 Current Transformers**

Current transformers, or CTs, are instrument transformers that are especially designed to accurately reflect primary, power system, current into secondary, low-current windings. CTs are used to provide low voltage, low-current inputs to metering devices, control relays, and protective

2 Voltage Transformers

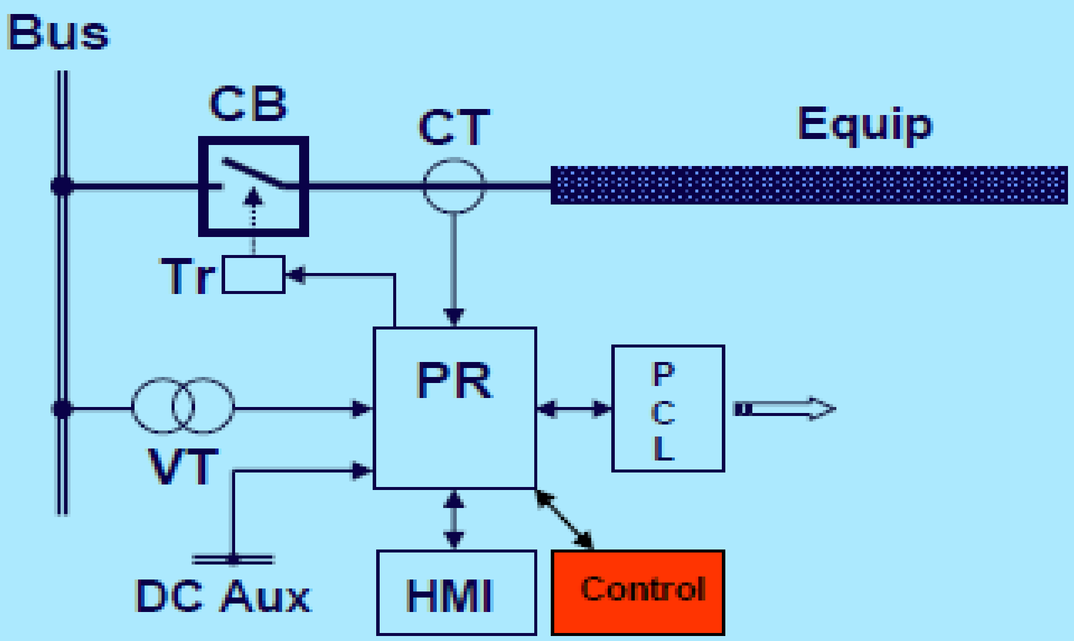
Voltage transformers, or VTs, are instrument transformers especially designed to accurately reflect primary, power system voltage into the secondary, low-voltage winding. Voltage transformers are connected in shunt with power system components. They are used to provide low voltage, low power inputs to metering devices, control relays, and protective

- **processing :** **Protective Relays**

Protective relays are devices specifically designed to detect abnormal power system conditions and to initiate appropriate power system

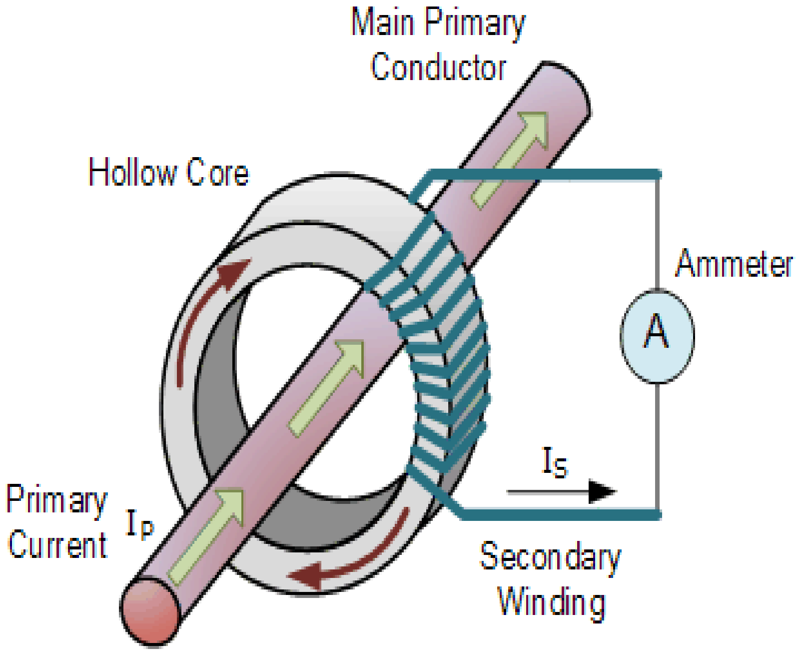
The function of most protective relays is to initiate circuit-breaker opening. Occasionally protective relays are used to inhibit circuit-breaker opening

Protection Function - Components

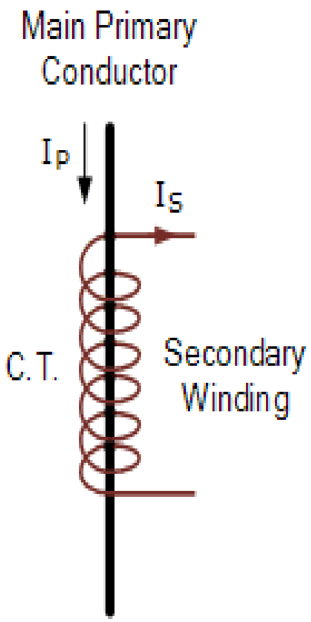


Basic Arrangement of a Protection Scheme

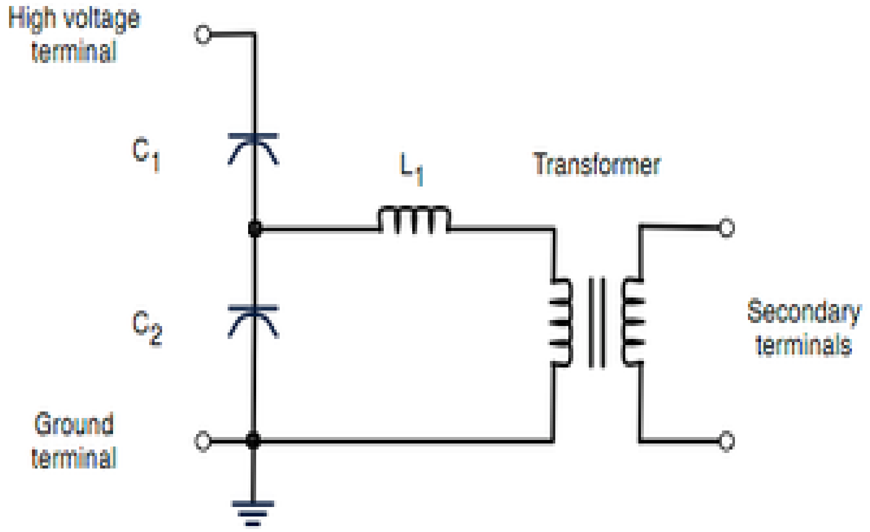
PR	Protection Relay
CB	Circuit Breaker
Equip	Protected Item
CT	Current Transformer
VT	Voltage Transformer
DC Aux	DC Auxiliary supply
HMI	Man-machine interface
PCL	Communications Link
Tr	CB trip coil



Construction



Circuit
Symbol

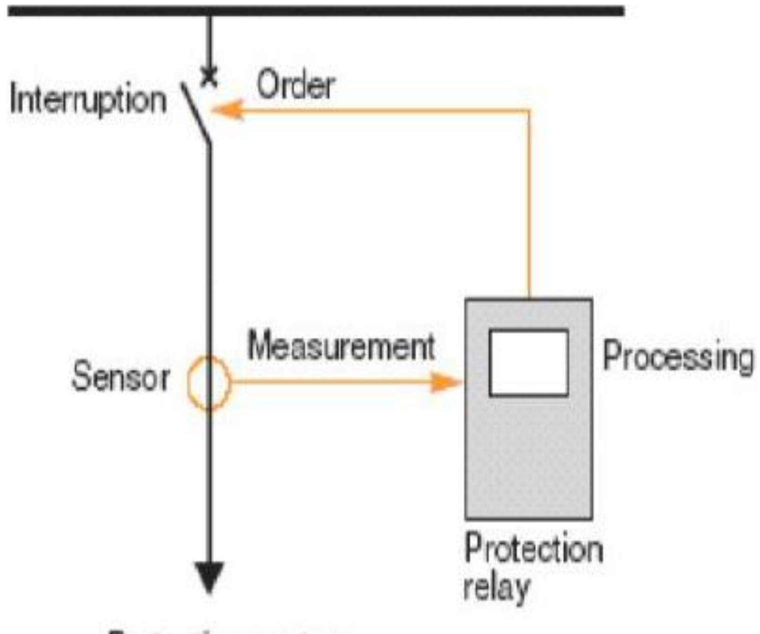

High voltage terminal
C_1
L_1
Transformer
C_2
Secondary terminals
Ground terminal

- **interruption :** **Circuit Breakers**

  Circuit breakers are fault-interrupting devices that enable or interrupt the flow of current to power system components.

  Since circuit breakers are designed to carry and interrupt both load current and fault (short-circuit) current, circuit breakers are used as switching devices as well as fault-interrupting devices.

- **AC / DC Supply :** **Power Supply For protective relays , and trip circuits supply.**



Protection system.

Basic and objectives of protecting the power system

The main objective of protecting the power system is to provide quick isolation of the power system’s area with fault, in order that shock in the rest of system to be minimized and to be intact for as long as possible.

