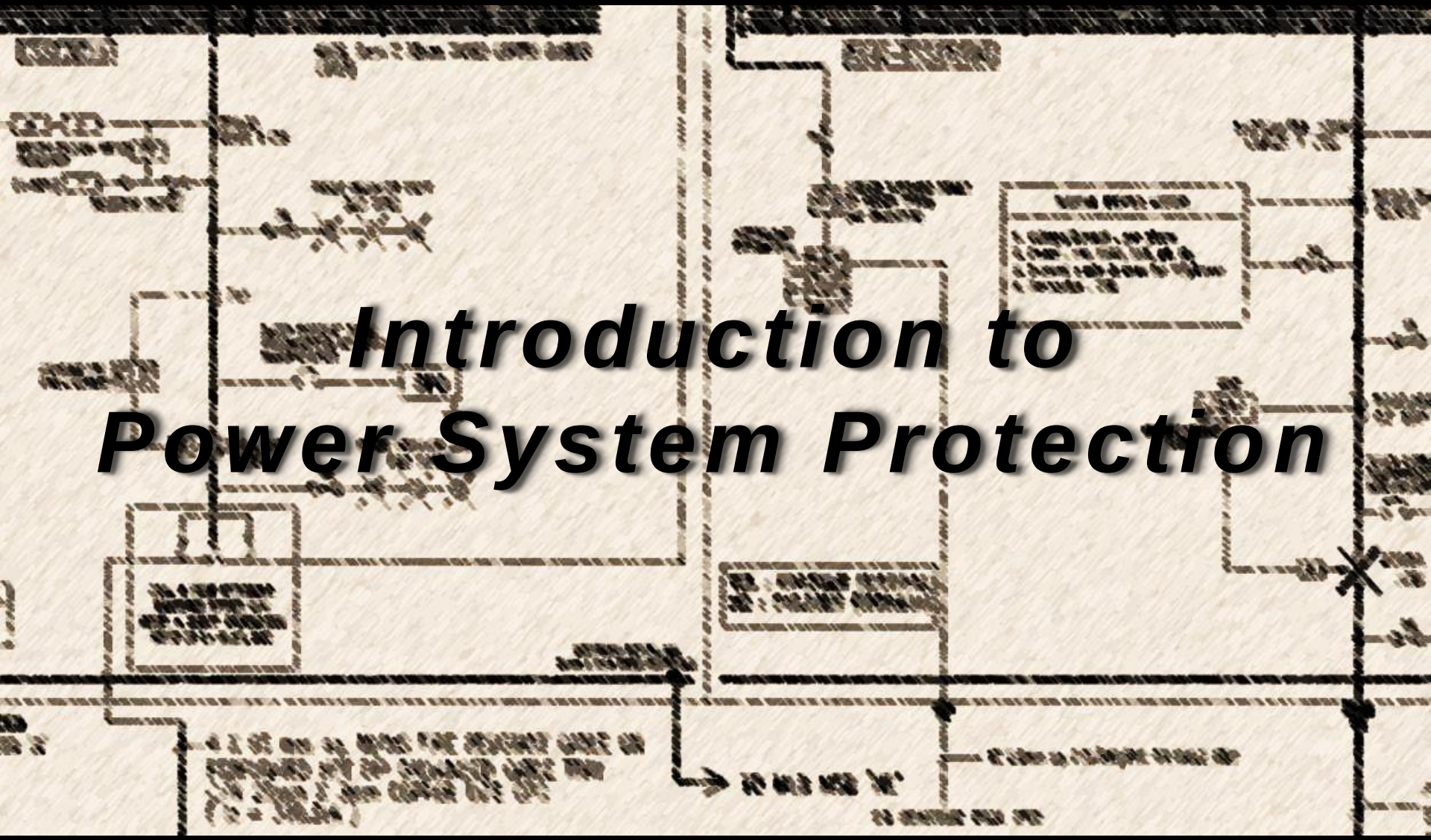


Introduction to Power System Protection

Definition of Protection

IEV Ref: 448-11-01 – Protection

Provisions for detecting faults or other abnormal conditions in a power system, for enabling fault clearance, for terminating abnormal conditions, and for initiating signals or indications.

Note:

1. The term "protection" is a generic term for protection equipment or protection systems
2. The term "protection" may be used to describe the protection of a complete power system or the protection of individual plant items in a power system e.g. transformer protection, line protection, generator protection.

Definitions

i. **Protection System**: a complete arrangement of protection equipment and other devices required to achieve a specified function based on a protection principal (IEC 60255-20)

ii. **Protection Equipment:** a collection of protection devices (relays, fuses, etc.). Excluded are devices such as CT's, CB's, Contactors, etc

iii. **Protection Scheme:** a collection of protection equipment providing a defined function and including all equipment required to make the scheme work (i.e. relays, CT's, CB's, batteries, etc.)

Compliance to Regulations & Standards

IEC 60364 Parts 4

Safety requirements (Types of protections)

- **4-41 Protection against electric shocks (basic, fault, enhanced and additional protection)**
- **4-42 Protection against thermal effect (fires and burns)**
- **4-43 Protection against overcurrent (overloads and short-circuits)**
- **4-44 Protection against overvoltage (industrial and high frequencies)**

	Protection			
	Electric shock	Thermal effect	Overcurrent	Overvoltage
Persons	X	X		
Properties		X	X	X

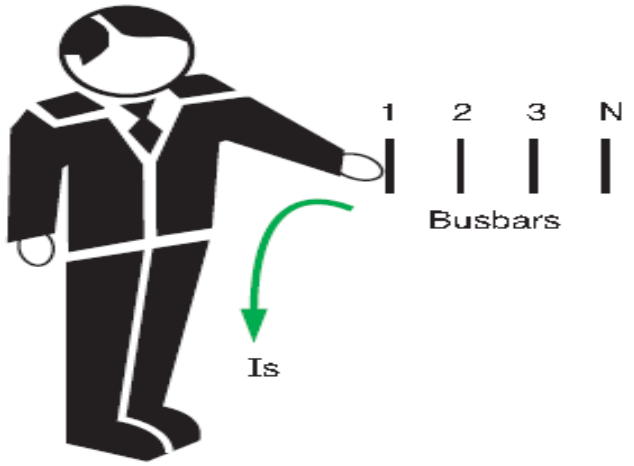
Protection For Safety

1. Protection against direct and indirect contact
2. Protection against overcurrent
3. Protection against earth fault
4. Protection against overvoltage & undervoltage
5. Protection against surge

1 | Protection Against Direct & Indirect Contact

Direct Contact

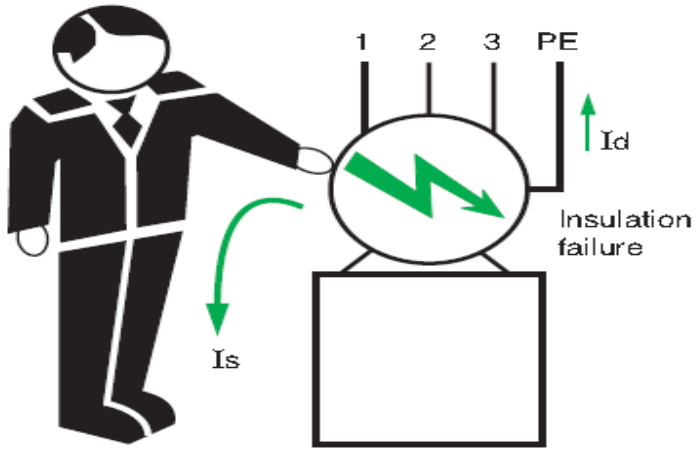
- Person coming into contact with a conductor which is live in normal circumstances



Is: Touch current

Indirect Contact

- Person coming into contact with an exposed-conductive-part which is not normally alive, but has become alive accidentally (due to insulation failure or some other cause).



Id: Insulation fault current

1 | Protection Against Direct & Indirect Contact

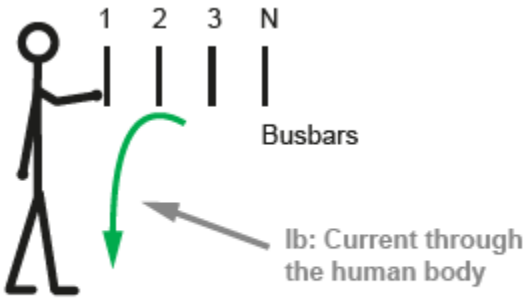


Fig. B11: Direct contact

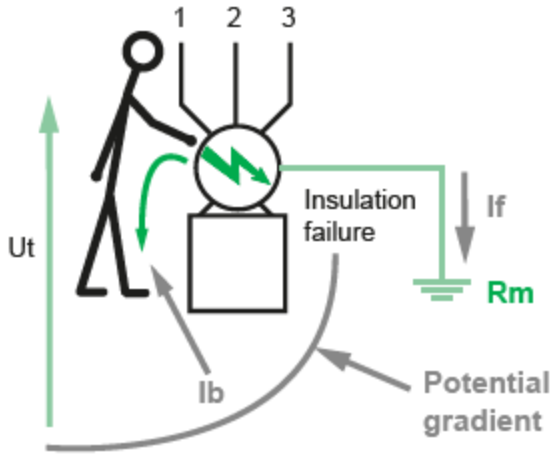
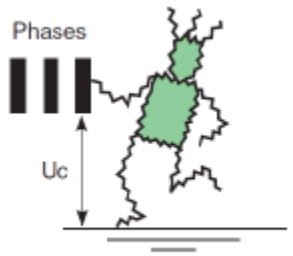
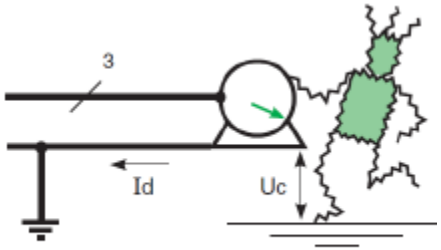


