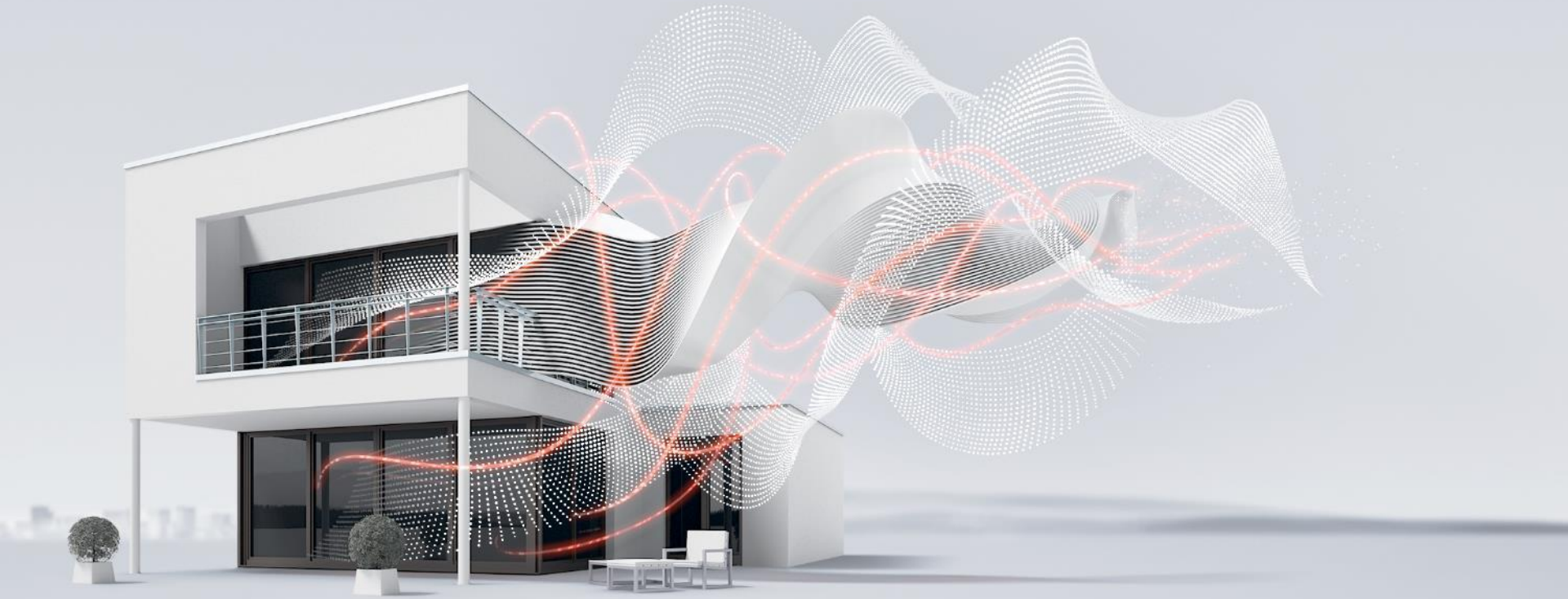


EXTRA SAFETY DAY, 21ST MARCH 2017

Extra Safety Campaign

Protects your life, protects your investment

Ong Peck Seng

Agenda



1. Introduction
2. Why Electrical System must be “Earthed” or “Ground”?
3. Indirect contact and people protection.
4. Indirect contact and property protection.
5. Earth Leakage / Fault protection.
6. Proposed solutions.

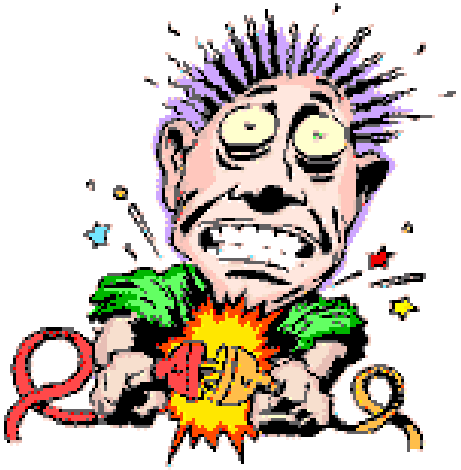
Earth leakage and earth fault protection of electrical distribution system

Introduction

Leakage current is inevitable in electrical system and it could be '**normal**' so that the system continue operative or at 'fault' that the system has to be interrupted.

Normally, it's a very small amount of current flowing through the unwanted path like insulation material, deteriorate low insulation surface etc. or

At **fault**, due to un-plan situation like touching the life part by accident, etc., and can cause serious injury, fatal or fire.





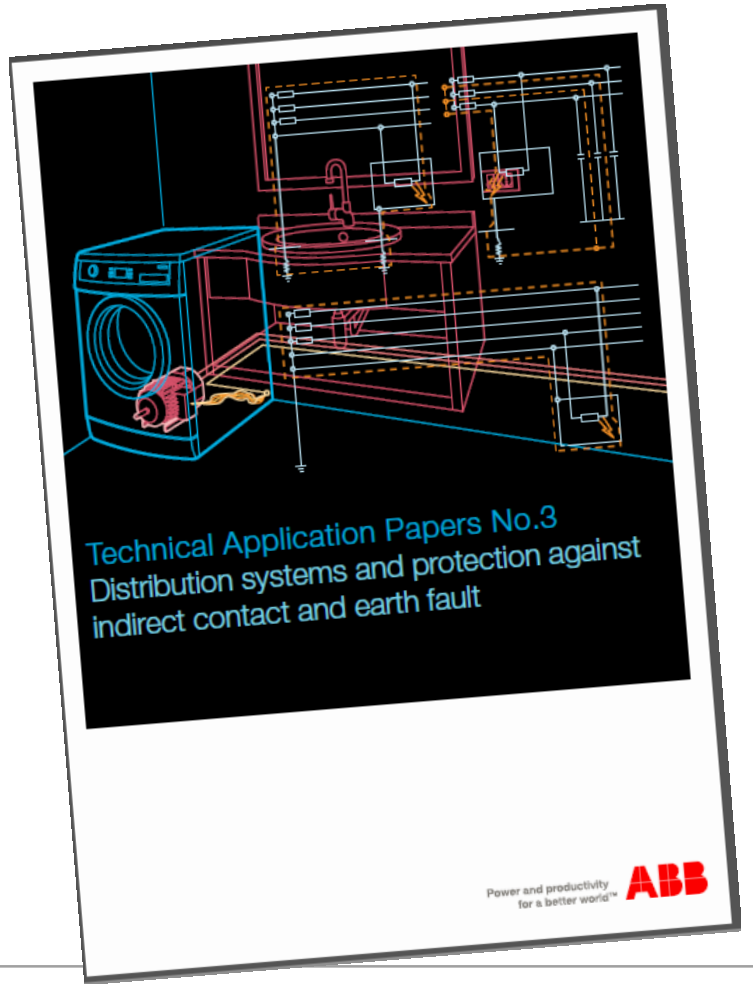
Earth leakage and earth fault protection of electrical distribution system

Introduction

Technical Application Papers No.3

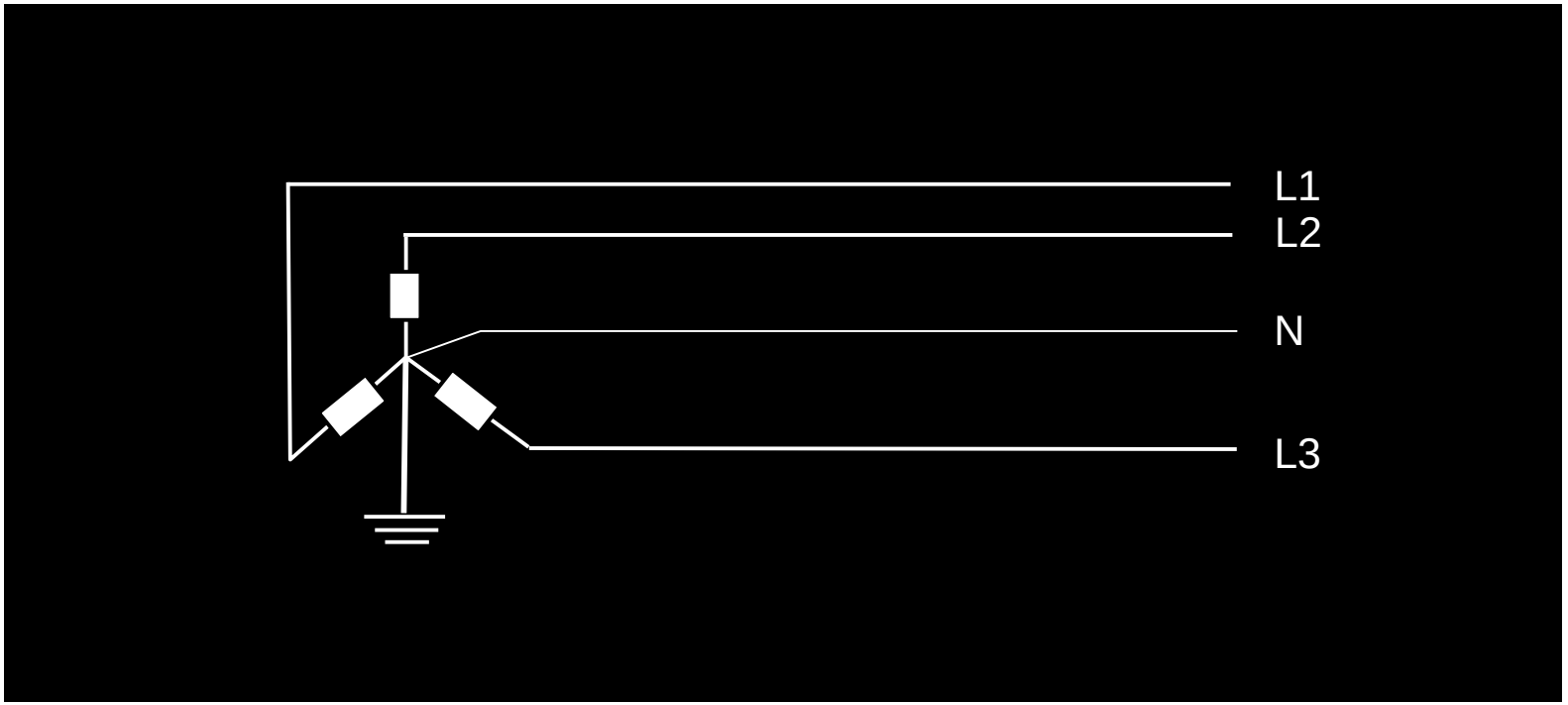
Distribution system and protection against indirect contact and earth fault

https://library.e.abb.com/public/d3175ee9ec6ab6b648257a700022b62d/1SDC007102G0202.pdf