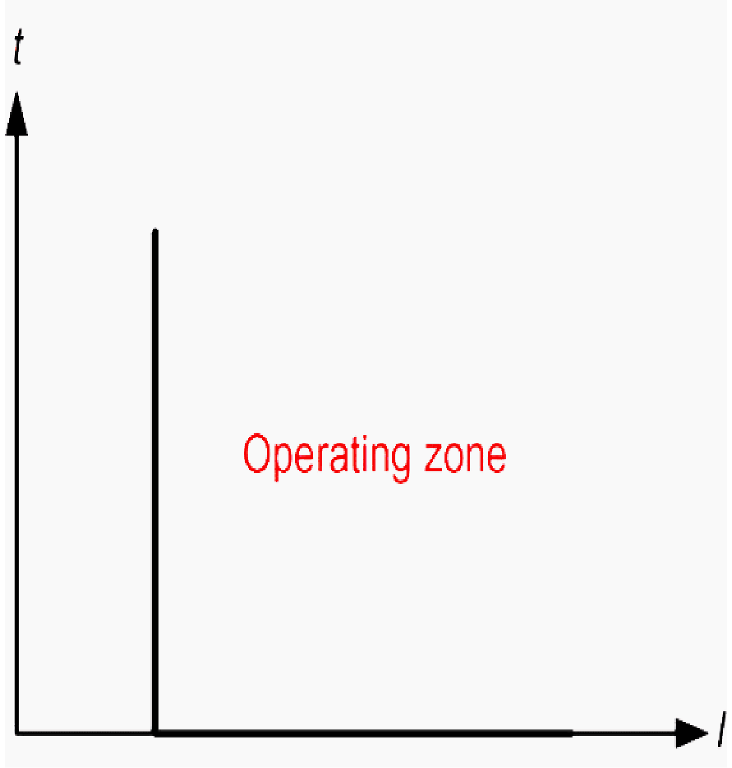
1. Overcurrent relays

The basic element in overcurrent protection is an overcurrent relay. The ANSI device number is 50 for an instantaneous overcurrent (IOC) or a Definite Time Overcurrent (DTOC) and 51 for the Inverse Definite Minimum Time. There are three types of operating characteristics of overcurrent relays:

1) Definite(Instantaneous)-Current Protection,
2) Definite-Time Protection and
3) Inverse-Time Protection.

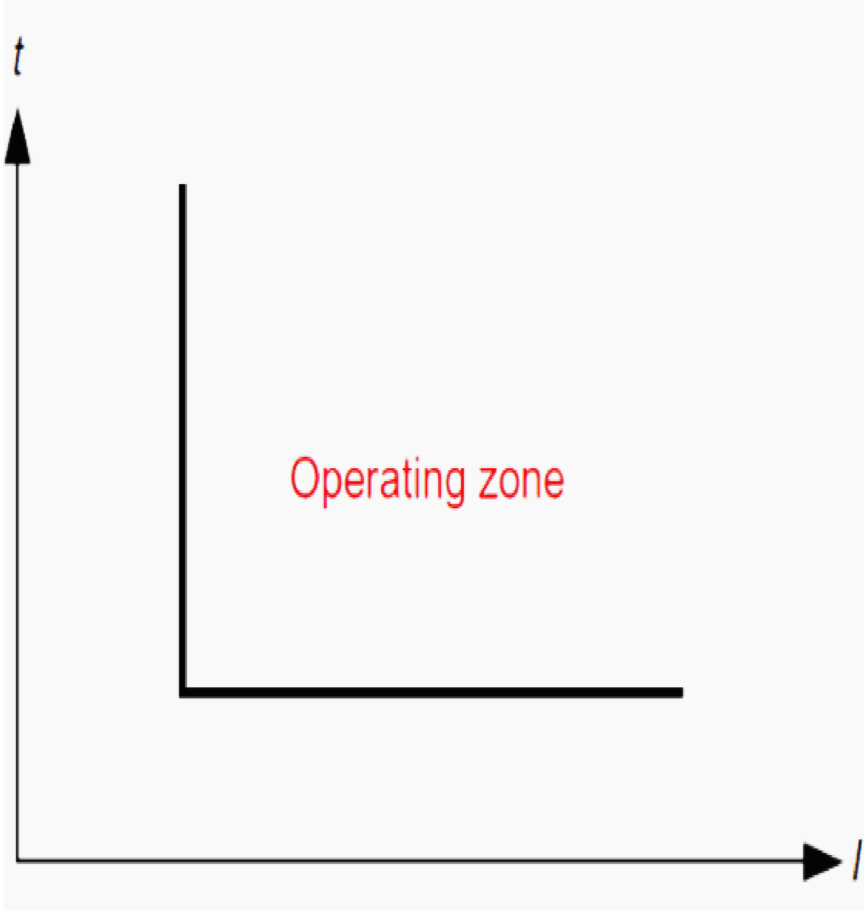
1) Definite (instantaneous)-current protection

This relay is referred as definite (instantaneous) overcurrent relay. The relay operates as soon as the current gets higher than a preset value. There is no intentional time delay set.



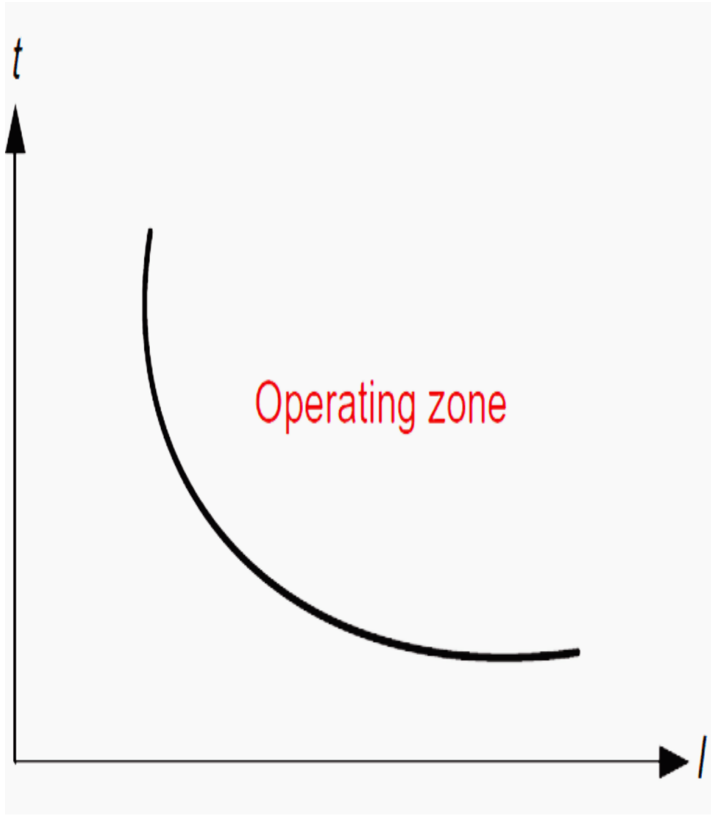
2) Definite-Time Protection:

In this type, two conditions must be satisfied for operation (tripping), current must exceed the setting value and the fault must be continuous for at least a time equal to the time setting of the relay.



3) Inverse-Time Protection

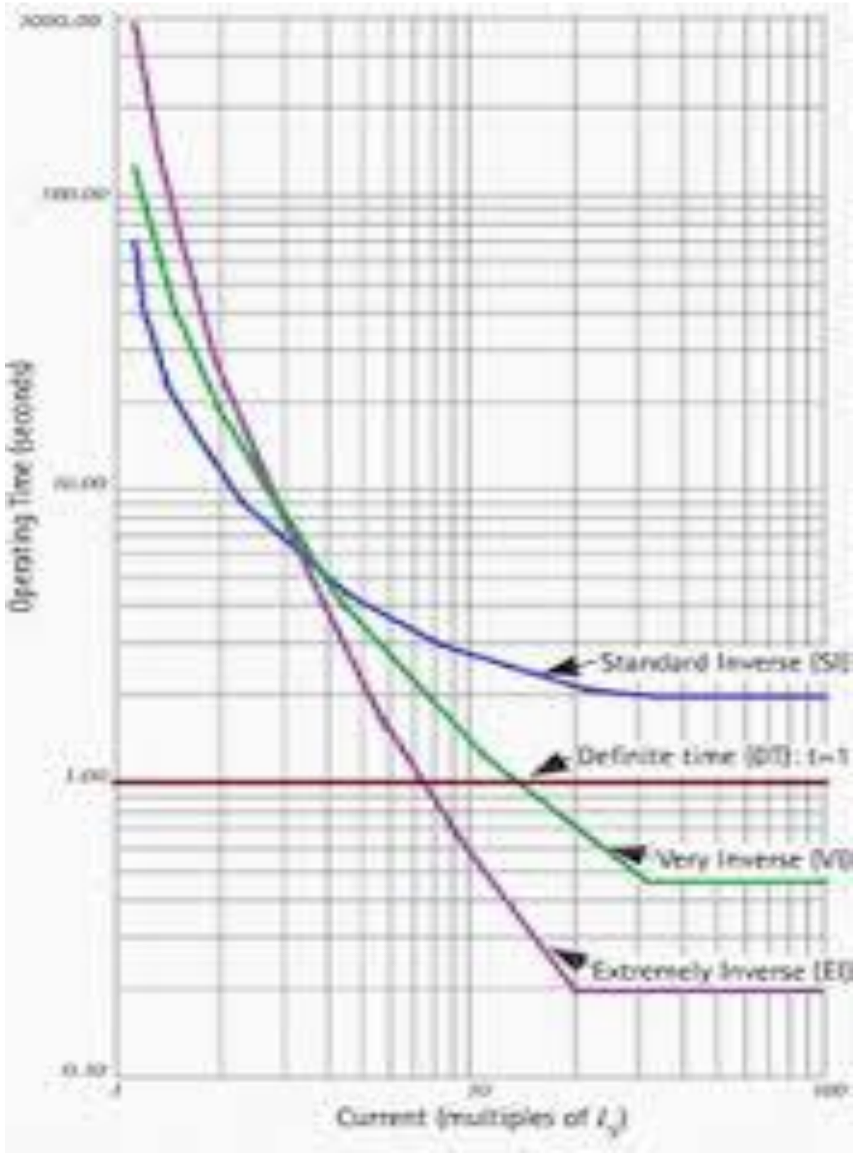
In this type, operating time is inversely changed with the current. So, high current will operate overcurrent relay faster than lower ones.