Fig B12: Indirect contact

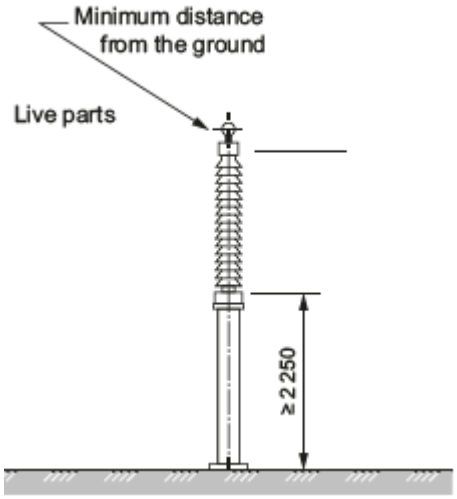


BASIC PROTECTION



FAULT PROTECTION

1 | Protection Against Direct & Indirect Contact



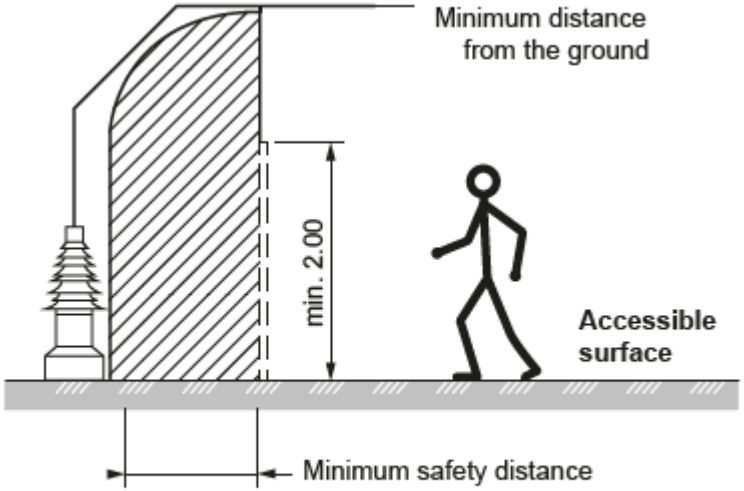


Fig. B15: Protection by installation of barriers. The safety distances are fixed by IEC 61936

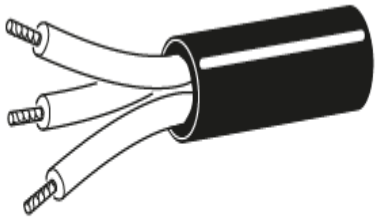


Fig. F4: Inherent protection against direct contact by insulation of a 3-phase cable with outer sheath

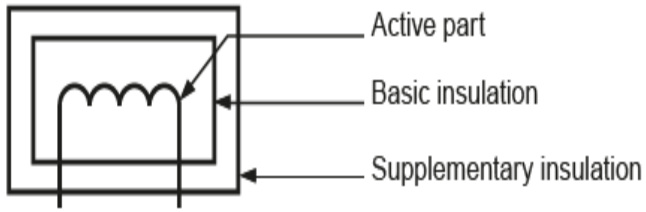


Fig. F23: Principle of class II insulation level

Touch Voltage & Step Voltage

Electrical Faults : Forensic

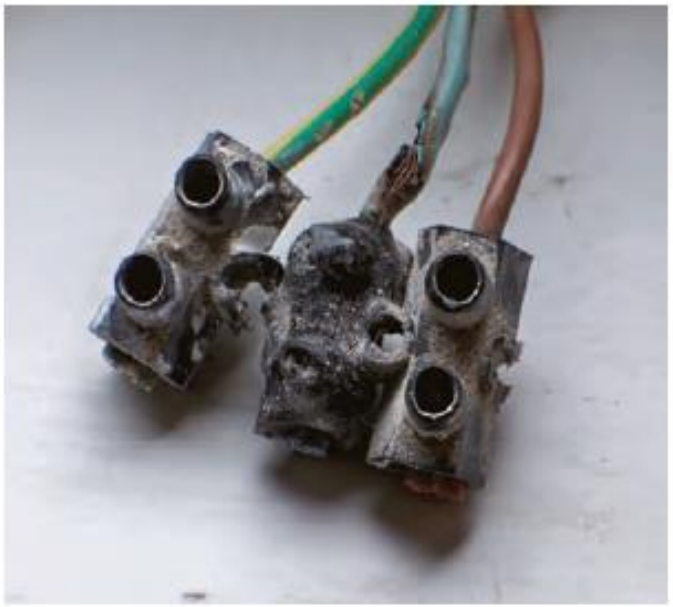


Fig. F76: Example of a carbonized connection

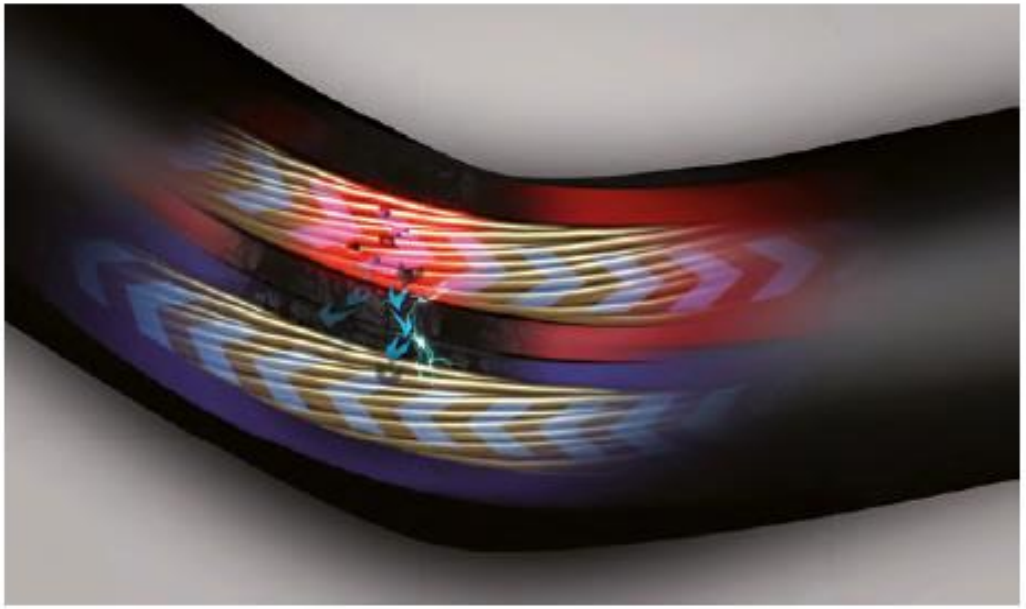
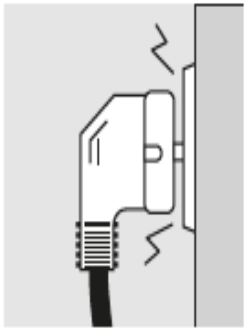
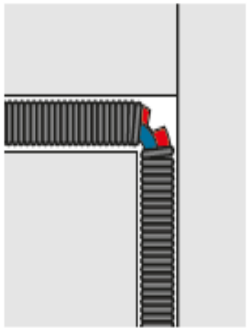


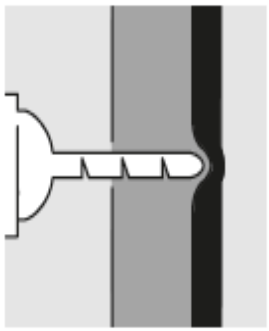
Fig. F77: Illustration of a resistive short circuit



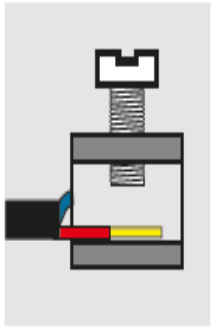
Power sockets in poor condition



Ageing of cable protective devices



Accidental damage to a cable

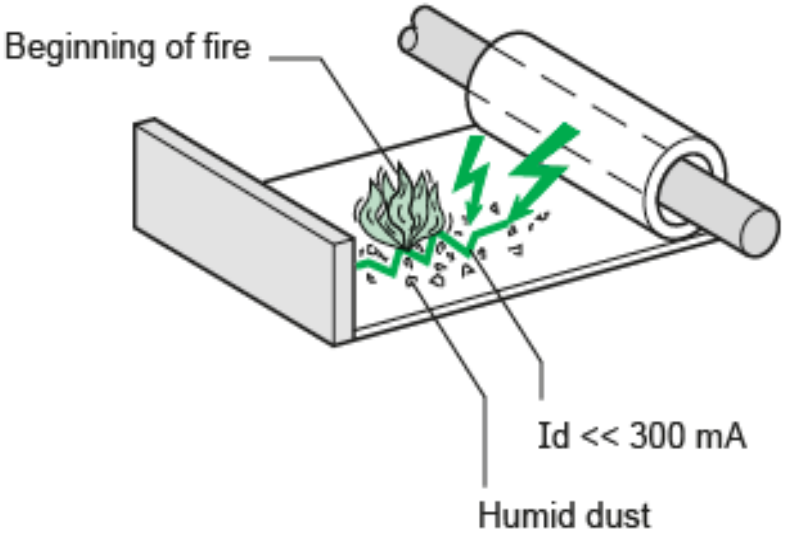


Loose connections

Cables damaged by their environment: UV, vibrations, moisture, rodents.