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Earthing (Grounding) System



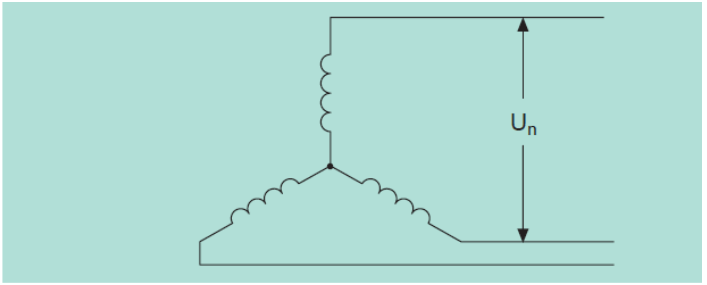
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Earthing System

Why Earthing?

three-phase systems with insulated neutral
or earthed neutral through an impedance

$U_{ne} = U_n$



Have you ever wander if the neutral of the power transformer is not connected to earth (ground), the risk of being electrocuted will be elaminated?

The answer is not so straight forward, please see few demo as follow:

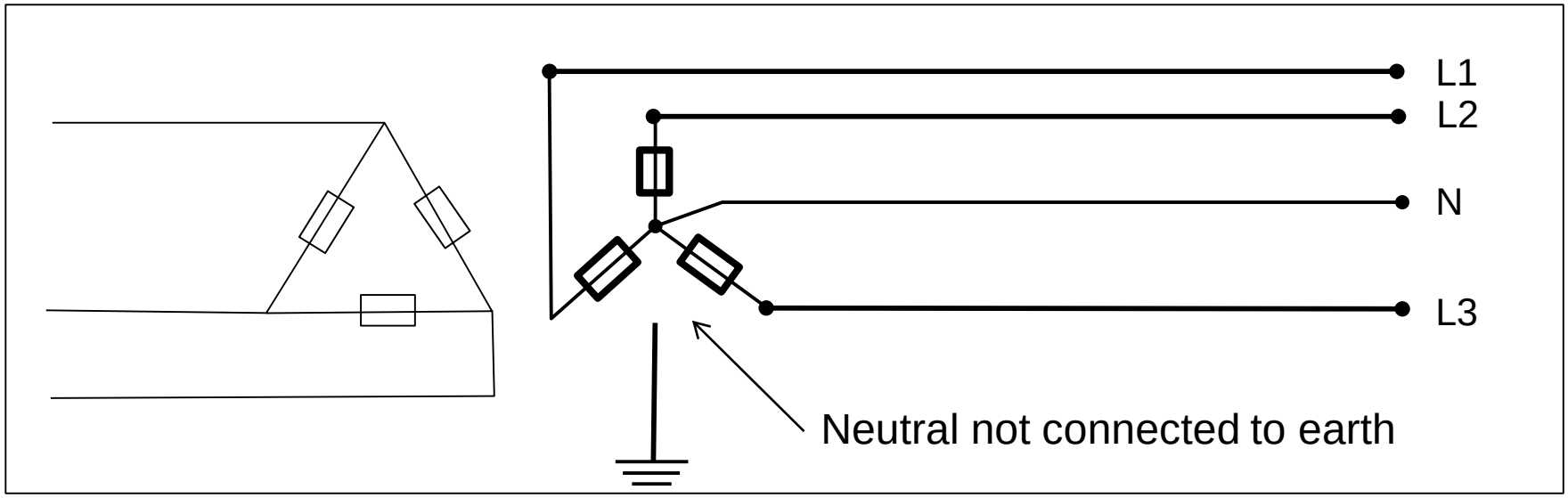
1.) Isolated earthing

2.) Vertual earth due to stray capacitance

3.) One of the “phase“ grounded

Earthing System

Isolated Earthing



Isolated earthing

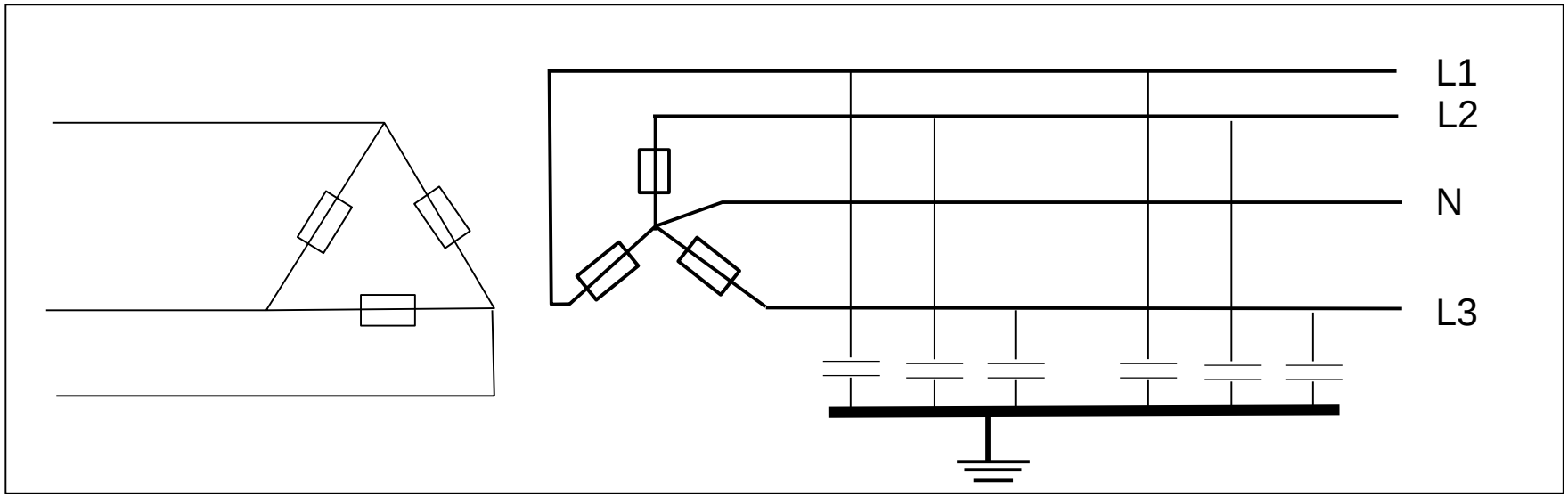
Neutral point of transformer secondary is not connected to earth (IT System)

Q, will I get a shock if I touch any one of the Line (L1, L2, or L3) since there is no return path.

A, Only if the out going cables are very short and no virtual earth is formed in the system.

Earthing System

Virtual Earth



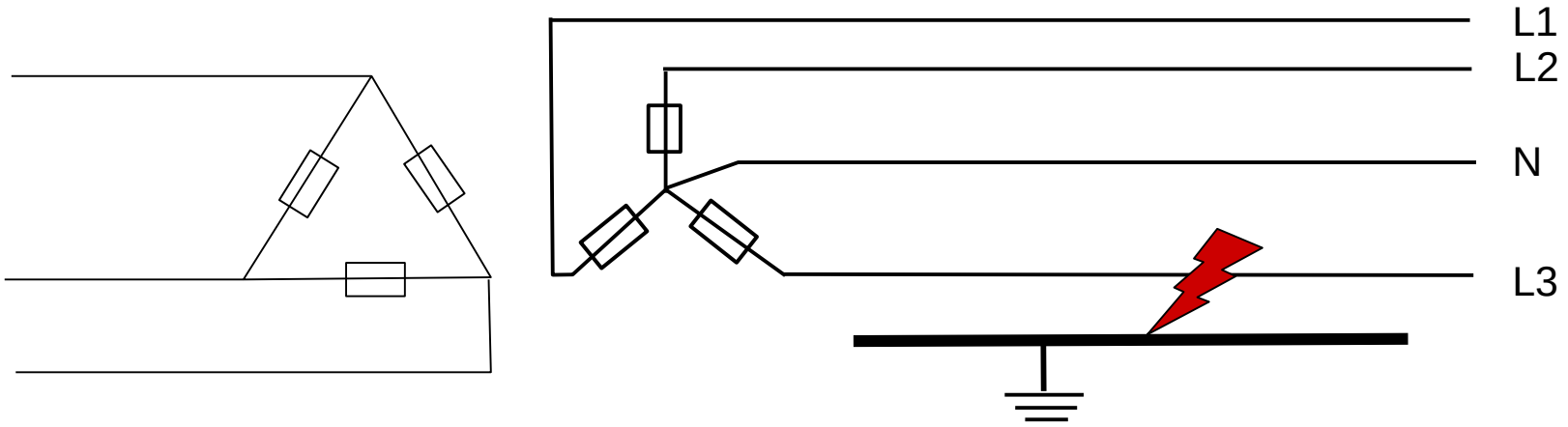
Virtual Earth will still be formed due to stray capacitence

Q, Will I in danger if I touch the Line (L1, L2 or L3)

A, Depends on the stray capacitence, leakage current various.