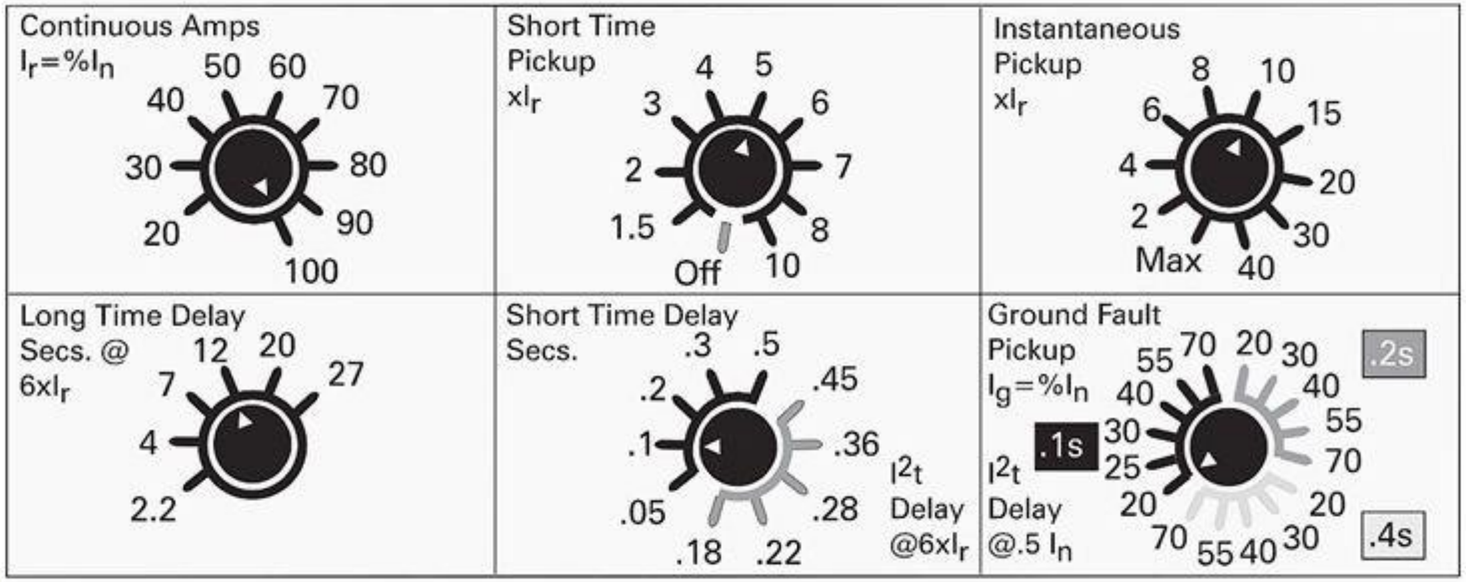


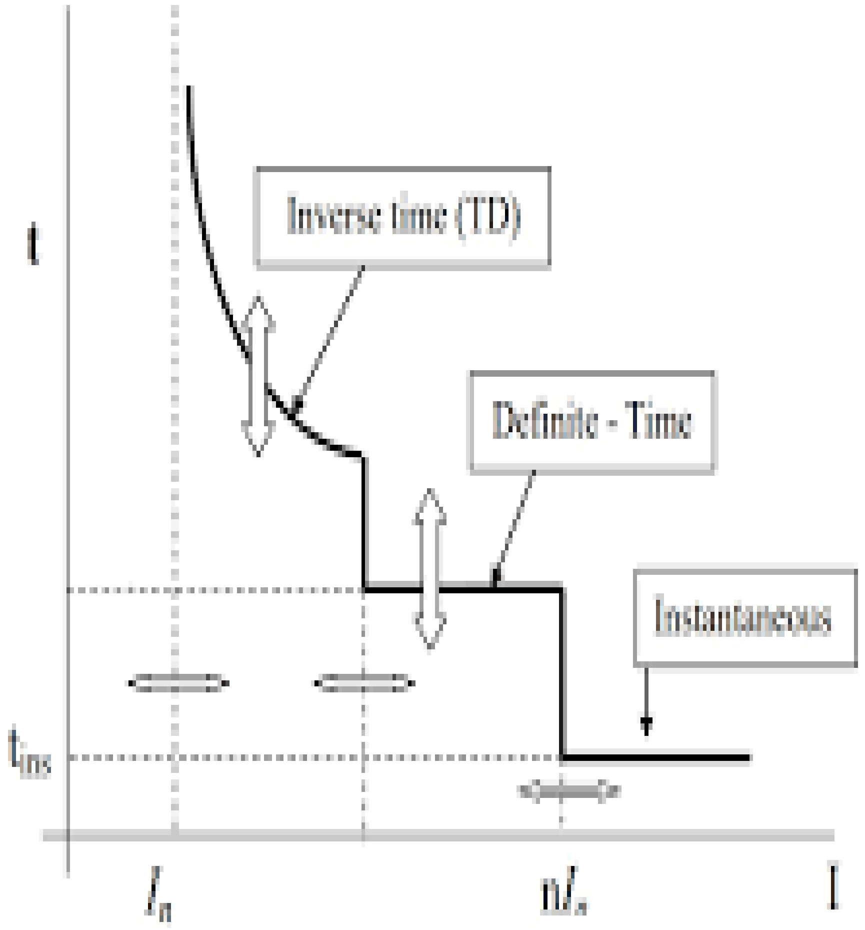
They are available with standard inverse, very inverse and extremely inverse characteristics.

Inverse Time relays are also referred to as Inverse Definite Minimum Time (IDMT) relay.

The difference in operating time of these two relays for the same fault is defined as discrimination margin. The adjustment of definite-time and inverse-time relays can be carried out by determining two settings: time dial setting and pickup setting.




Continuous Amps
Ir=%In
40 50 60 70 30 80 20 90 100
Short Time
Pickup
xIr
3 4 5 6 2 7 1.5 8 Off 10
Instantaneous
Pickup
xIr
6 8 10 15 4 20 2 30 Max 40
Long Time Delay
Secs. @
6xIr
7 12 20 27 4 2.2
Short Time Delay
Secs.
.2 .3 .5 .45 .1 .36 .05 .28 .18 .22
I2t
Delay
@6xIr
Ground Fault
Pickup
Ig=%In
55 70 20 30 40 40 55 30 25 70 20 20 70 55 40 30
.1s
.2s
.4s
I2t
Delay
@.5 In