Electrical Faults : Forensic - Cause of Fire

RCDs are very effective devices to provide protection against fire risk due to insulation fault because they can detect leakage current (ex : 300 mA) wich are too low for the other protections, but sufficient to cause a fire



Some tests have shown that a very low leakage current (a few mA) can evolve and, from 300 mA, induce a fire in humid and dusty environment.

Fig. F26: Origin of fires in buildings

2| Protection Against Overcurrent

Purpose

- Safety of Personnel (Shock) and Property (Fire Hazards).
- Maintain reliable life of equipment and systems.

Overcurrent

- a current exceeding the rated value of a circuit or the current-carrying capacity of a conductor.
- Overload
- Fault : Short-circuit fault & Earth fault

Overcurrent Devices

- Fuses (HBC/HRC)
- Miniature circuit breakers (MCBs)
- Combined MCB and RCD (RCBOs)
- Moulded case circuit breakers (MCCBs)
- Air circuit breaker + IDMTL relay

Purpose of system earthing in an electrical system:

- Provides a low resistance path to ground for any surges or lightning strikes that may occur on the electrical system; protection of buildings and installations against lightning.

- Provides a low resistance path to ground for fault currents, and thus trips the over- current protective device (circuit breaker or fuse) quickly when a fault or short circuit occurs; and most importantly,

- Provides a stable reference point for the voltages in each phase of a circuit. A solid ground point prevents the phase-to-ground and the phase-to-phase voltages from fluctuating.

- Electromagnetic compatibility (EMC) i.e. limitation of electromagnetic disturbances

Regulation 36. Protection against earth leakage current.

PERATURAN ELEKTRIK 1994	KADARAN PERANTI ARUS BAKI (RCD/RCCB)	TEMPAT / LOKASI DI PASANG
36(1)	10mA	Tempat Hiburan Awam
36(2)	10mA	Lantai Basah / Dinding Rintangan Rendah
36(3)	30mA	Kelengkapan / Radas / Perkakas dipegang dengan tangan digunakan
36(4)	100mA	Selain disebut dalam 36(1), 36(2) & 36(3)

Earthing System : Letter code meanings

1st letter : situation of the electrical system in relation to the earth

T - direct connection of one point to earth

I - all live parts isolated from earth or connection of one point to earth throughout an impedance

2nd letter : situation of the exposed-conductive-parts of the installation in relation to the earth.

T - direct electrical connection of Exposed-conductive-parts to earth

N - direct electrical connection of the exposed-conductive-parts to the earthed point of the power system in AC systems, the earthed point of the power system is normally the neutral point.

Subsequent letter (if any): N and PE conductors arrangement;

S - N and PE conductors separated.

C - N and PE conductors combined in a single conductor (PEN conductor).

Earthing System

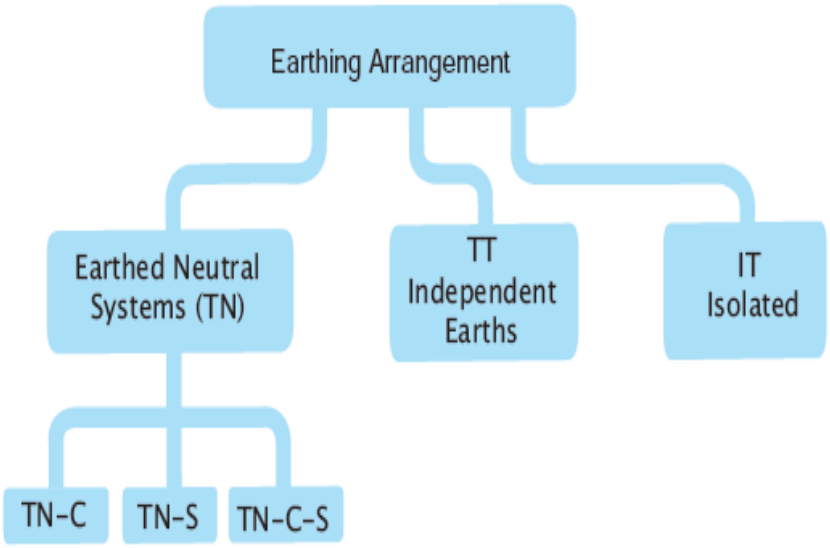
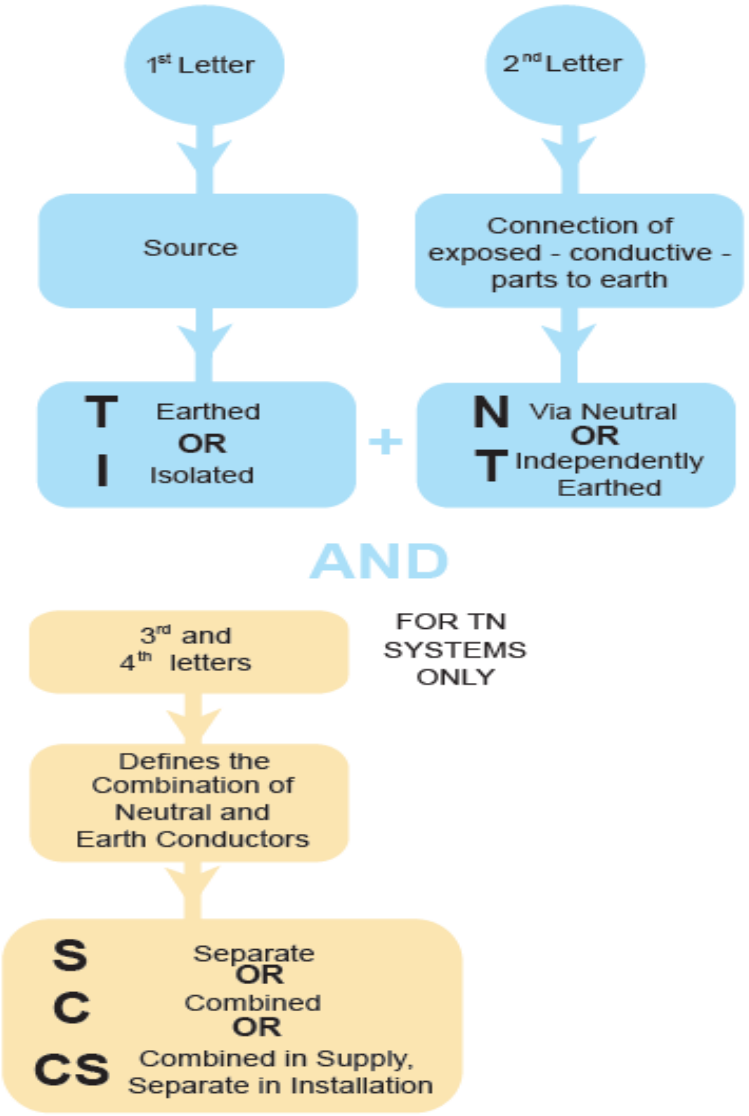


Figure E 2.1 Earthing arrangement hierarchy.



Earthing System

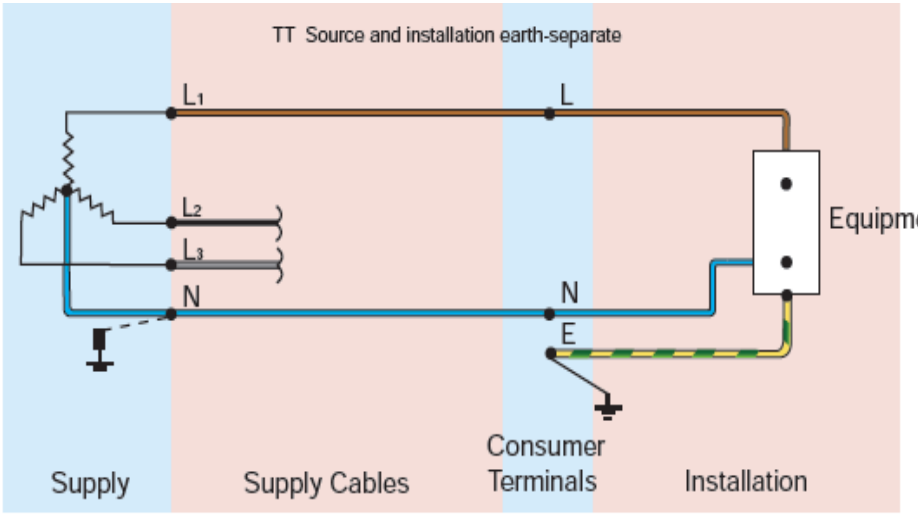


Figure E 2.7 TT system earthing.

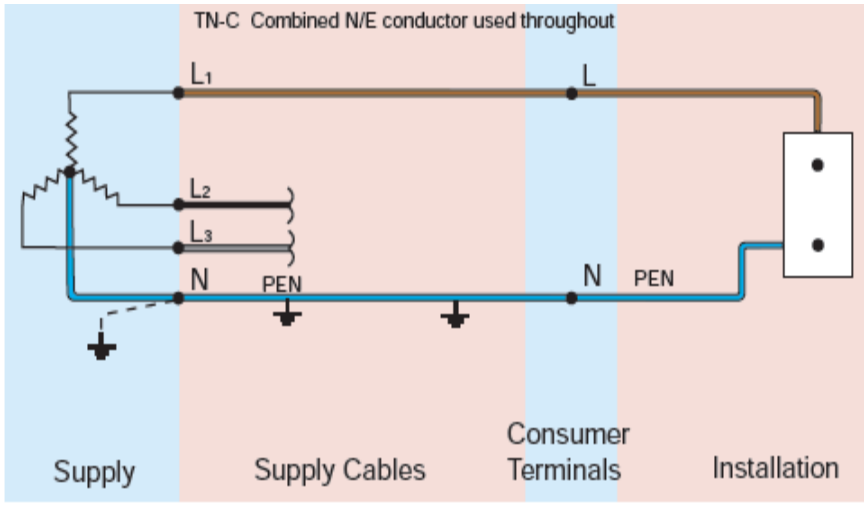


Figure E 2.3 TN-C system earthing.