Earthing System

One Phase Shorted to Earth



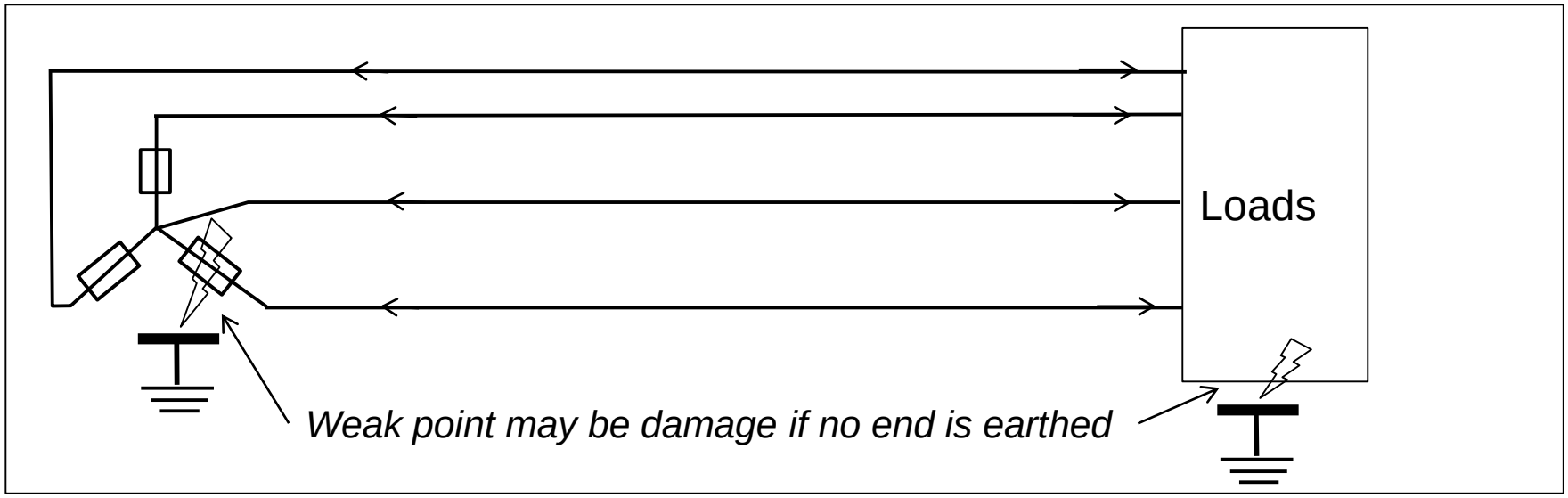
Q: What happen if one phase shorted to earth?

A: 1.) There will not be having a fault.

2.) The other two phases (in this case L1 & L2) will have line voltage with respect to earth, in this case, will be 433Volts. Neutral to earth will be about 250 Volts.

Earthing System

One More Reasons to Earth the System



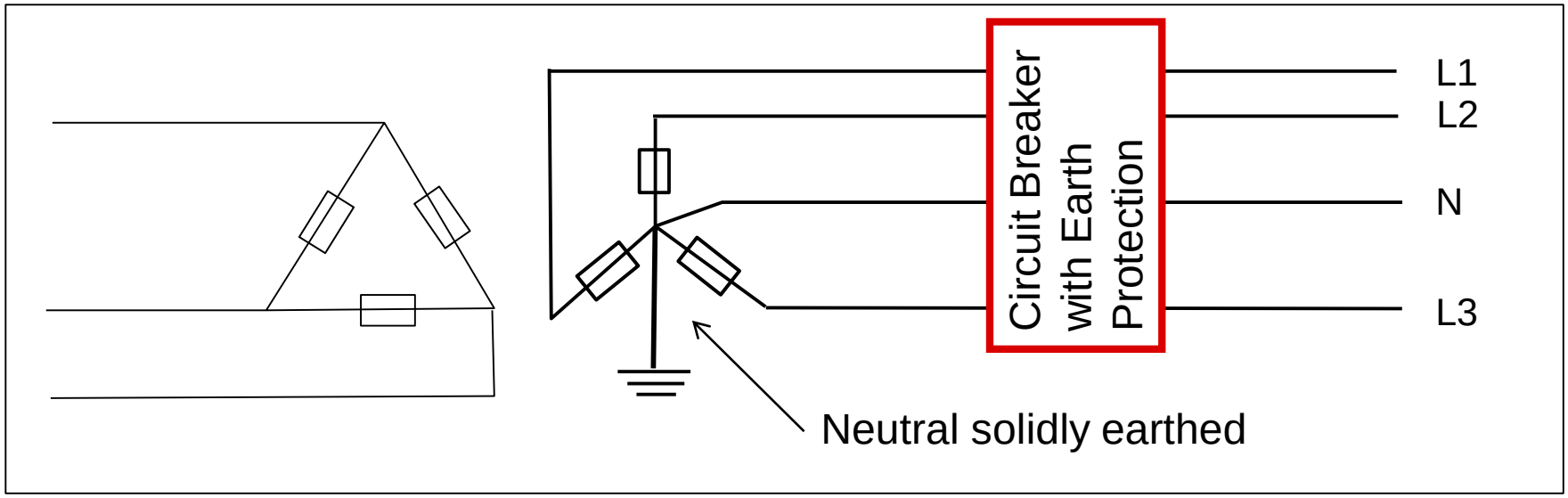


Strong disturbance appeared due to switching or lightning, extra high voltage surge refer to earth (common mode) will travel towards both ends, weak insulation point may be damaged.

Earthing of Neutral point will minimized this problem, surge arrestor is also advise to install at the load end.

Earthing System

Neutral Earthed



To minimze the above mentioned phenomenon, earthing of neutral is compulsary except for some special requirement like IT system.

Earthing Systems

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

Earthing Systems

Letter code meanings:

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 a.c. systems, the earthed point of the power system is normally the neutral point

Earthing Systems

Letter code meanings:

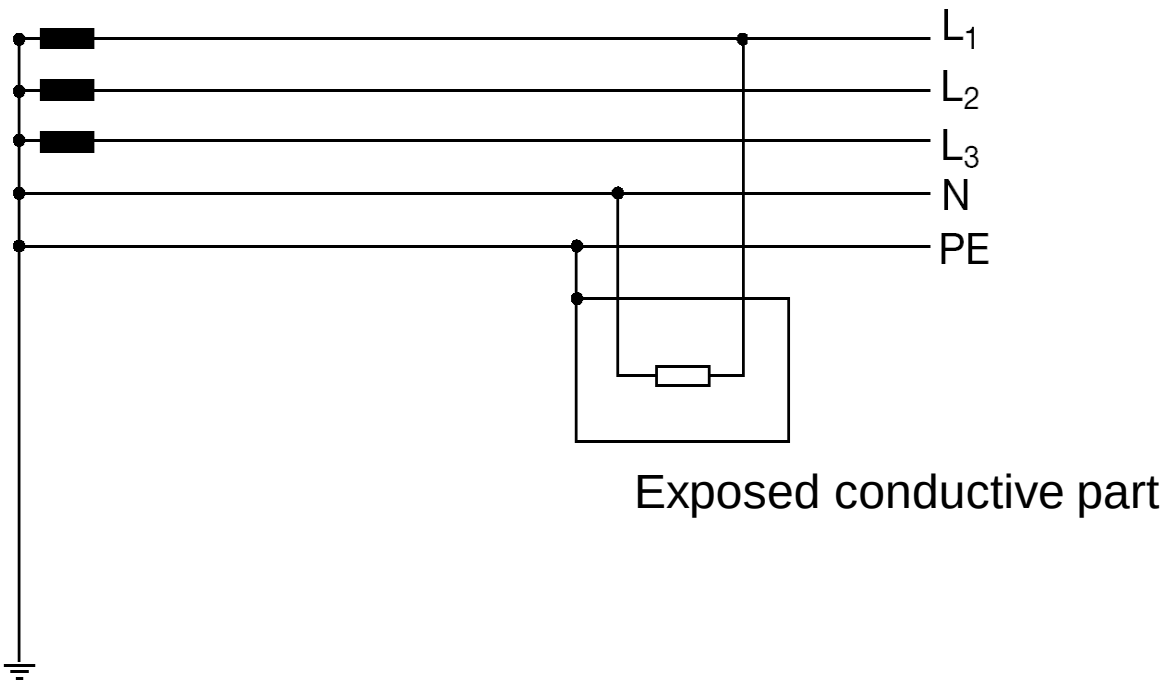
Subsequent letter (if any): N and PE conductors arrangement