t
Inverse time (TD)
Definite - Time
Instantaneous
tins
In
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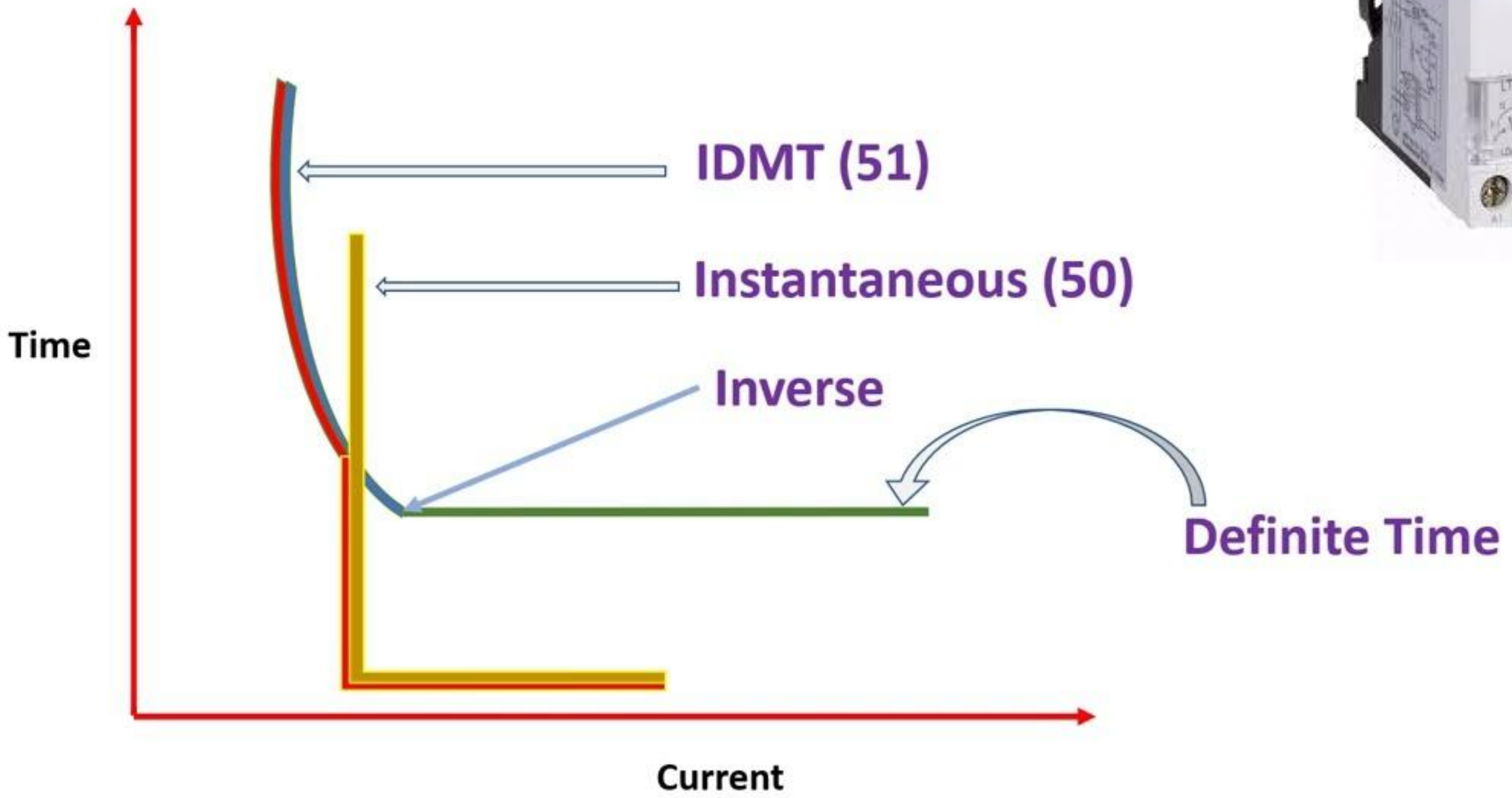
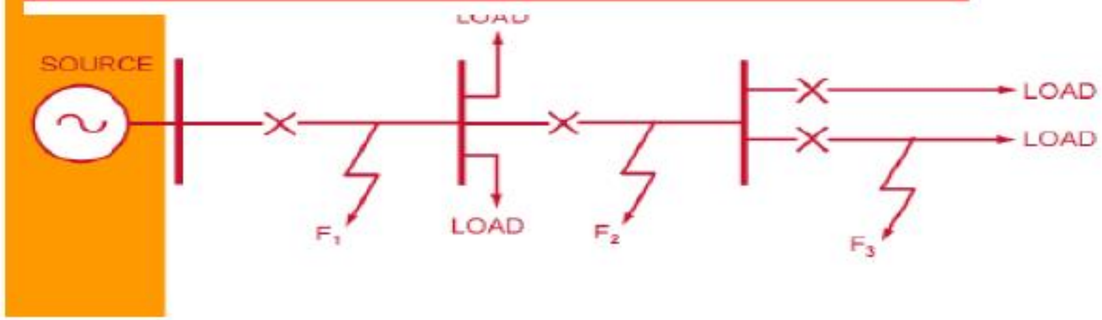
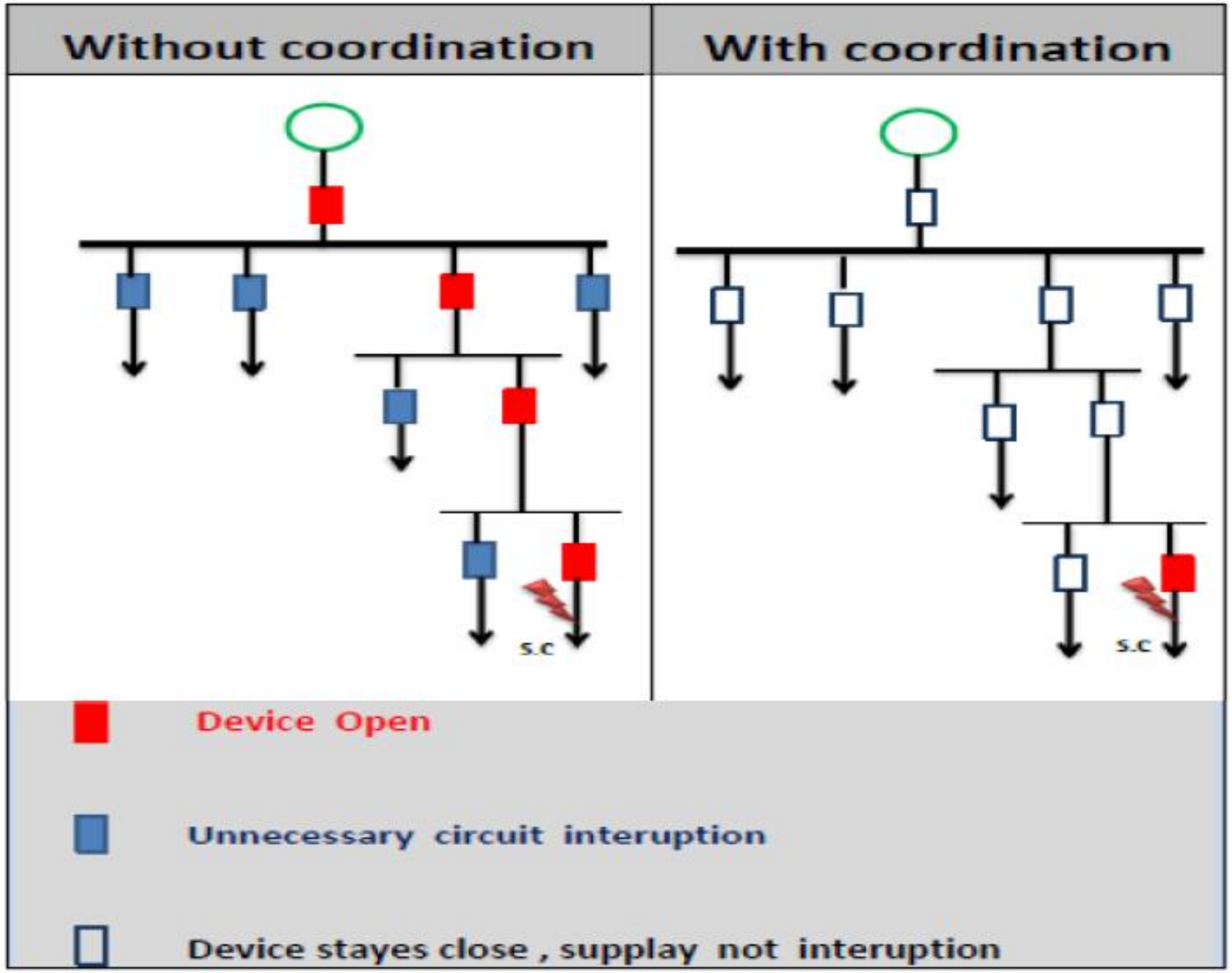
I

IDMT RELAY CHARACTERISTICS



What is the coordanation :-



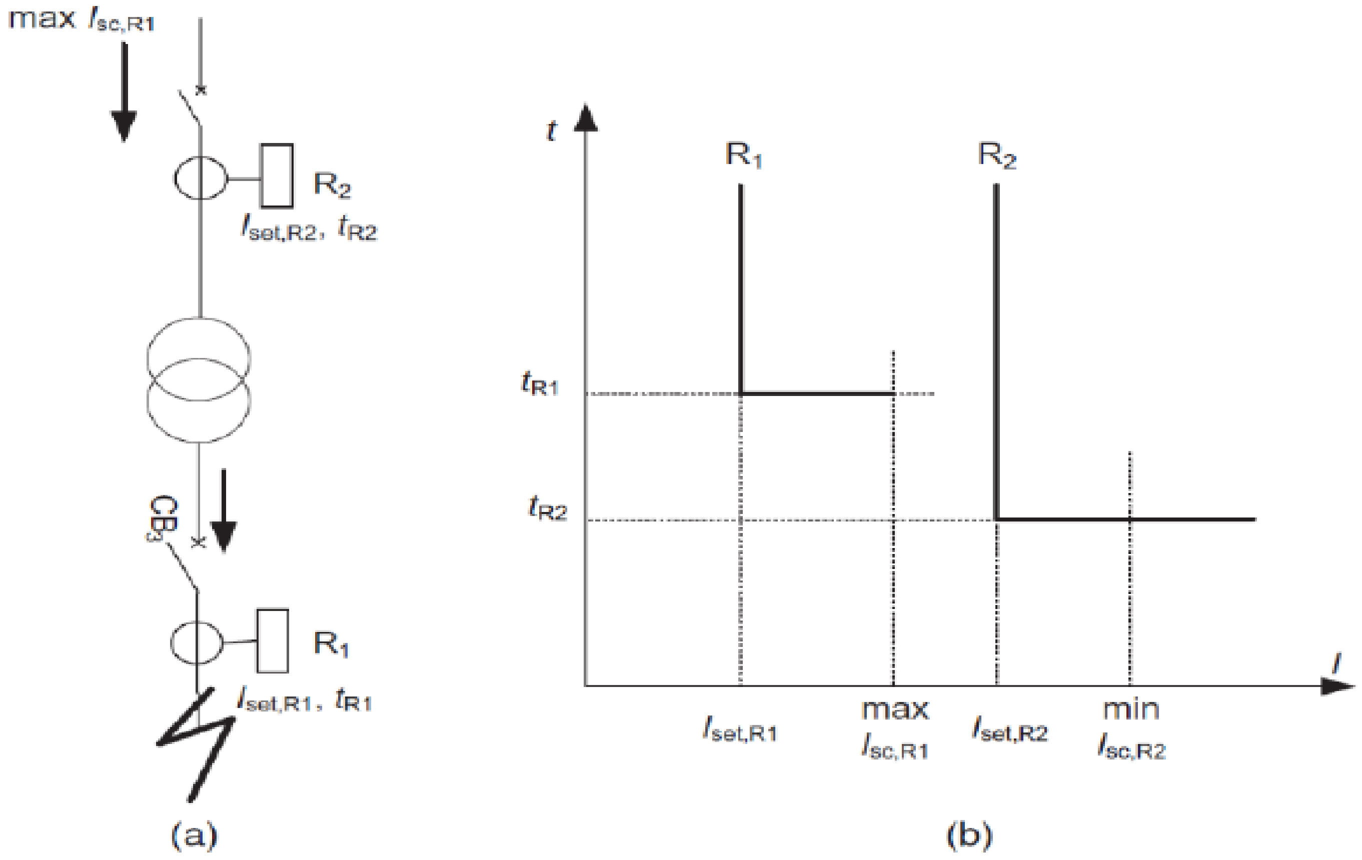


one of the following schemes can be employed, depending on the system conditions .