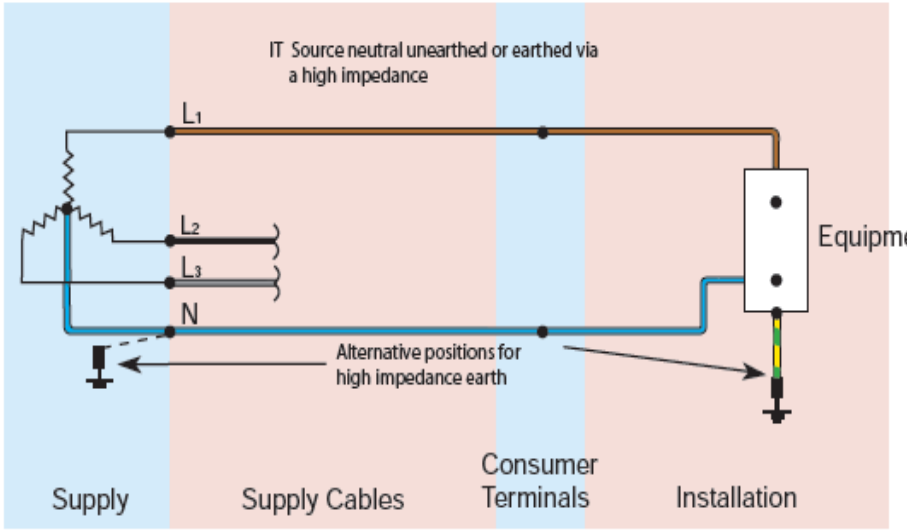


Figure E 2.8 IT system earthing.

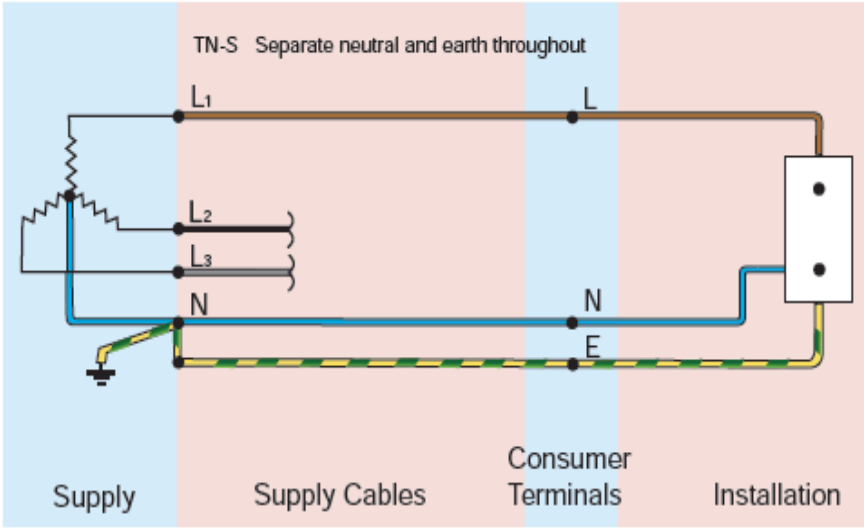


Figure E 2.4 TN-S system earthing.

TT System

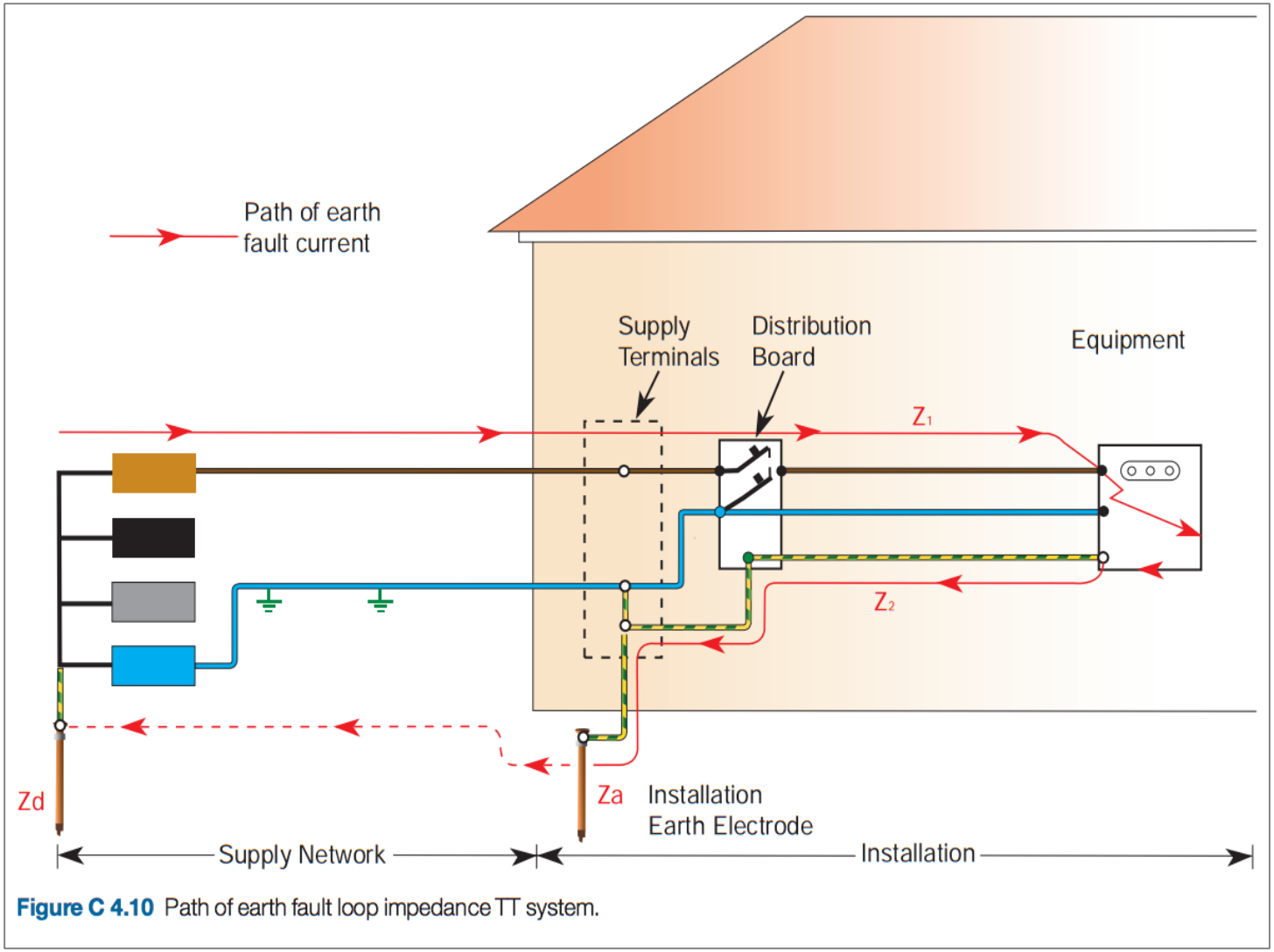


Figure C 4.10 Path of earth fault loop impedance TT system.

- High earth fault loop impedance
- Low earth fault current
- Utility company need not to provide earth for consumer