S ➡ N and PE conductors separated

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

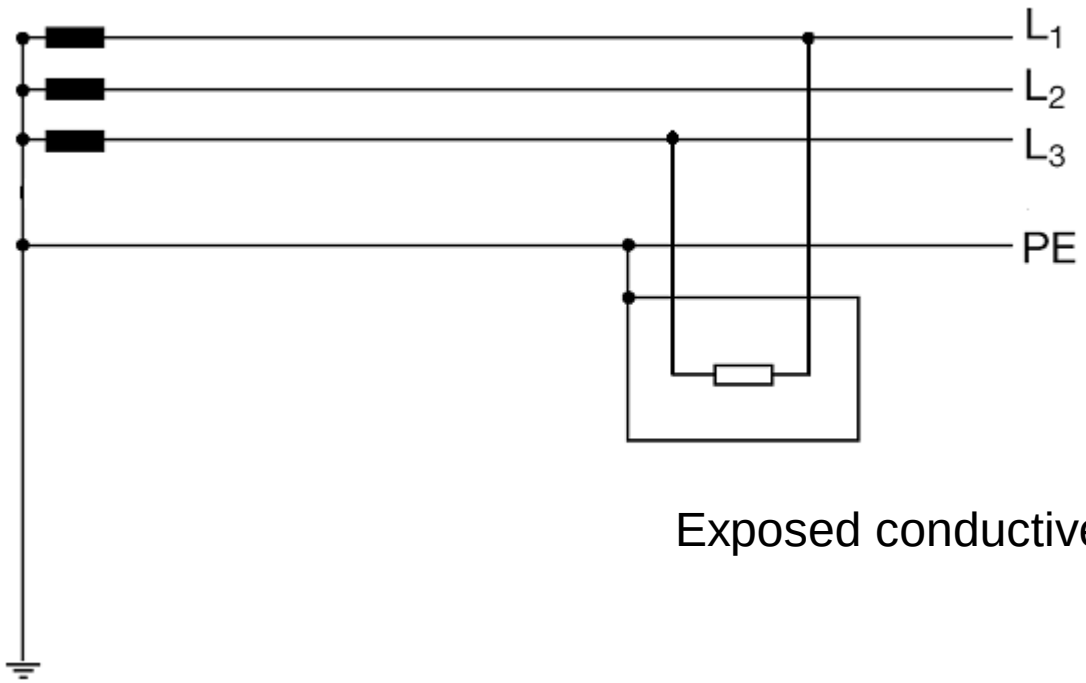
Earthing Systems: TN SYSTEM

TN-S system
5 wires



Earthing Systems: TN SYSTEM

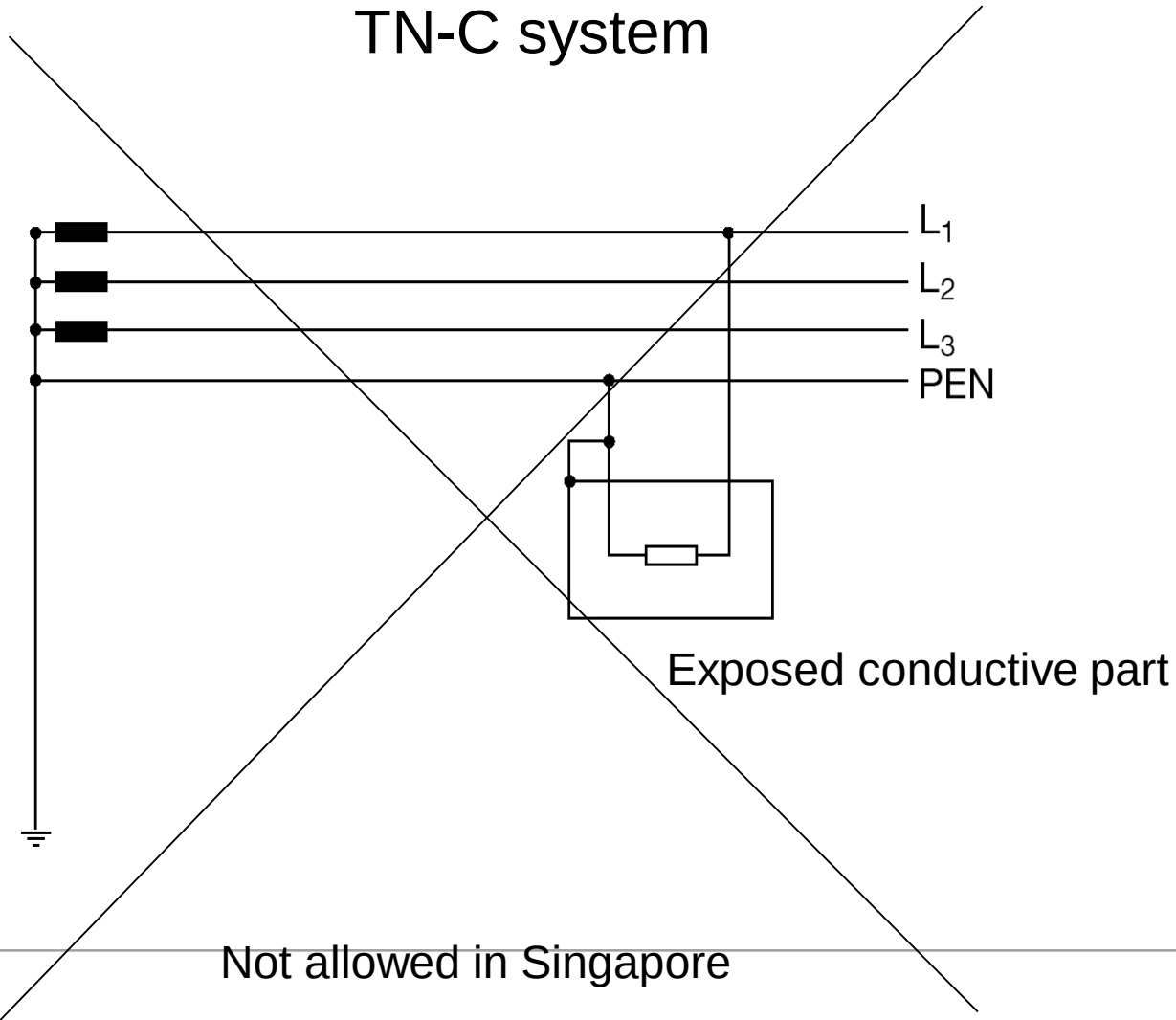
TN-S system
4 wires



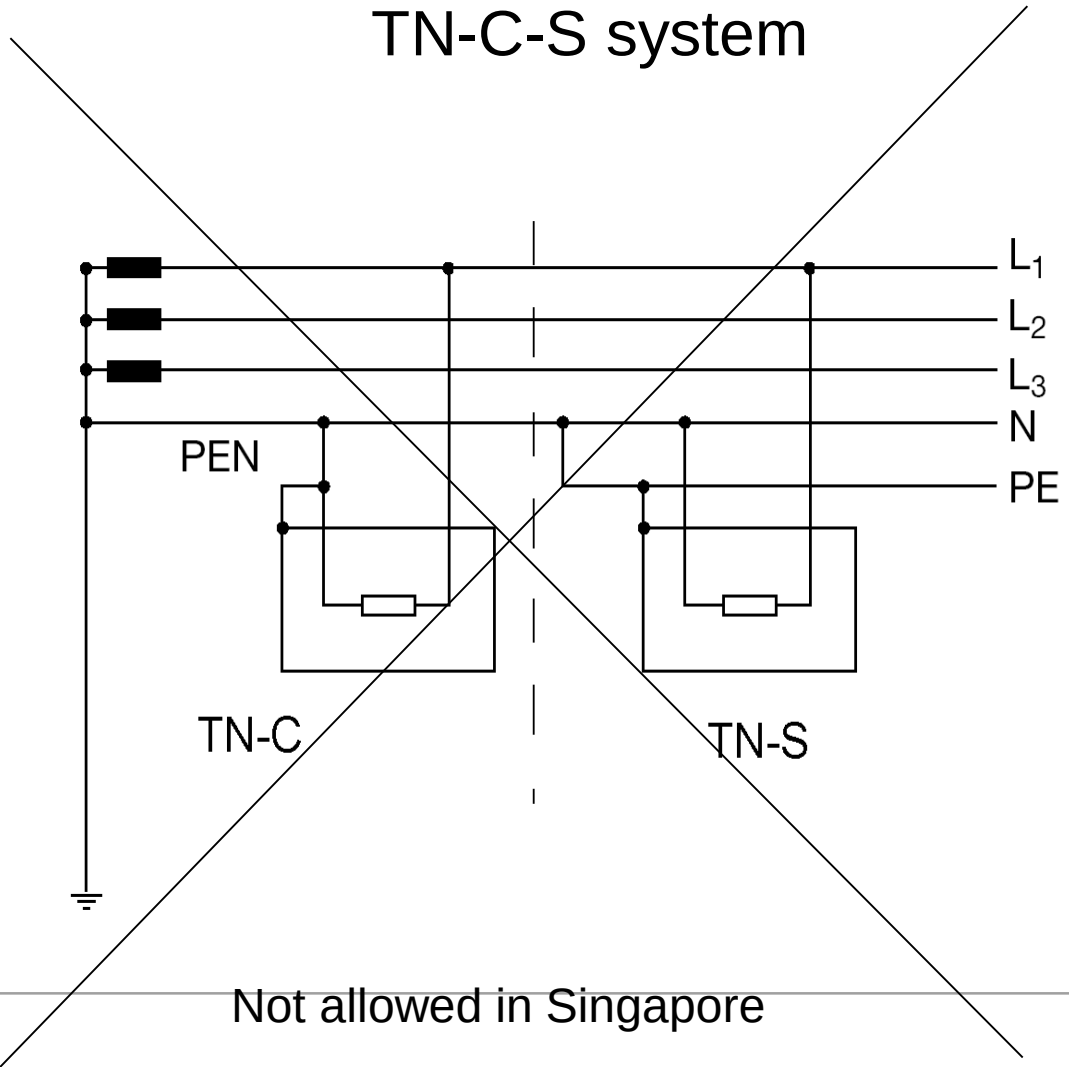
Exposed conductive part

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Earthing Systems: TN SYSTEM

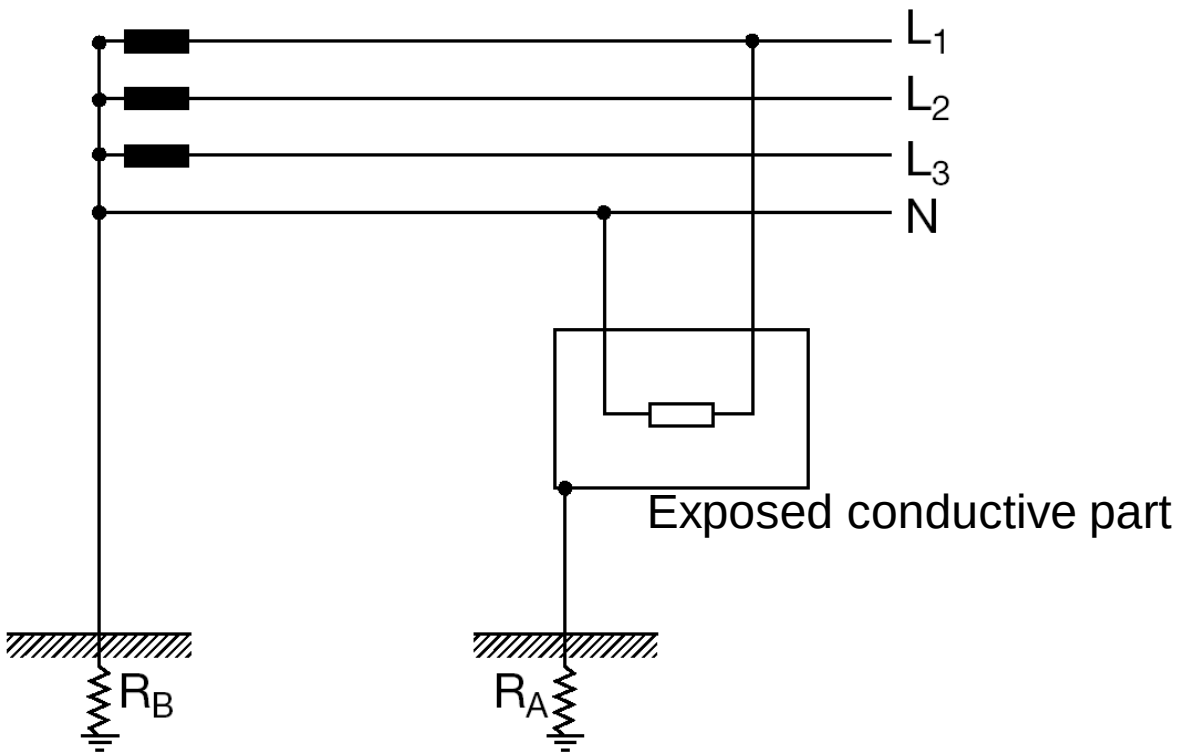


Earthing Systems: TN SYSTEM



Not allowed in Singapore

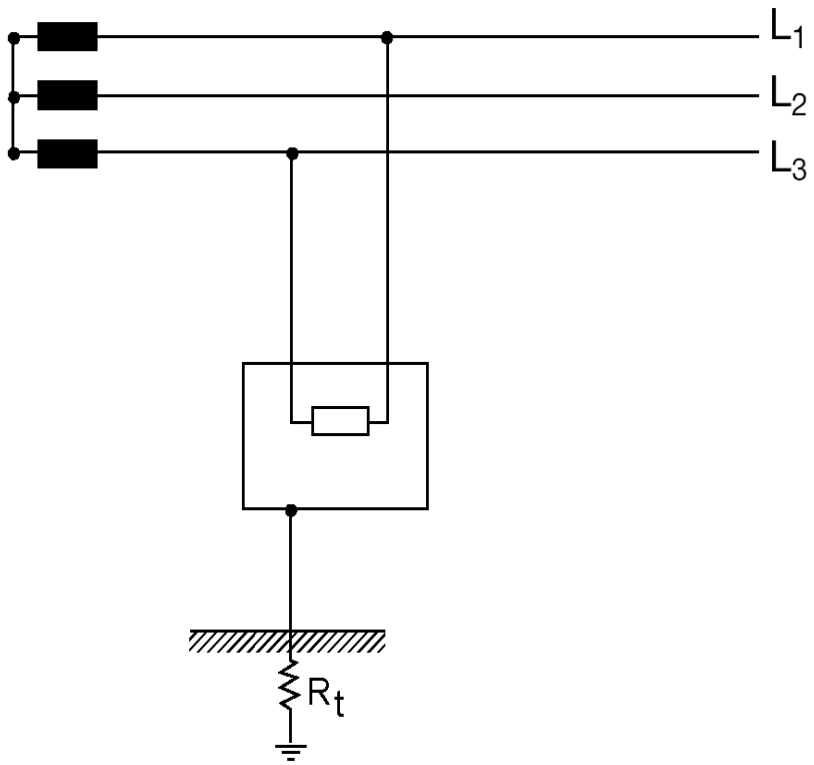
Earthing Systems: TT SYSTEM



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Earthing Systems: IT SYSTEM

IT system



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Earthing Systems: IT SYSTEM

Power system:
no connection between live parts and earth
or