- Current –graded system .
- Time-graded system .
- A combination of time and current grading .

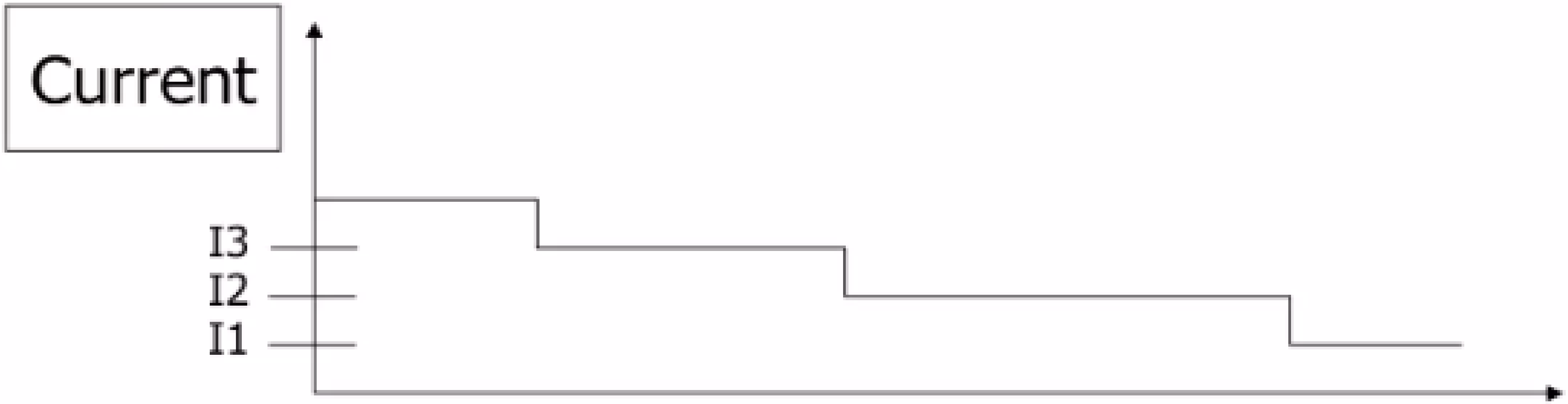
1. Current-Based Coordination

Discrimination by current relies on the fact that the fault current varies with the position of the fault because of the difference in impedance values between the source and the fault.



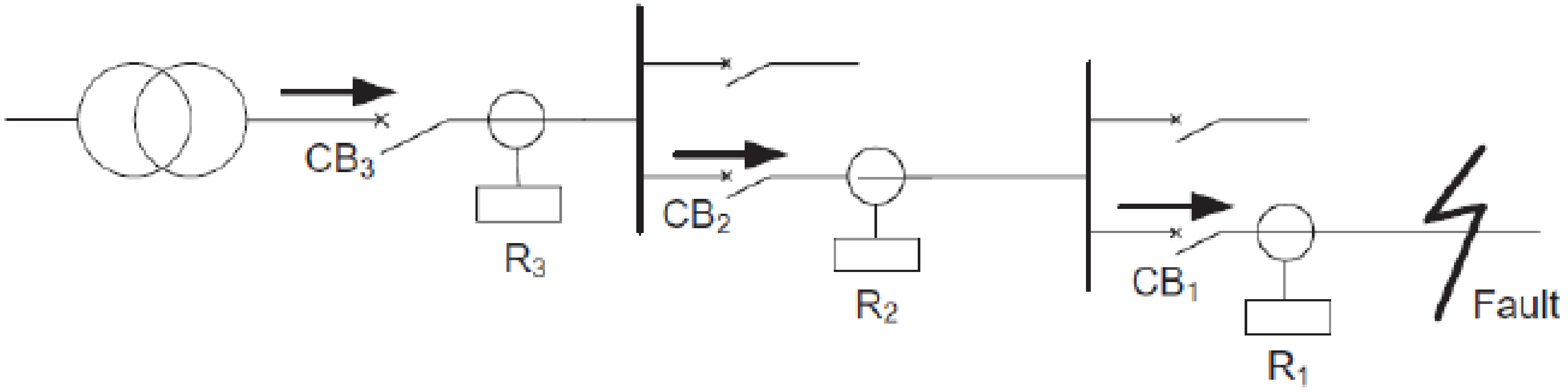
(a) Line diagram, (b) tripping curves

Current graded co-ordination means downstream has lower current setting than upstream.

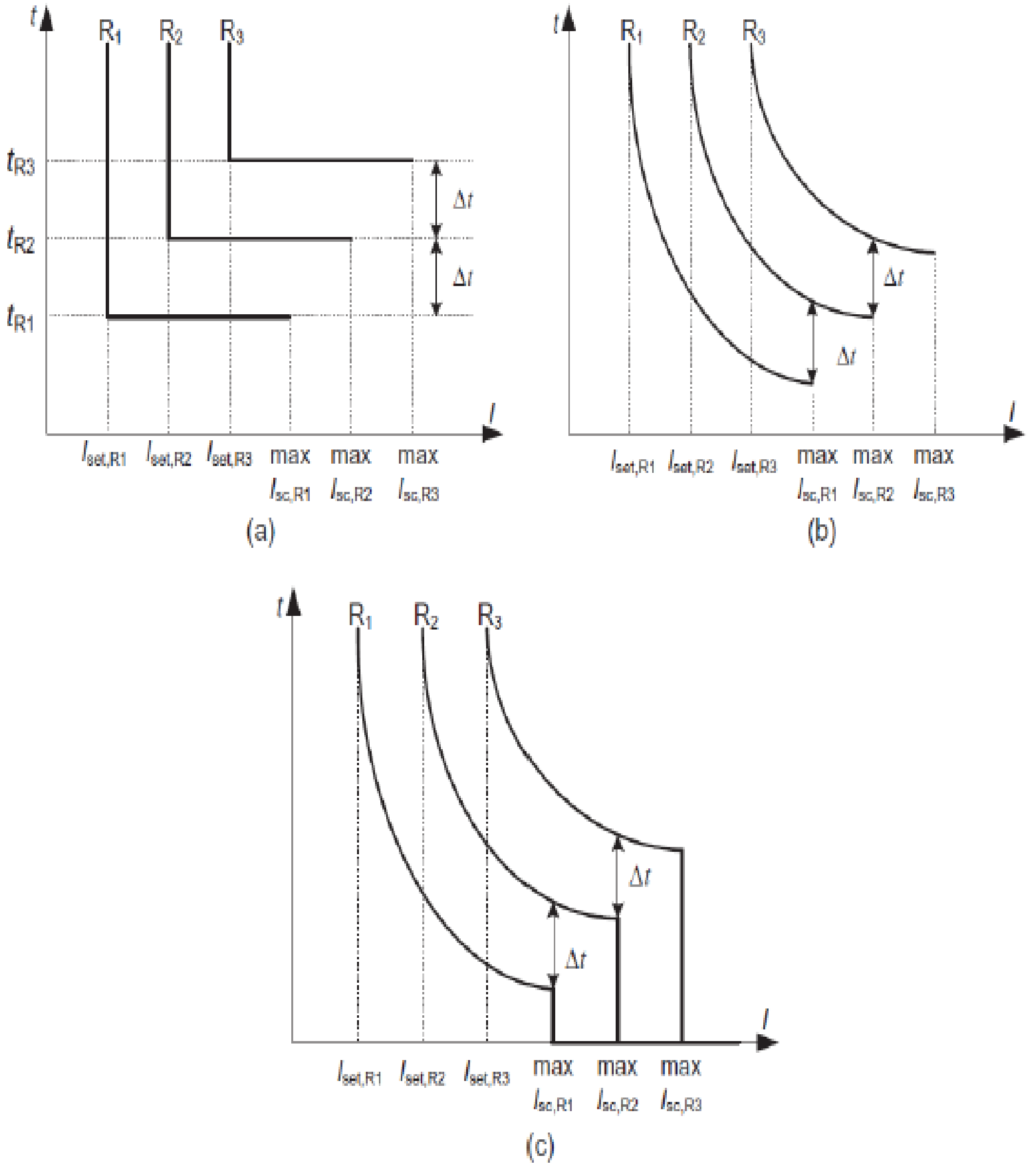


2. Time-Based Coordination

In this method, an appropriate time setting is given to each of the relays controlling the circuit breakers in a power system to ensure that the breaker nearest to the fault opens first.