TN-S System

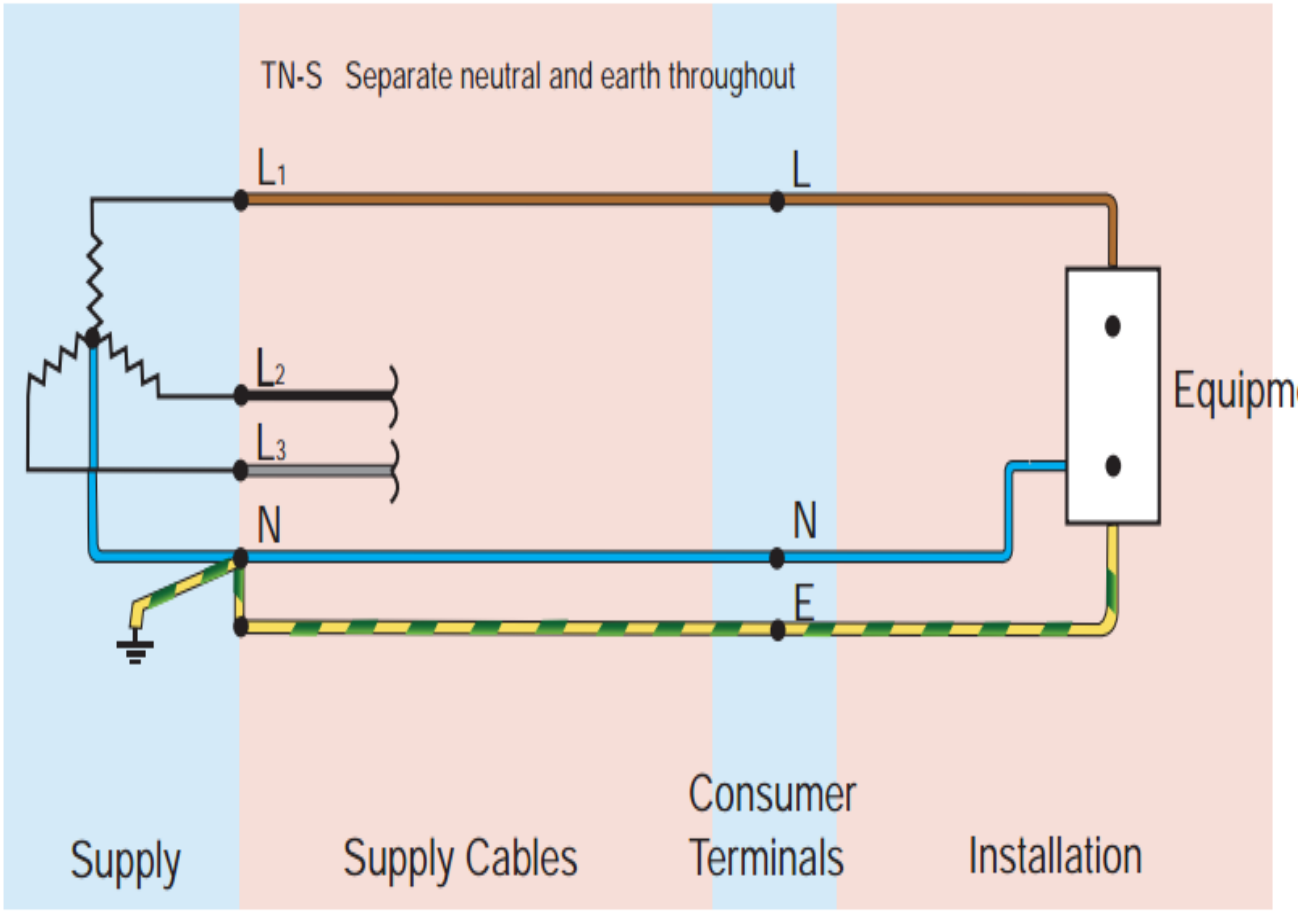


Figure E 2.4 TN-S system earthing.

- Low earth fault loop impedance.
- High earth fault current.

IT System

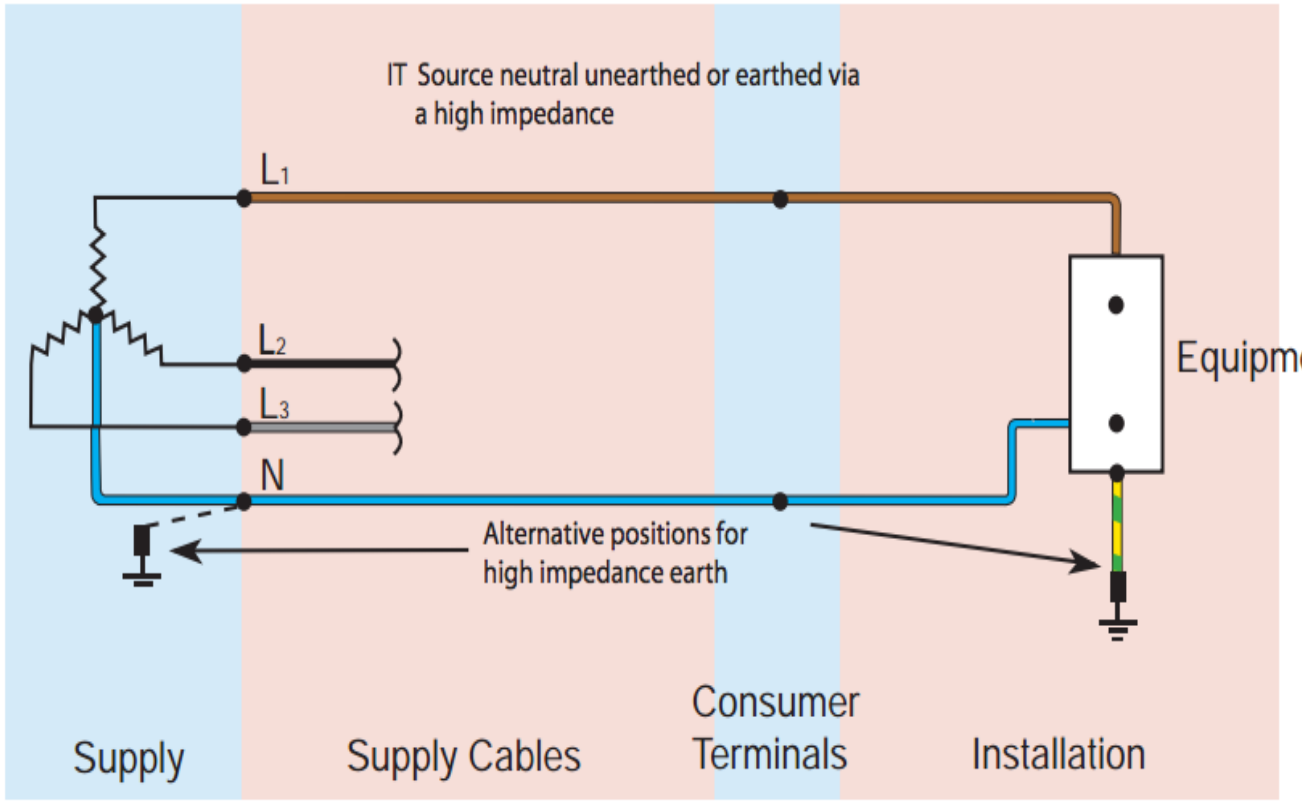


Figure E 2.8 IT system earthing.

- When supply has to be maintained even in the event of fault.
- Better accident prevention the fault current is limited by the body impedance, earthing resistance and the high impedance of the earth fault loop.

TN-C-S System

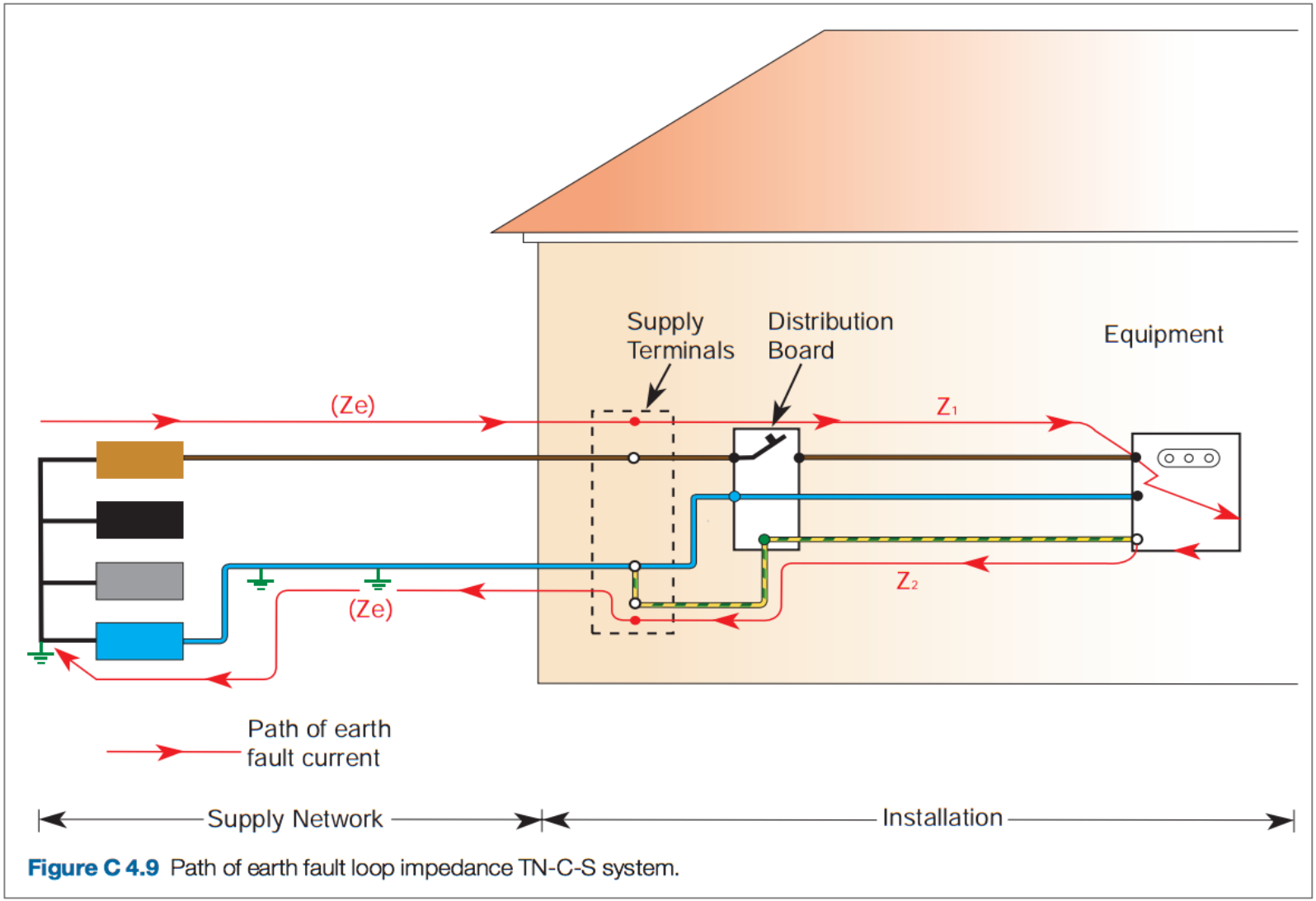


Figure C 4.9 Path of earth fault loop impedance TN-C-S system.