connection by high value impedance

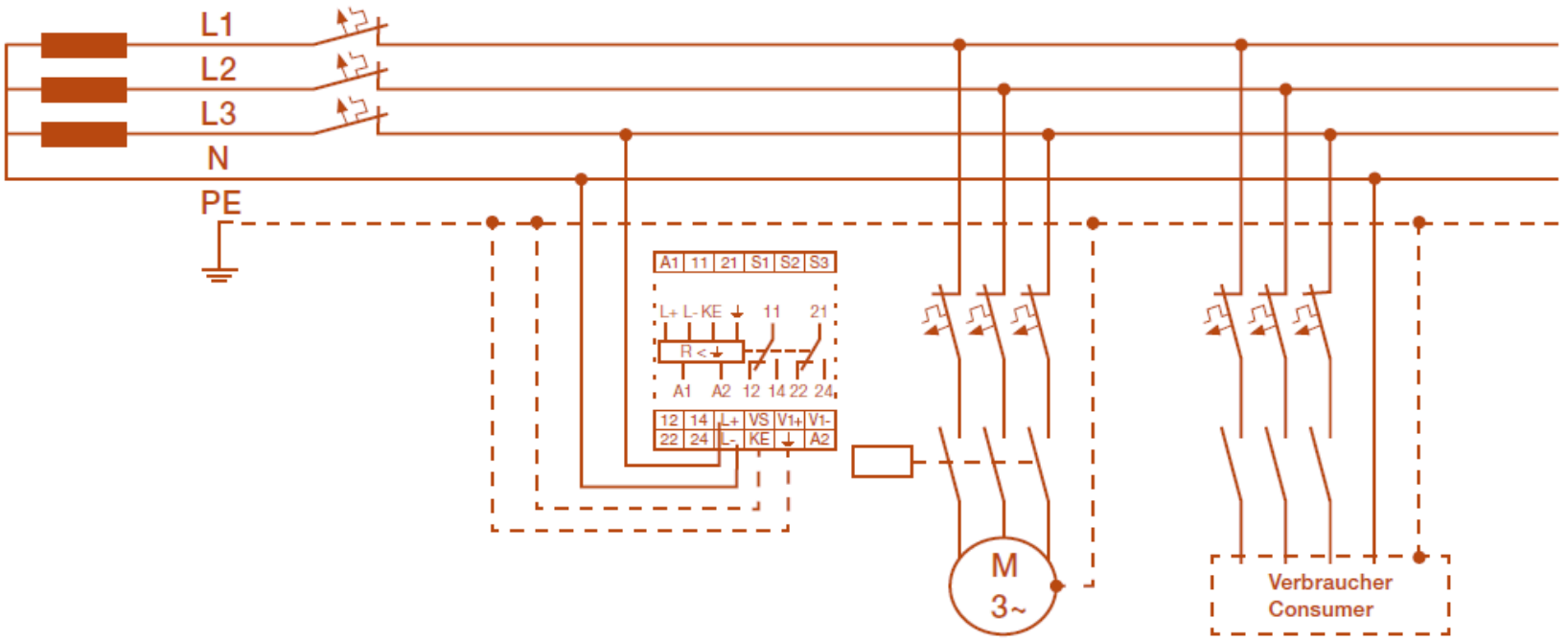
Electrical installations:
exposed conductive parts connected
(independently or collectively) to earth

Earthing Systems: IT SYSTEM

- Typical applications:
  - industrial or utilities installations (especially chemical, petrochemical and telecommunications) for which a very high level of service continuity is required;
  - installations for IT apparatuses fed by UPS
- Small values of short circuit currents to earth (1st fault), typically 1 to 10 A (0.1A/km cable);
- Medium-high values of short circuit currents to earth (2nd fault)
- It is strongly recommended not to distribute the N-conductor

Isolation monitors for ungrounded supply mains

Isolation monitoring in IT systems



Indirect contact protection













Protection against Contact:

People Protection

IEC 60479-1

RAPPORT TECHNIQUE

TECHNICAL REPORT

CEI IEC 479-1

Troisième édition
Third edition
1994-09

PUBLICATION FONDAMENTALE DE SÉCURITÉ
BASIC SAFETY PUBLICATION

Effets du courant sur l'homme et les animaux domestiques –

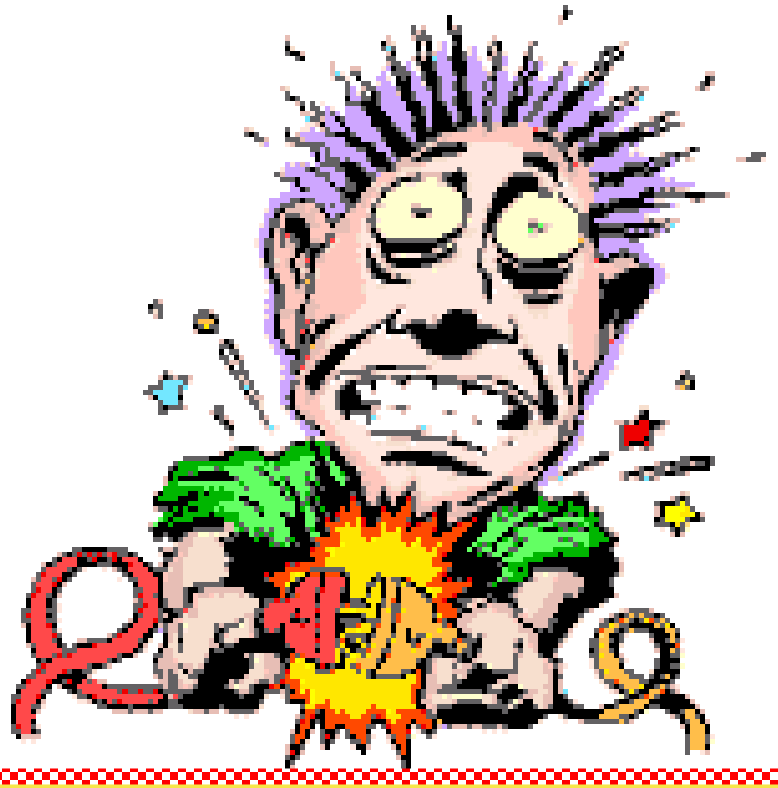
Partie 1:
Aspects généraux

Effects of current on human beings and livestock –

Part 1:
General aspects

IEC

Numéro de référence
Reference number
CEI/IEC 479-1: 1994



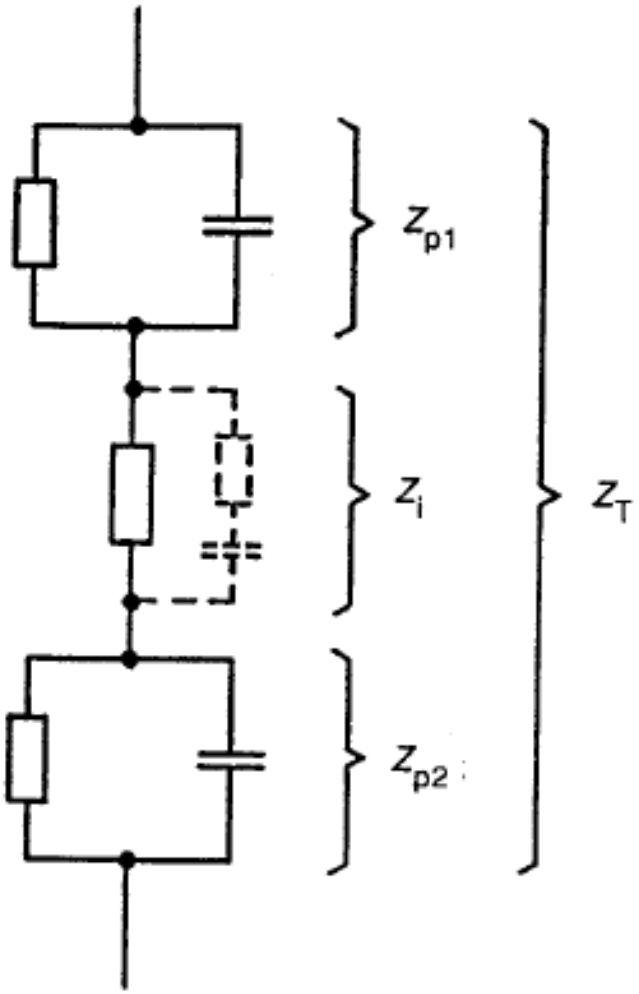
Effects of current on human beings and livestock



SS 97
IEC 61008

Impedance of the human body

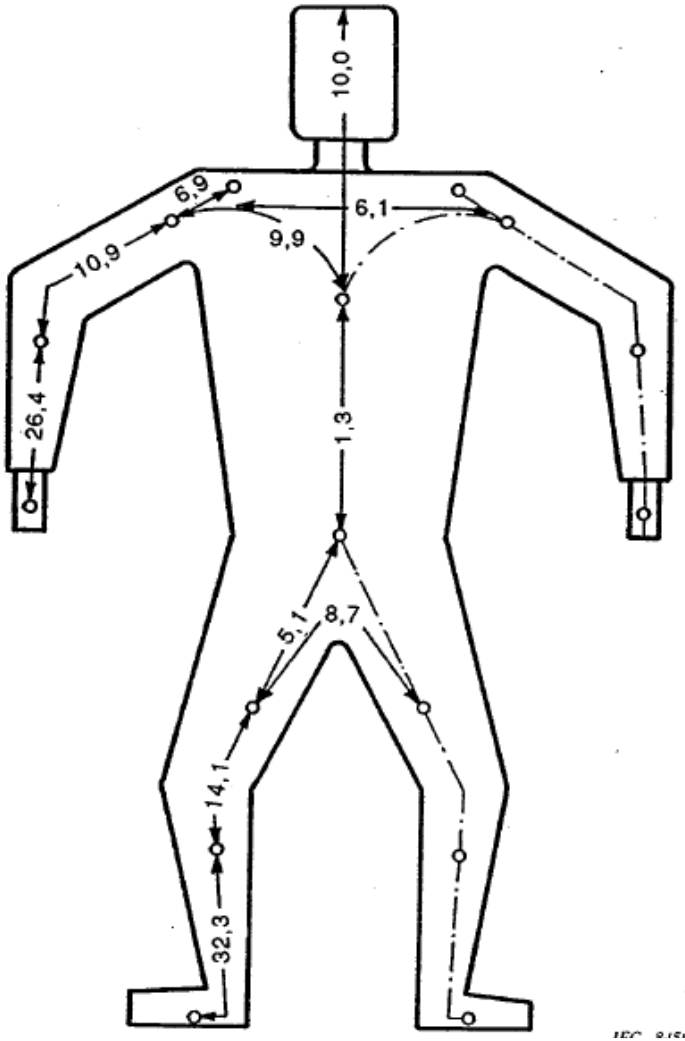




Z_i	internal impedance
Z_{p1}, Z_{p2}	impedance of the skin
Z_T	total impedance

IEC 844/94

Internal impedances of the human body



The numbers indicate the percentage of the internal impedance of the human body for the part of the body concerned, in relation to the path hand to foot.

NOTE – In order to calculate the total body impedance Z_T for a given current path, the internal impedances for all parts of the body of the current path have to be added as well as the impedances of the skin of the contact areas.

Effects of alternating current

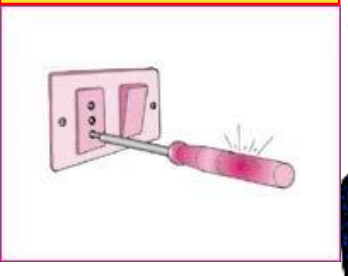
1.3.2.1 **threshold of perception:** Minimum value of current which causes any sensation for the person through which it is flowing.

1.3.2.2 **threshold of reaction:** Minimum value of current which causes involuntary muscular contraction.

1.3.2.3 **threshold of let-go:** Maximum value of current at which a person holding electrodes can let go of the electrodes.

1.3.2.4 **threshold of ventricular fibrillation:** Minimum value of current through the body which causes ventricular fibrillation.

No perception



Perception

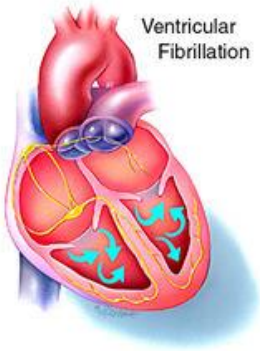


Reaction (involuntary contraction)



Let-go





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Effects of alternating current

3.1 *Threshold of perception and threshold of reaction*



The thresholds depend on several parameters, such as the area of the body in contact with an electrode (contact area), the conditions of contact (dry, wet, pressure, temperature), and also on physiological characteristics of the individual.

A general value of 0,5 mA, independent of time, is assumed in this technical report for the threshold of reaction.



3.2 *Threshold of let-go*

The threshold of let-go depends on several parameters, such as the contact area, the shape and size of the electrodes and also on the physiological characteristics of the individual.

An average value of about 10 mA is assumed in this technical report.