The coordination interval is the difference in operating time Δt between two successive protection units, the advantage of this coordination system is simplicity and providing its own backup,



(a)Definite time protection, (b) IDMT protection and (c) combined inverse time and instantaneous protection.

The main disadvantage of this method of coordination is that the longest fault clearance time occurs for faults in the section closest to the power source, where the fault level (MVA) is highest.

The principle of time-based coordination is applied to radial distribution systems. The time delays set are activated when the current exceeds the relay settings.

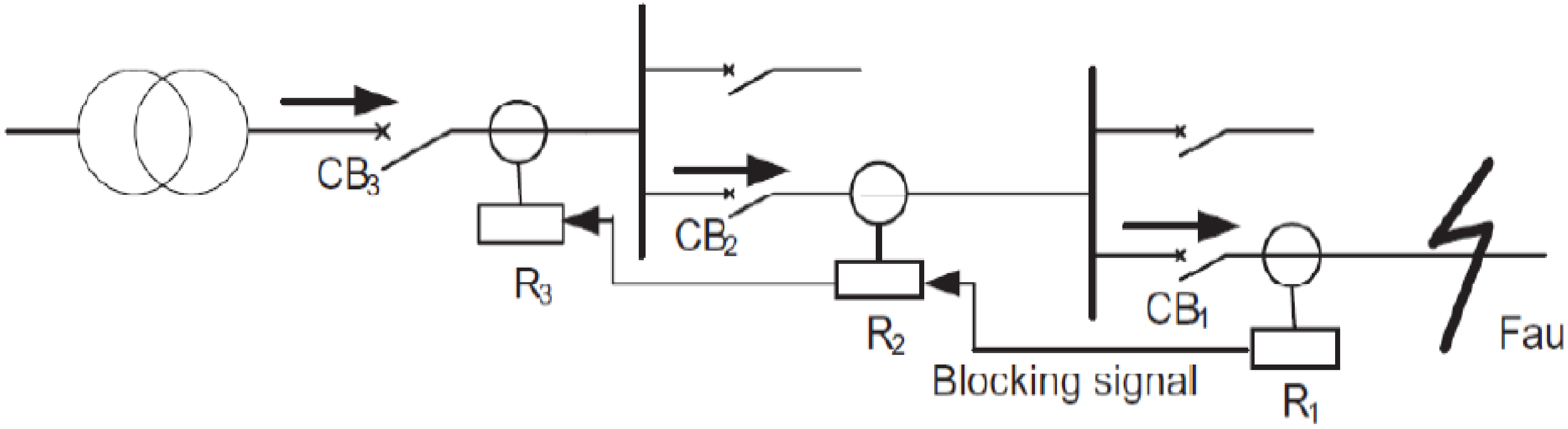
Three types of time delay are applied according to protection characteristics definite-time, inverse-time, and combined inverse-time and instantaneous protection systems.

Time graded co-ordination means downstream has lower time setting than upstream.

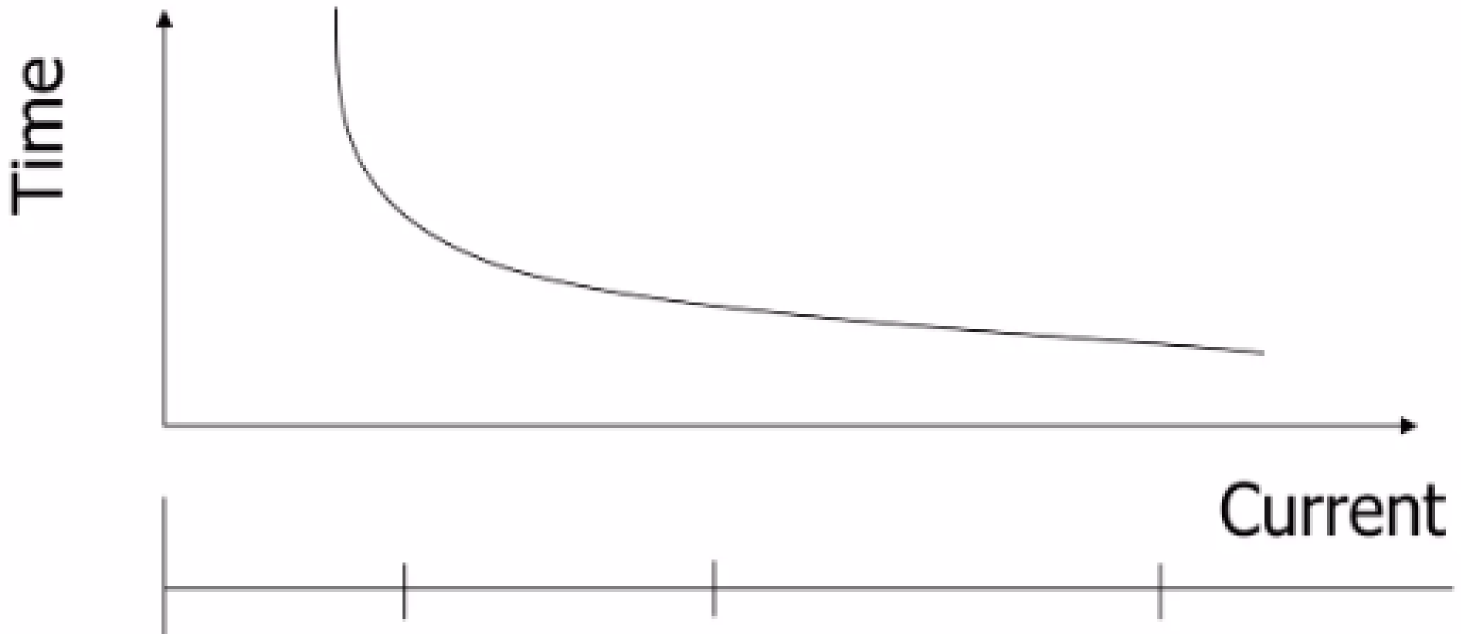
3. Logic Coordination

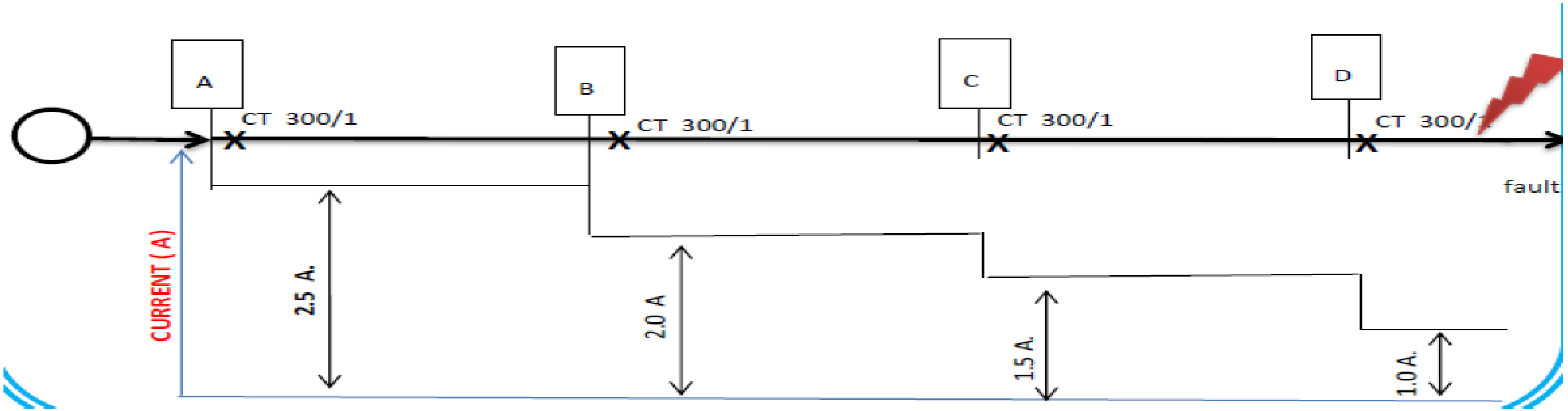
Each of the two methods described so far has a fundamental disadvantage. In the case of discrimination by time alone, the disadvantage is due to the fact that the more severe faults are cleared in the longest operating time.

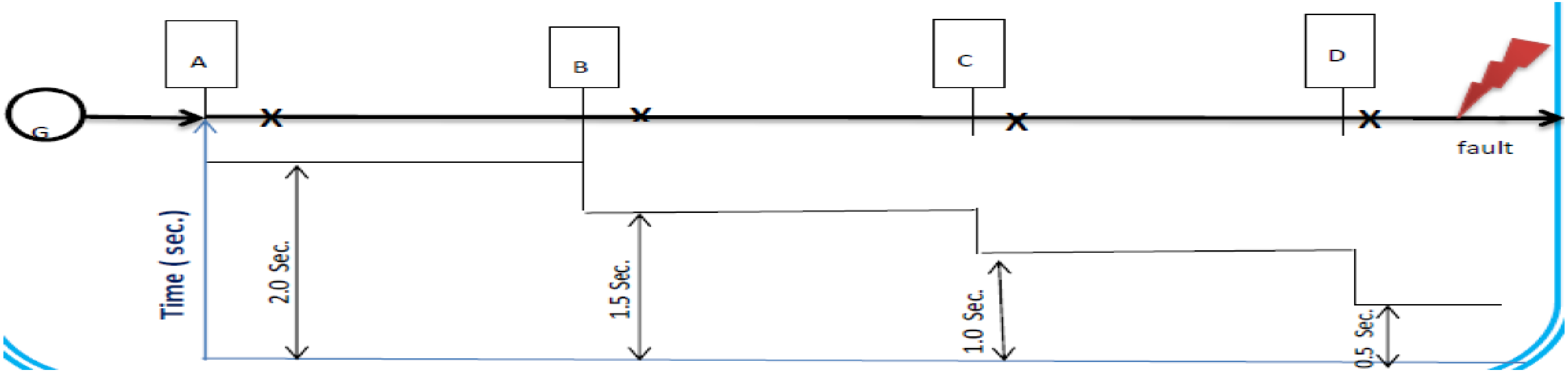
Logic coordination it is designed and developed to solve the drawbacks of both time-based and current-based coordination.