Understanding Protection Schemes

1. Knowledge of the different protection relays and their applications.
2. Understanding current and voltage transformers.
3. Reading AC and DC connection drawings.
4. Knowing how to set the relays.
5. Ability to calculate fault currents and voltages.
6. Capability to carry out commissioning, maintenance and trouble shooting tests.
7. Understanding how to interpret the test results.
8. Knowledge of the behavior of electrical equipment, e.g. when energising a power transformer or after the loss of excitation of a generator.
9. Ability to analyse relay operation

Types of Relays

Protection relay

- Trips circuit breaker or gives alarm when it detects dangerous or harmful.

Regulating relay

- Works with other equipment to maintain electrical output quantities, e.g. voltage and power factor when they are outside preset limits.

Auto-transfer relay

- Attempts to restore supply by closing the circuit breaker of a second income following the loss of its normal supply due to an upstream fault.

Reverse power relay (RPR)

- RPR is a directional power relay that is used to monitor the power from a distributed generator which is running in parallel with another generator or the utility.
- to prevent a reverse power condition in which power flows from the bus bar to the generators.

Types of Relays

Auto-reclosing relay

- Attempts to restore supply by closing the same breaker for a transmission or distribution line that has just tripped in the hope that it was a transient or temporary fault.

Synchronising relay

- Checks that it is safe to synchronising a generator.

Synchro-check relay

- Checks that it is safe to close the circuit breaker for a parallel circuit.

Auxiliary relay

- General purpose device used for tripping, intertripping (sending a trip signal to an upstream or downstream CB),lockout (trip and disable closing circuit),contact multiplication, time-delay, etc.

Type of Relays

Undervoltage Relay

- Jika voltan bekalan jatuh ketahap yang ditetapkan seharusnya bekalan perlu diputuskan untuk menghindarkan bahaya dan gangguan. Geganti ini akan menyebabkan pemutus litar akan terbuka jika berlaku keadaan sedemikian.

Restricted Earth Fault Relay

- Geganti REF dipasang untuk melindungi alatubah atau generator jika berlaku kerosakan ke bumi didalam alat-alat tersebut. Ia hanya melindungi peralatan tersebut dan bukannya pemasangan, perlindungan ini kadang-kadang dipanggil sebagai ‘unit protection’.

Performance & Design Criteria for Protection System Devices

1	Reliability	Devices must **function consistently** when fault conditions occur. **Back-up** protection operates when **main** protection fail.
	a) Dependability	Operate correctly for **in-zone faults** in response to a system disturbance. (Trip when you should)
	b) Security (Stability)	Not to operate for **out-of-zone faults** (Don't trip when you shouldn't)
2	Selectivity (Discrimination)	Operate in **preference** to another protective device in series.
	a) Current selectivity	Utilises overload or fault current
	b) Time selectivity	Time selectivity uses devices with different trip time settings.
3	Speed	Usually the faster the better in terms of **minimizing equipment damage and maintaining system integrity**, with only very precise intentional time delays.
4	Economics	Provide **maximum** protection at **minimum** cost
5	Simplicity	Minimize protection circuitry and equipment. KISS (keep it short and simple)

Performance & Cost

- Differential relay offer very sensitive and fast protection for a clearly defined zone of protection but costs more.
- It is to be noted that even the fastest protection device cannot totally avoid injuries and damage due to any fault; it can only minimise any such effects.
- The much cheaper OCEF relay will be able to isolate a fault, but its much slower speed of operation will probably result in considerable injuries and damage.
- The design has to consider the benefits of a fast protection against its high cost and the probability of faults.

Simplicity Vs Complexity

- Numerical relay offer a number of options of protection functions to the user.
- Some of the more complicated schemes may involve tripping of all the incomers and will require considerable skill in design, setting and testing.
- In some cases, critical information required for the setting may not be easily available.
- The user has to weigh the consequences of under protection against the complexity of over protection.

Comparison of protection relays with insurance

You need insurance for your property or health.

Amount of premium depends on the importance of the things to be protected if something bad happen.

If nothing happen, good for you.

You need protection for your electrical system.

Why invest so much money for things might not operated???

Comparison of protection relays with car insurance

The type if insurance you wish to buy depends:	The type of protection you install depends:
How expensive is the car	Type of electrical system (HV/LV, cost, etc)
Risk you want to take	Risk – extent of damage to the electrical system
Amount of money you wish to spend	Money
What happens if you do not have insurance ? OK as long as you do not have an accident or lose your car	What happens if you do not have protection for your electrical system? OK as long as there is no electrical fault

Components of Protection System

"Sensors"

Current Transformer (CT)

Voltage Transformer (VT) (for HT)

Current Voltage

Sent input to the relay

"Brain"

Protective Relay

(E/F, O/C, IDMT)

Types of protection relay:-

Overcurrent protection relay (O/C)

Earth fault relay (E/F)

Earth leakage relay (ELR) (≤250A)

Combined O/C & E/F

a) microprocessor based

b) electronics

Analyze & decide input, then send it to switching device

Relays	Brains
CTs and VTs	Eyes and ears
Circuit breaker (CB)	Muscles
Wiring	Nerves
Battery	Heart
DC	Oxygen

"Arm"

Switching Device

Air Circuit Breaker (ACB)

Moulded Case Circuit Breaker (MCCB)

Miniature Circuit Breaker (MCB)*

Contactor*

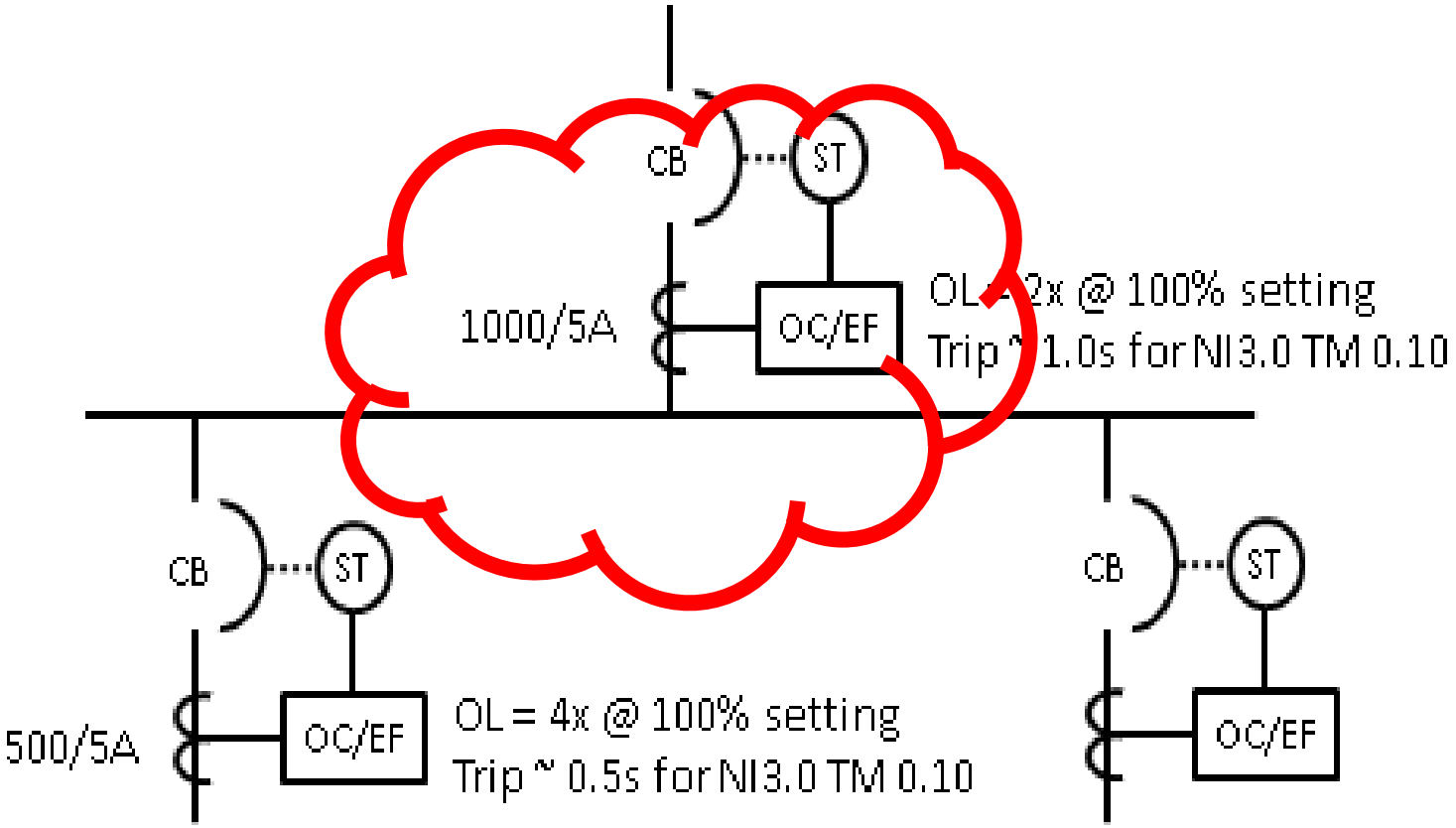
(*don't require relay to trip)

Trip with clearance time

"Mouth"