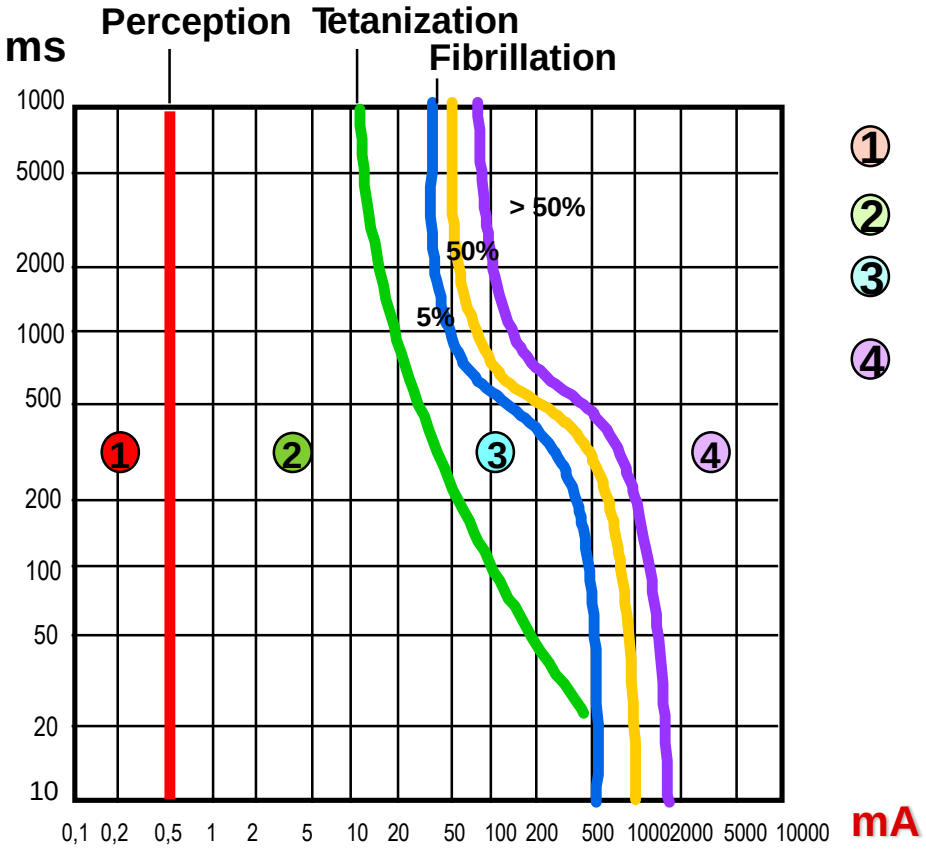
3.3 *Threshold of ventricular fibrillation*

The threshold of ventricular fibrillation depends on physiological parameters (anatomy of the body, state of cardiac function, etc.) as well as on electrical parameters (duration and pathway of current flow, current parameters, etc.).

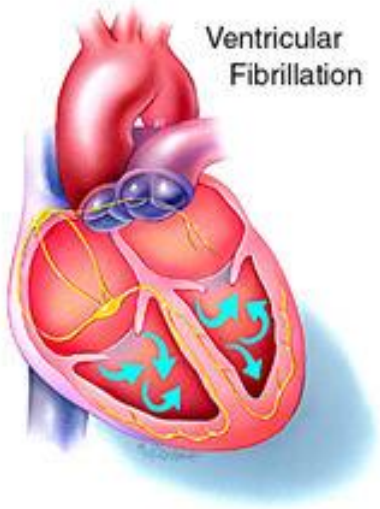
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Physiological effects

IEC describes as follow the current effects:

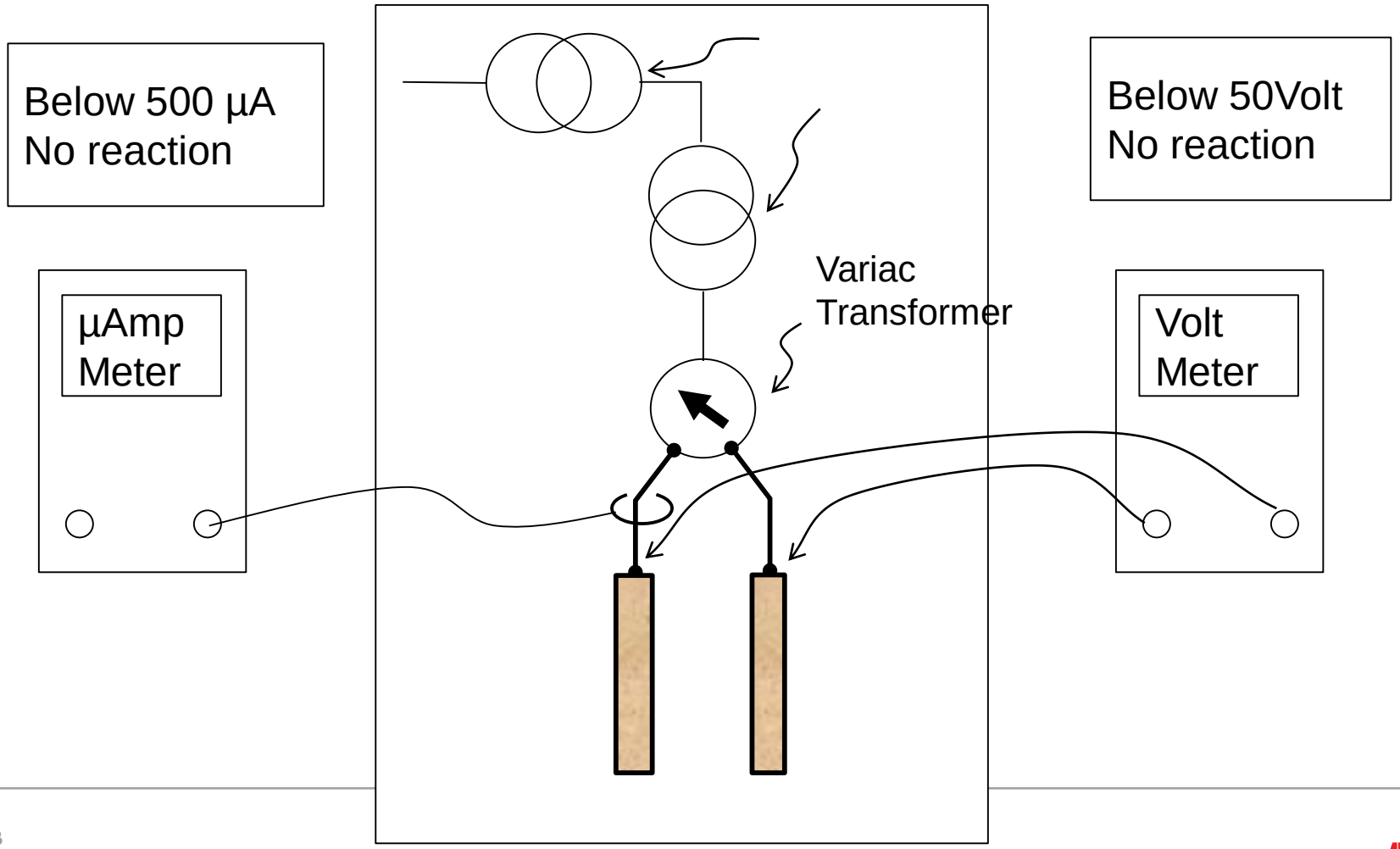


① No reaction
② No harmful physiological effect
③ Reversible pathological effects
④ Fibrillation risk greater than 50%



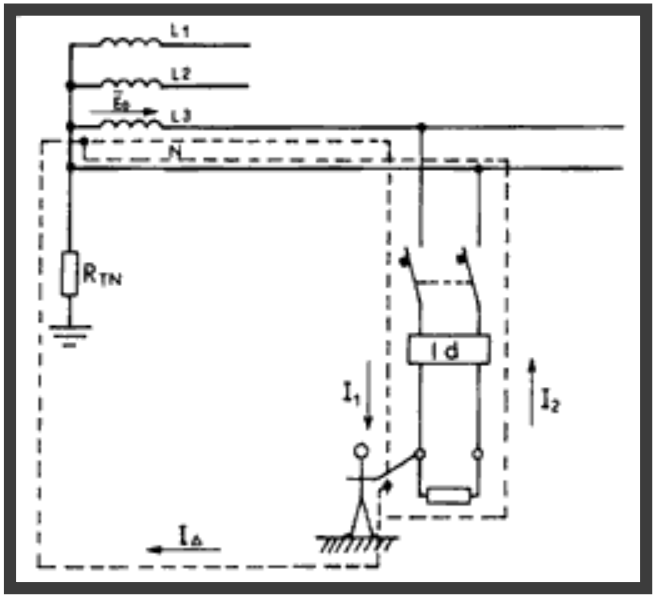
Earthing System Demo

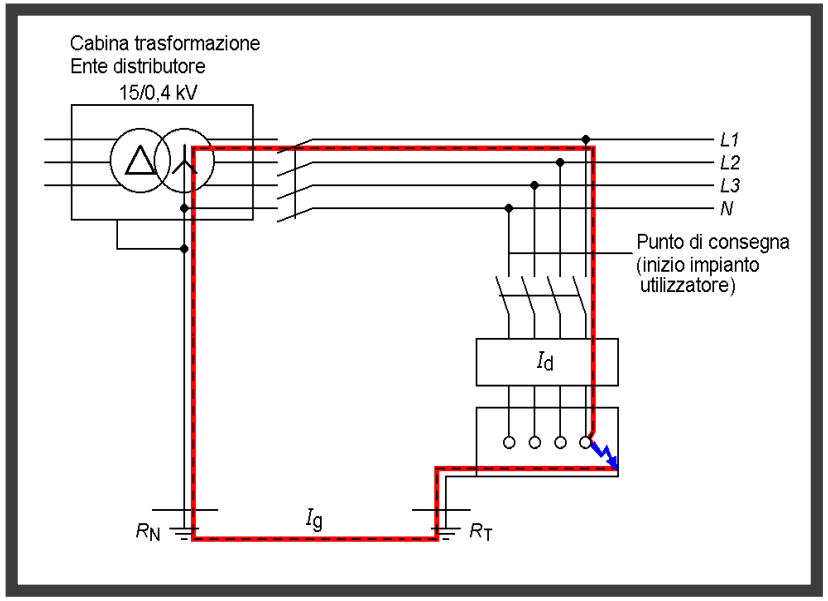
Physiological Effect



Earthing System

Selectivity





10mA, 30mA, 100mA, → Human Life Protection, protection against indirect contact by the automatic disconnection of supply