The principle of Both Time and Current Graded is that higher the current lower the relay trip time.




A
B
C
D
CT 300/1
CT 300/1
CT 300/1
CT 300/1
fault
CURRENT (A)
2.5 A.
2.0 A
1.5 A.
1.0 A.


G
A
B
C
D
fault
Time (sec.)
2.0 Sec.
1.5 Sec.
1.0 Sec.
0.5 Sec.

Protection function

Protection equipment is necessary to detect and isolate faults from the system. Protection relays detect faults by comparing the quantity (and angles in some cases) of the primary circuit current or voltage to a pre-determined setting.

The main protection functions are briefly explained below:

The relay starts to operate (pick up) when **current magnitude exceeds the preset current setting**. Overcurrent can be detected in phase conductors, neutral conductors and/or the earth return path:

1) **Phase-overcurrent or “overcurrent” protection** is where current in a phase conductor is measured.

2) **Ground-overcurrent or “earth fault” protection** is used to detect earth faults

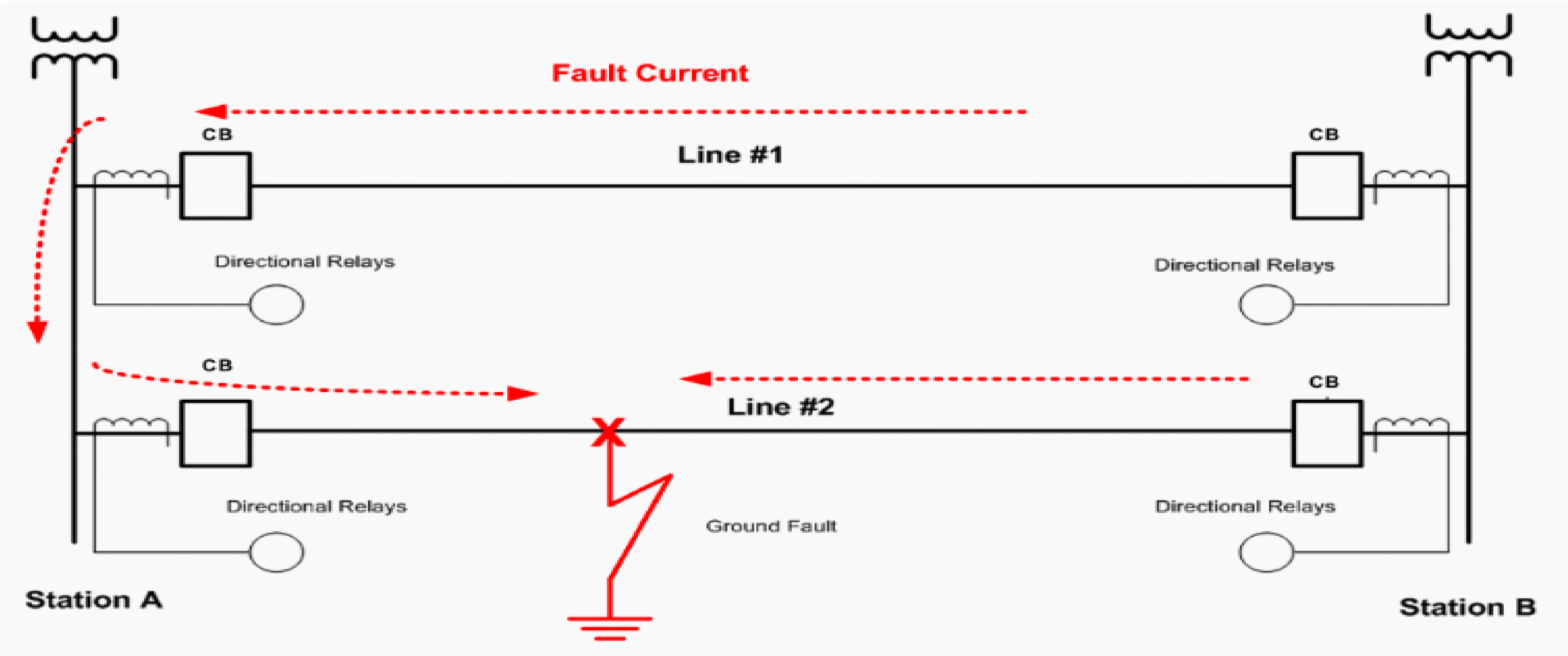

ABB
REF615
Ready
Start
Trip
Clear
Indications and LEDs
=Cancel
Programmable LEDs
=Cancel
Events
=Cancel
Disturbance records
=Cancel
O/C TRIP
E/F TRIP
OV/UV TRIP
NPS
LINE PT VOLT. HEALTHY
READY TO CLOSE
SPARE
NO FAULT
TRIP CKT. HEALTHY
Clear
REDMI NOTE 8
AI QUAD CAMERA


SEL
SCHWEITZER ENGINEERING LABORATORIES
SEL-751
FEEDER PROTECTION RELAY
Phasors
02/14/2017
15:11:39
AUX 1
LOCK
CLOSE
TRIP
SEL
SCHWEITZER ENGINEERING LABORATORIES
SEL-787
TRANSFORMER PROTECTION RELAY
SEL-787-3S
TRNSFRMR RELAY
TARGET RESET
ESC
ENT
ENABLED
TRIP
DIFF
INST OC
PHASE TOC
O/U VOLT
O/U FREQ
V/Hz
BRKR1
BRKR2
BRKR3
AUX 2
LOCK
CLOSE
TRIP
AUX 1
ELECTRICAL ENGINEERING PORTAL

1. Directional overcurrent protection:

The direction of a fault can be known by comparison of the primary circuit voltage and current. Directional overcurrent is widely used in protection of ring or parallel feeders, where fault current can flow in either direction depending on the location of the fault and supply source.

Directional overcurrent protection for two parallel transmission lines:

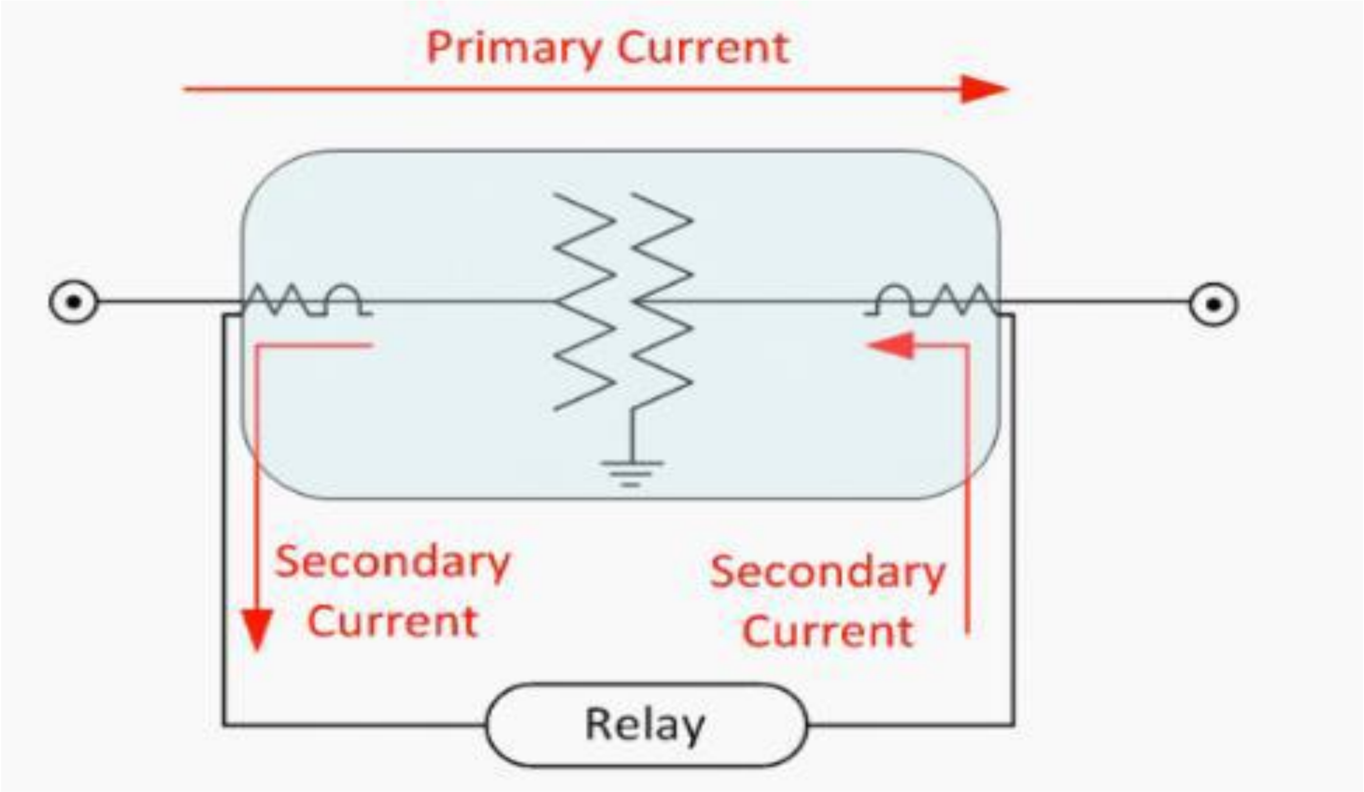


2. Differential protection:

Differential protection compares the current entering the protected circuit (or zone) to the current leaving the zone. **What goes in must come out?** A zone is bounded by measuring CTs at the terminals of the protected circuit.