Alarm

Example of Installation



2000A Fault
Overcurrent

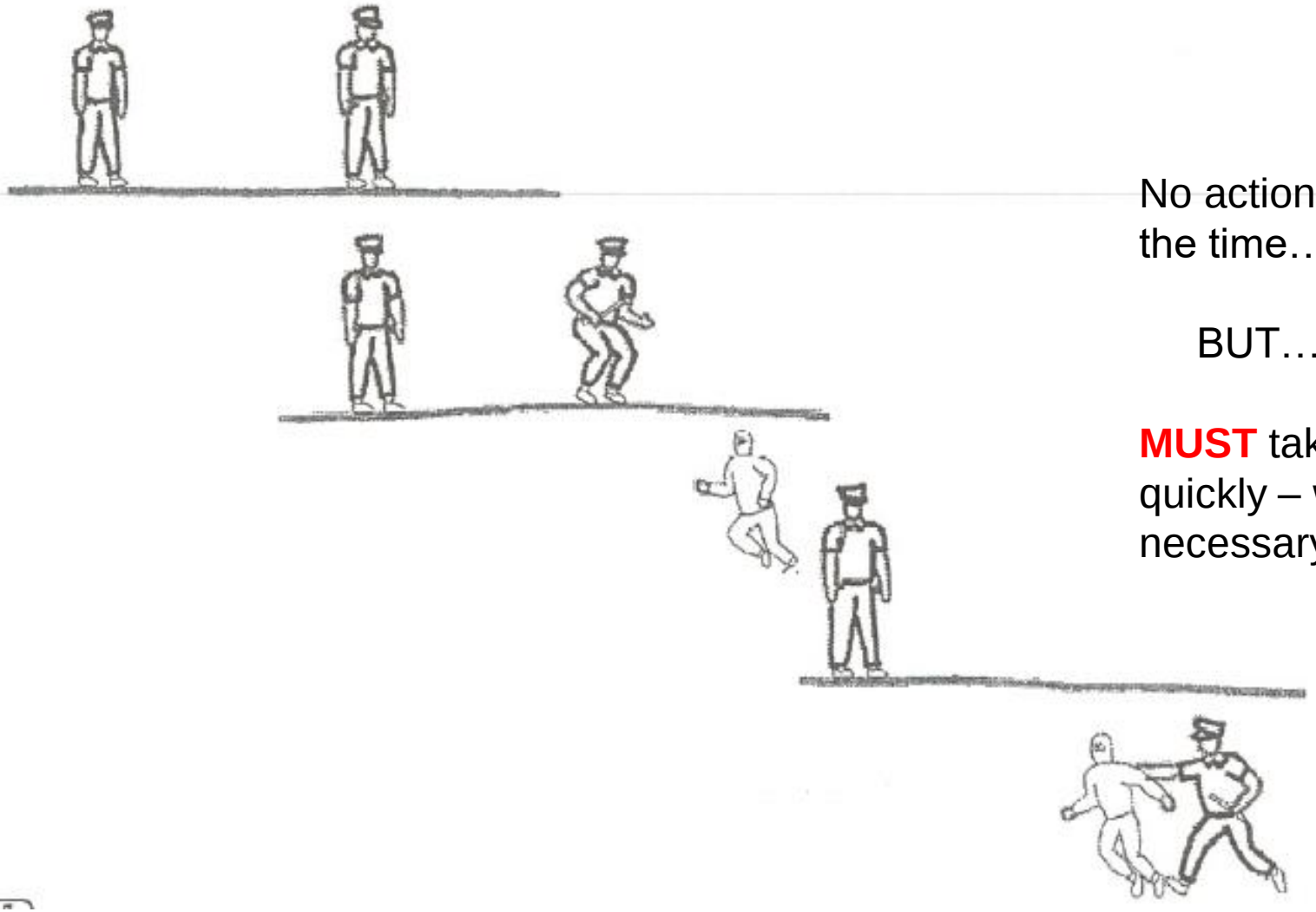
Load Side

Principle of Protection

What does a protection relay normally do ?

- ✓ Monitors continuously system parameters (current, voltage, power, frequency, direction, etc.)
- ✓ No action for most of its life – perhaps never !!
- ✓ No need for action if there is no disturbance !!

Principle of Protection



No action almost all the time….

BUT…….

MUST take action quickly – when necessary !!!!!!

Principle of Protection

What a protection relay *must not* do ?

- ✓ *Not to operate wrongly (mal-operate)*
- ✓ Must have *discrimination/stability*

Disturbances in Power Systems

- Over or under voltage
- Short circuit or earth fault
- Over or under frequency
- Overload
- Loss of generator prime mover or excitation

Most common disturbances;

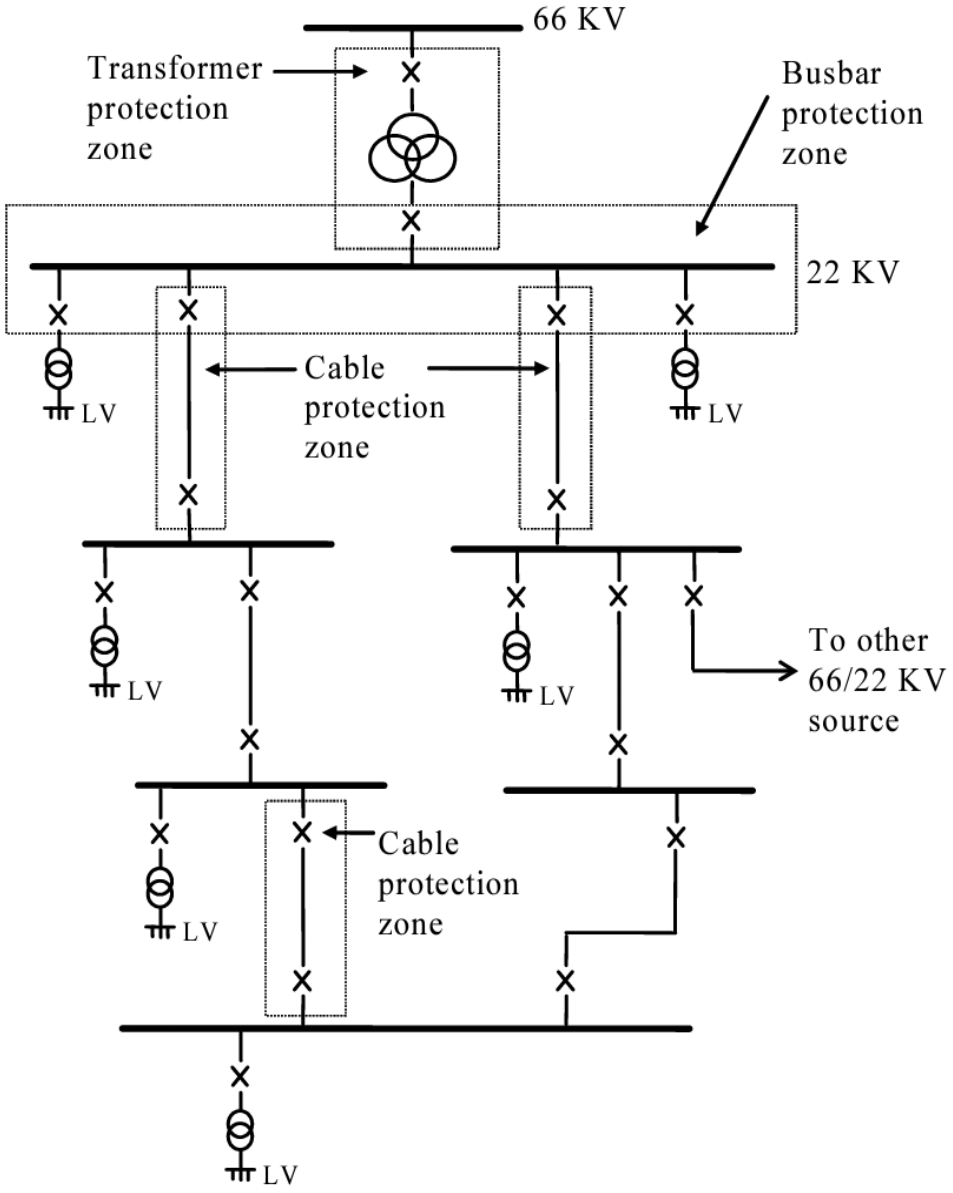
✓ Short circuit
✓ Earth fault
✓ Overload

Zones of Protection

- Each relay has a specific *zone of protection.*
- A relay must trip its CB for *internal fau* in the zone of protection.
- A relay must not trip (stable) for *exter faults* outside the zone.
- Zones of protection should overlap, s that no part of the power system is le unprotected.

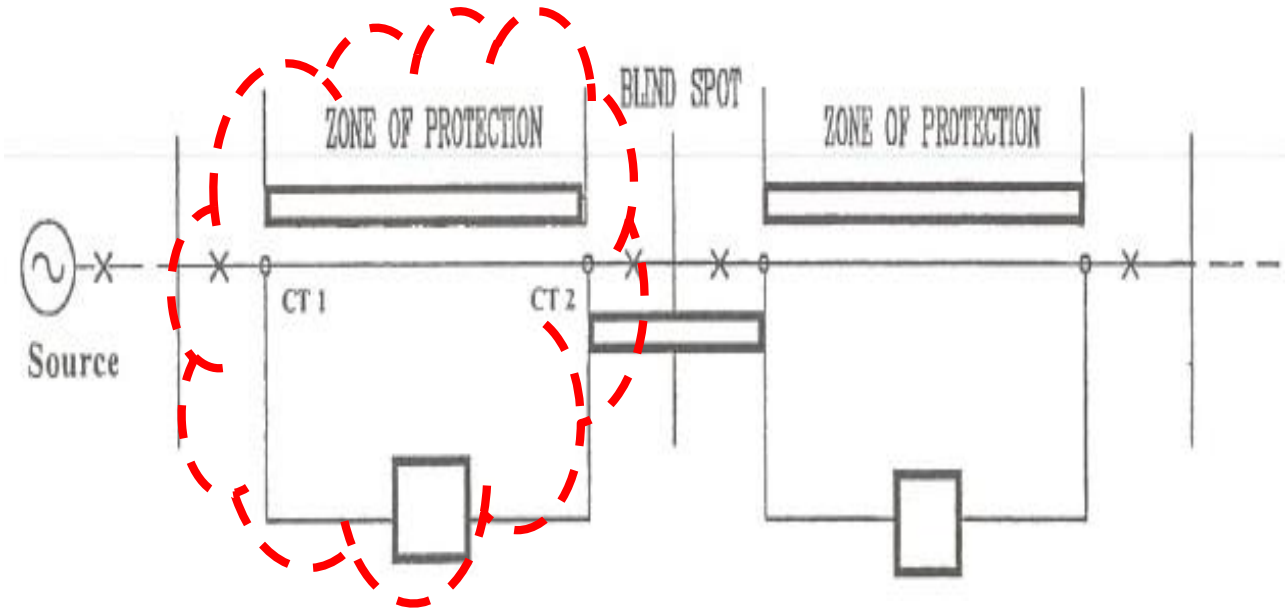
Relays can be divided as follows:

- ❑ Unit protection
- ❑ Non-unit protection



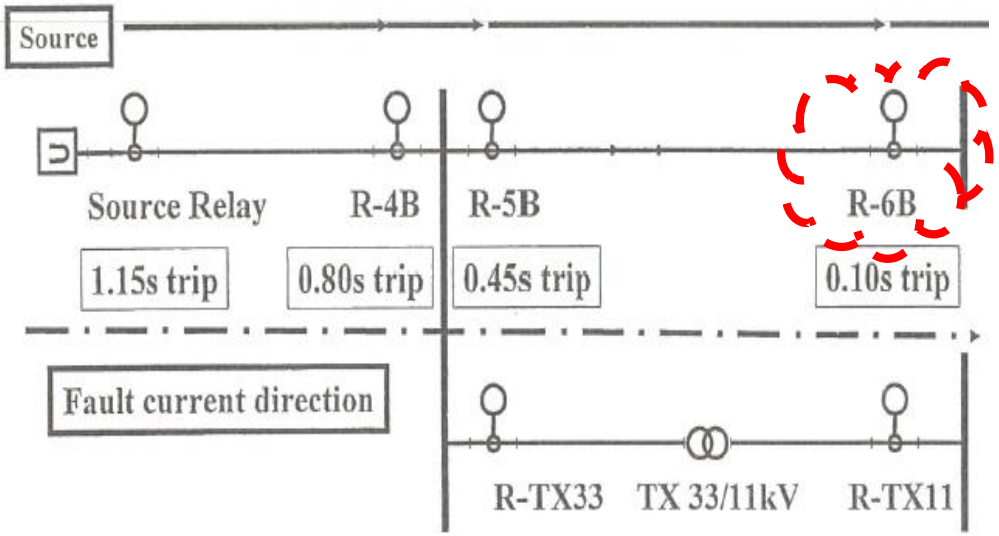
Zones of Protection: Unit Protection

- It has two sets of CTs.
- It has a *zone of protection* between *two sets of CTs*.
- It must *trip instantaneously* for *internal faults*.
- It is used for more expensive or important equipment.
- It protects a " *unit* " of equipment, e.g. cables, transformers, generators, etc.



Zones of Protection: Non-unit protection

- It has one sets of CTs.
- Different relays have different tripping times.
- When a fault occurs, a fault current will flow through a number of relays.
- The relays that see the fault current will "start" but only the *nearest one relay will trip* its CB.
- When the CB opens, it clears the faults.
- All the relays then *reset* or return to the original position.
- This is required for *all electrical circuits*.



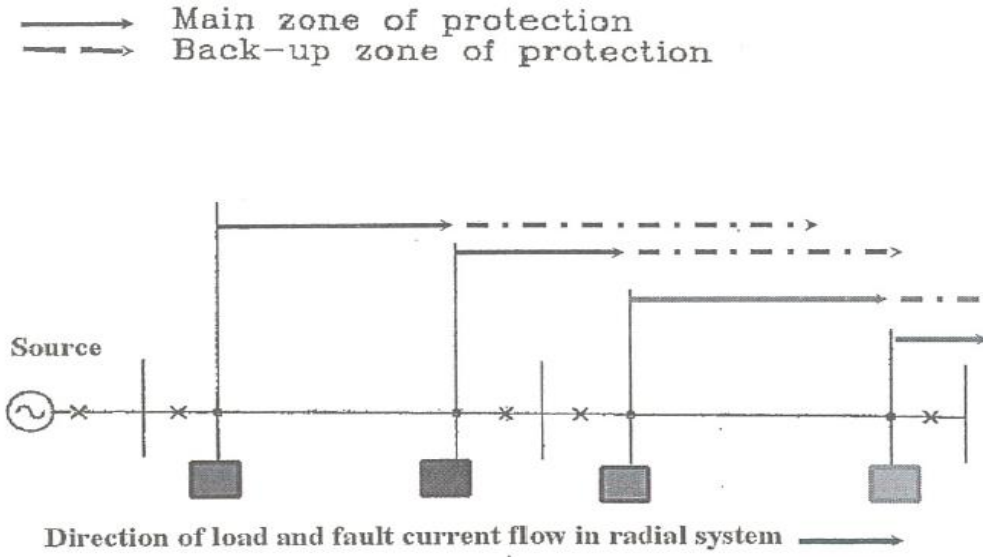
Comparison between Unit and Non Unit Protection

Features	Unit Protection	Non Unit Protection
Zone of protection	Between 2 CTs, Circuit Breakers	Downstream
Main protection	Yes	Yes
Back Up protection	No	Yes
Speed (ROT)	Fast / Instantaneous	Time Delayed
Cost	Usually high	Cheaper
Application	Costly equipment	All equipment
Current Transformers	Class X – Originally, for high impedance protection but currently extended to other protection, which requires high knee point voltage such as distance, biased differential and pilot wired	Class 5P, 10P
Communication -	Pilot wire, Fiber Optic	Not Applicable

Upstream and Downstream Relays

- The location of the source and direction of current flow are very important for non-unit protection relays.
- In a *radial system*, the *current flows* in *one direction*, like the flow of water in a river.
- A relay that is closer to the power source is called the *upstream protection*; the relay further away is the *downstream protection.*
- During a fault, the relay just before the fault should trip. All the other upstream relay must not trip.

- The zone of protection is always downstream of the relay in a radial system.
- The *main purpose* of each relay is to *protect* against *any internal fault*, downstream of its location.
- However if a relay fails to operate during such a fault, the next upstream relay must operate as a backup protection after a further time delay.
- A non-unit relay thus has two zones of protection;
  * Main zone (until the next relay) – for internal fault
  * Backup zone – for external fault



What Happens When a Relay Fails?

- The first relay to operate correctly during a faults is the *main protection.*
- The main protection *can be a unit or non-unit protection.*
- If it fails, another relay must take over.
- This will be the *next non-unit protection* relay.
- It is called the *backup* protection.
- The backup protection must be *slower.*
- Basically, it is a non-unit protection operating for an external fault.

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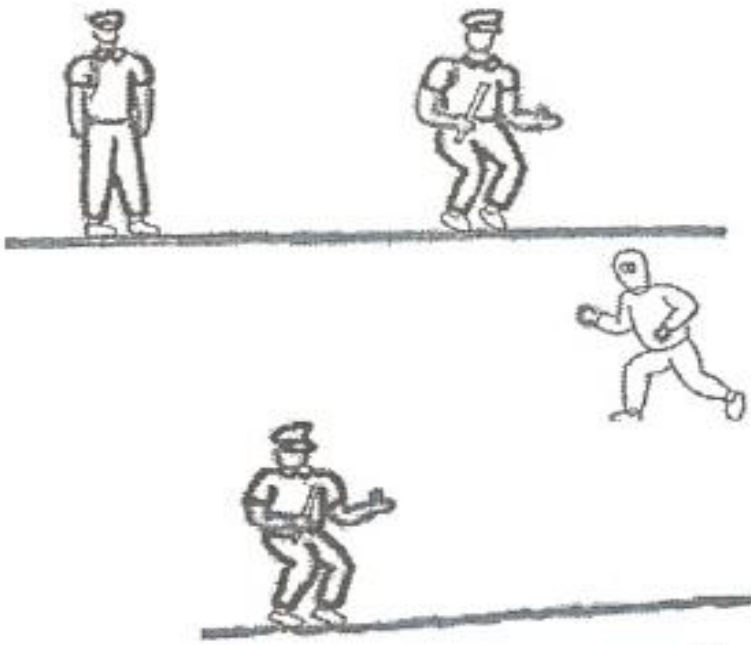

If the main protection fails……..

…..there **MUST** be a backup protection

Key points

- Components of protection scheme.
- Relay must trip only when necessary.
- Relay must not trip wrongly.
- Zones of protection – internal and external faults.
- Unit and non-unit protections.
- Main and backup protections.
- Unit protection relays can only operate for internal faults; non-unit protection relays may operate for both internal and external faults.