As differential protection only operates **for faults within a zone of protection**, there is no requirement to consider the operation times of protection outside the zone; instantaneous operation is therefore often applied to differential protection.

Differential protection:



In short, the sum of the currents flowing in essentially equals the sum of the currents flowing out during normal operation.

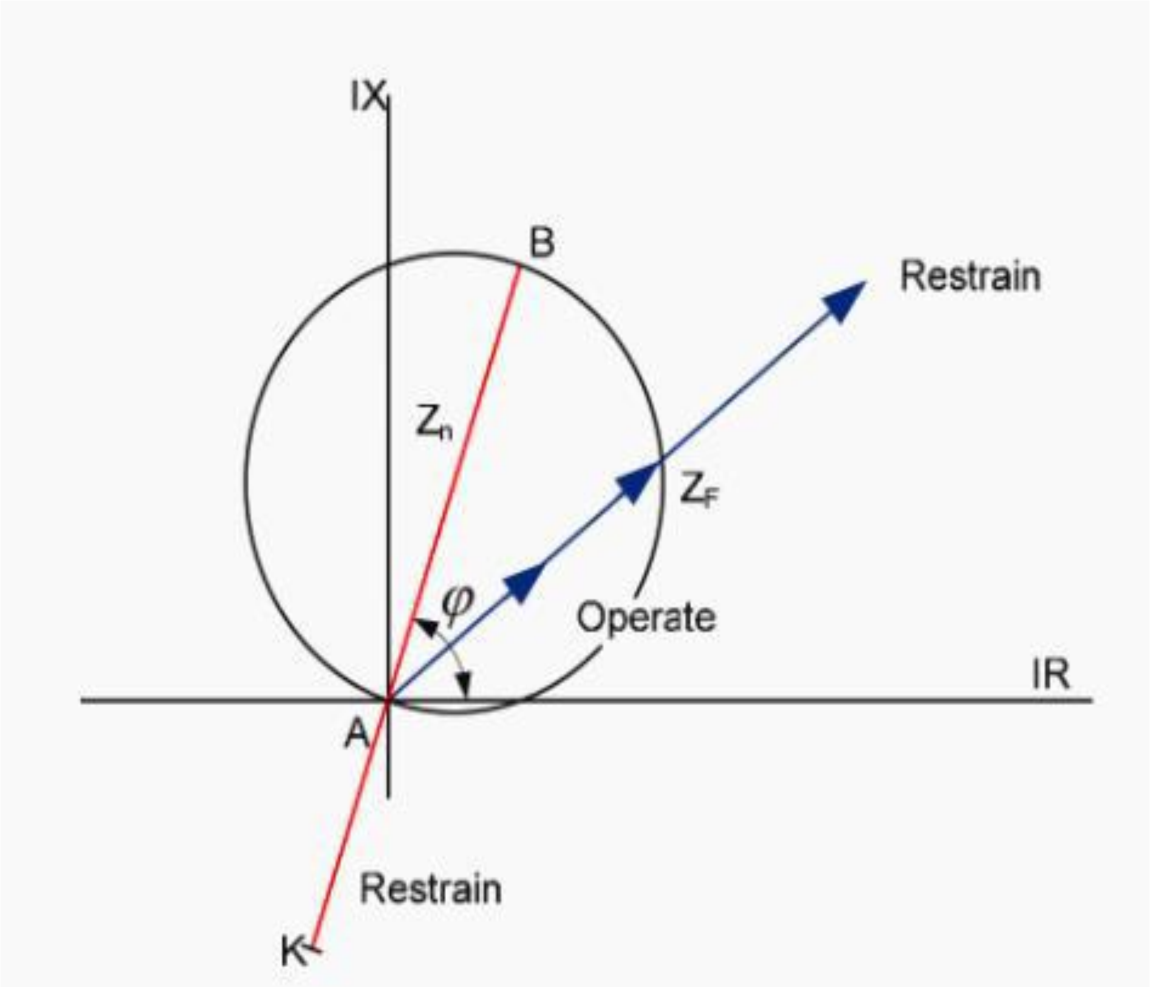
3. Distance protection:

Distance relaying principles are based on **impedance measurement** and so require the values of primary circuit voltage and current for any instant time.

The impedance of any given circuit is a fixed quality; if the impedance measured by the relay has decreased to some value below a predetermined setting, then a fault is assumed on the circuit and tripping can be initiated.

Distance relaying should be considered when overcurrent relaying is too slow or is not selective. Distance relays are generally used for phase-fault primary and back-up protection on sub transmission lines, and on transmission lines where high-speed automatic reclosing is not necessary to maintain stability and where the short time delay for end-zone faults can be tolerated.

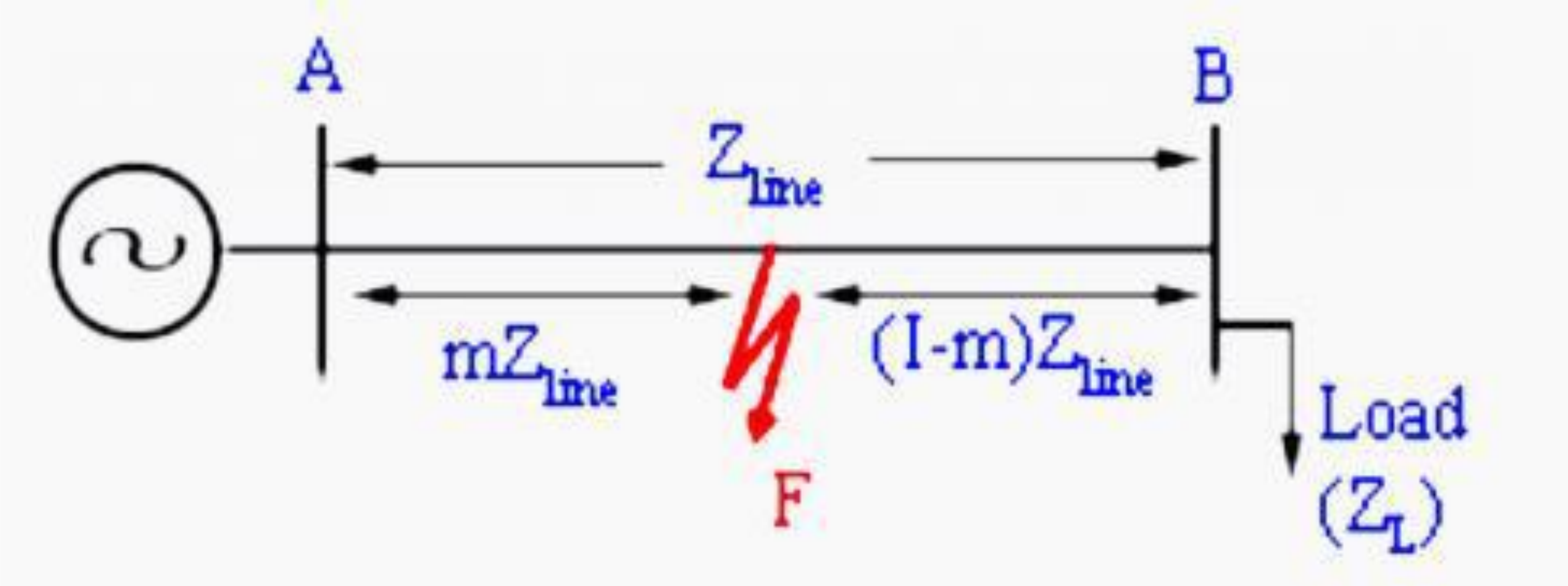
The common types compare either the relative amplitude or phase of two input quantities to obtain operating characteristics that are **either straight lines or circles when plotted on an R/X diagram.**



Consider a simple radial system, which is fed from a single source. Let us measure the **apparent impedance (V/I)** at the sending end.

For the unloaded system, **I = 0**, and the apparent impedance seen by the relay is infinite. As the system is loaded, the apparent impedance reduces to some finite value (**ZL+Zline**) where ZL is the load impedance and Zline is the line impedance. In presence of a fault at **a per-unit distance** ‘m’, the impedance seen by the relay drops to a **mZline** as shown in figure below.

Fault in transmission line



The basic principle of distance relay is that the apparent impedance seen by the relay, which is defined as the ratio of phase voltage to line current of a transmission line **(Zapp)**, reduces drastically in the presence of a line fault.

A distance relay compares this ratio with **the positive sequence impedance** (Z^1) of the transmission line. If the fraction **Zapp/Z^1** is less than unity, it indicates a fault. This ratio also indicates the distance of the fault from the relay.

Because, impedance is a complex number, the distance protection is inherently directional. The first quadrant is the forward direction i.e. impedance of the transmission line to be protected lies in this quadrant.