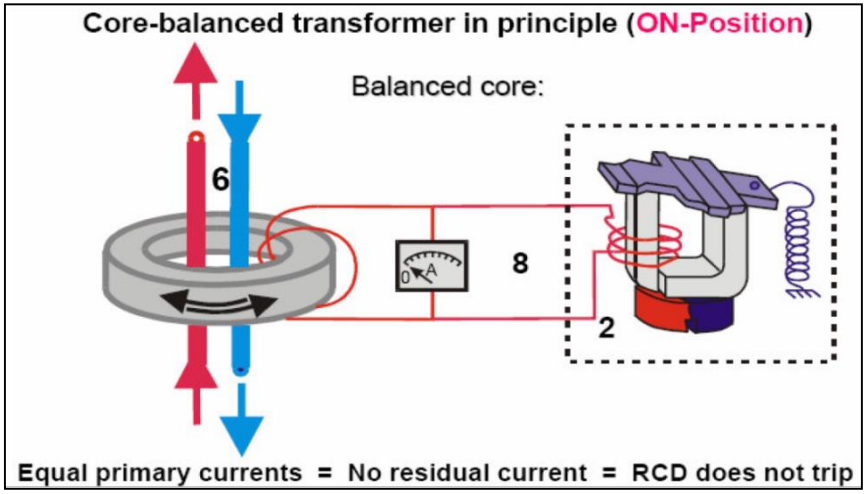
300mA, 500mA, 1000mA, → Fire Protection

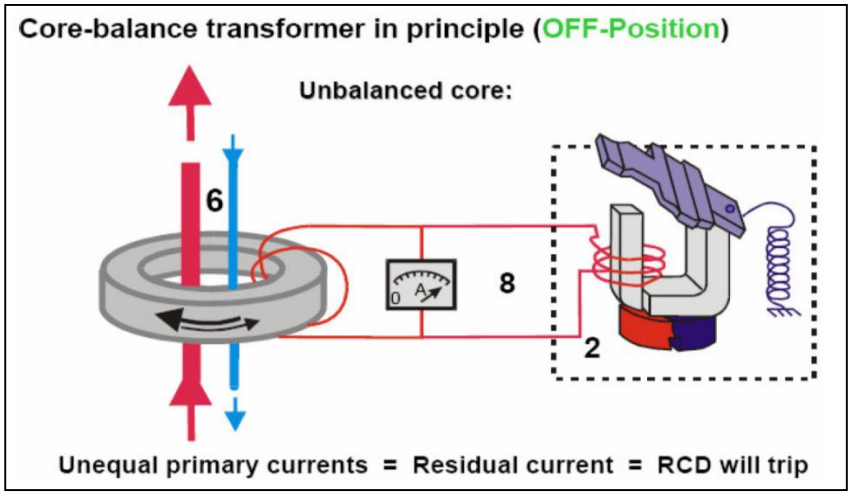
Higher than the above value is consider earth fault.

Earthing System – Auto-disconnection of supply

RCD, RCCB, ELCB, RCBO, ELR, EFR

- RCD, RCCB, ELCB,
  - Voltage independent type, operating based on induced secondary current.
  - Voltage dependent RCD is equipped with an amplification circuit.





- RCBO – A device with the combination of RCD and Circuit Breaker
- ELR/EFR, A measurement device giving output contact to trip the shunt trip coil of a circuit breaker

Earthing System

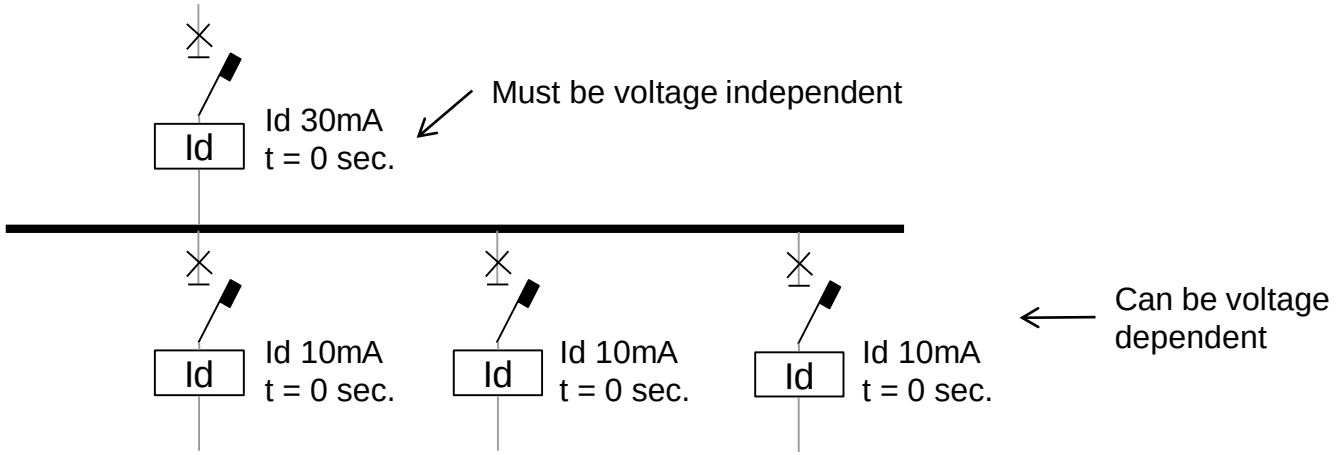
Selectivity 10mA

10mA:

Sensitive human life protection

- Hospital
- Kindergarten, etc

Final distribution circuit for better protection and discrimination



Earthing System

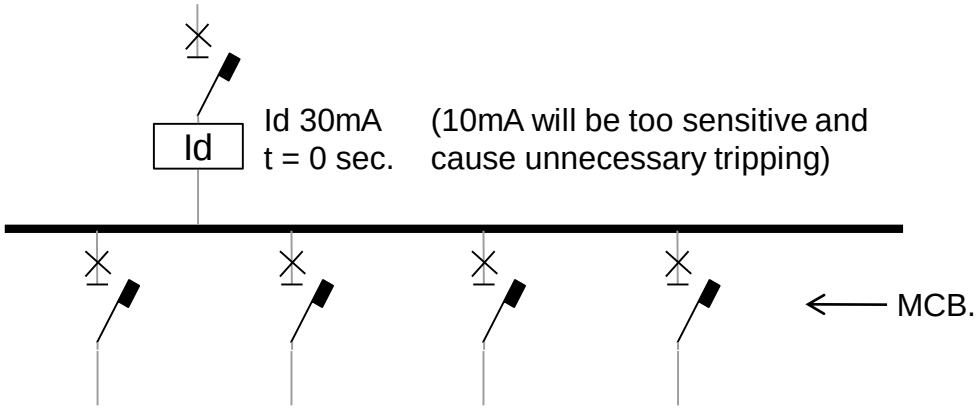
Selectivity 30mA

30mA:

Human life protection

- Household, office

Consumer unit



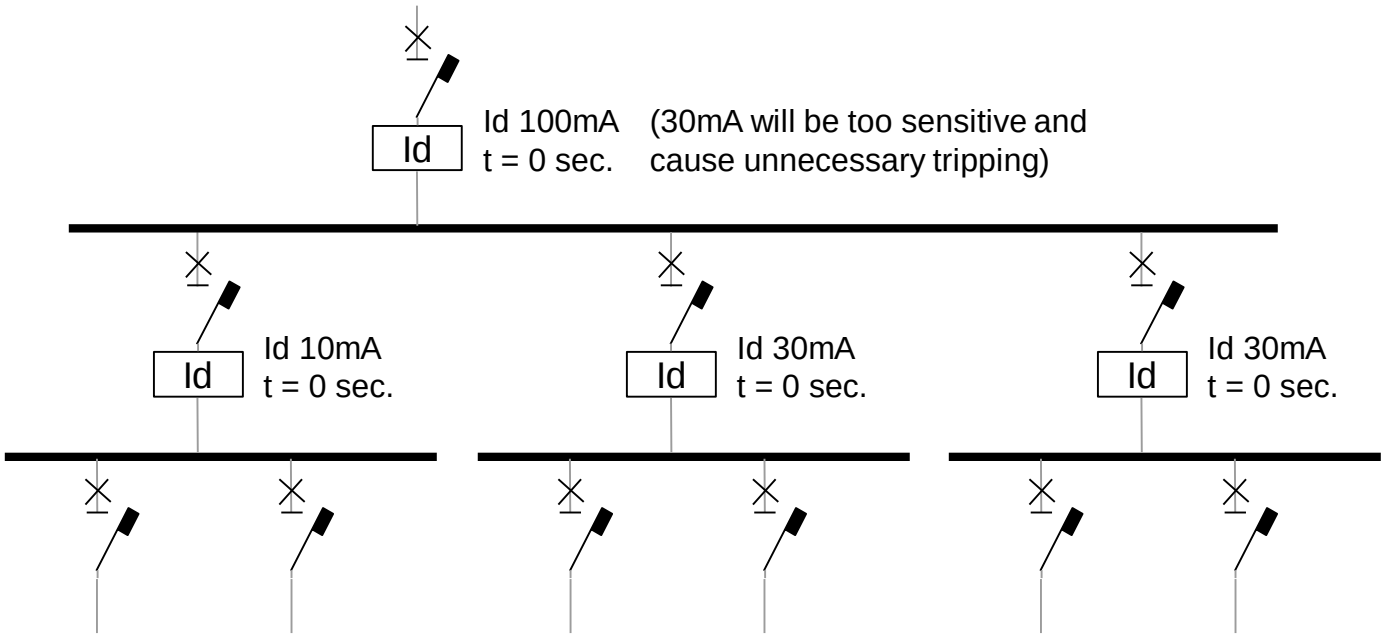
Earthing System

Selectivity 100mA

100mA:

Human life protection and proper discrimination

- Sub-board circuit

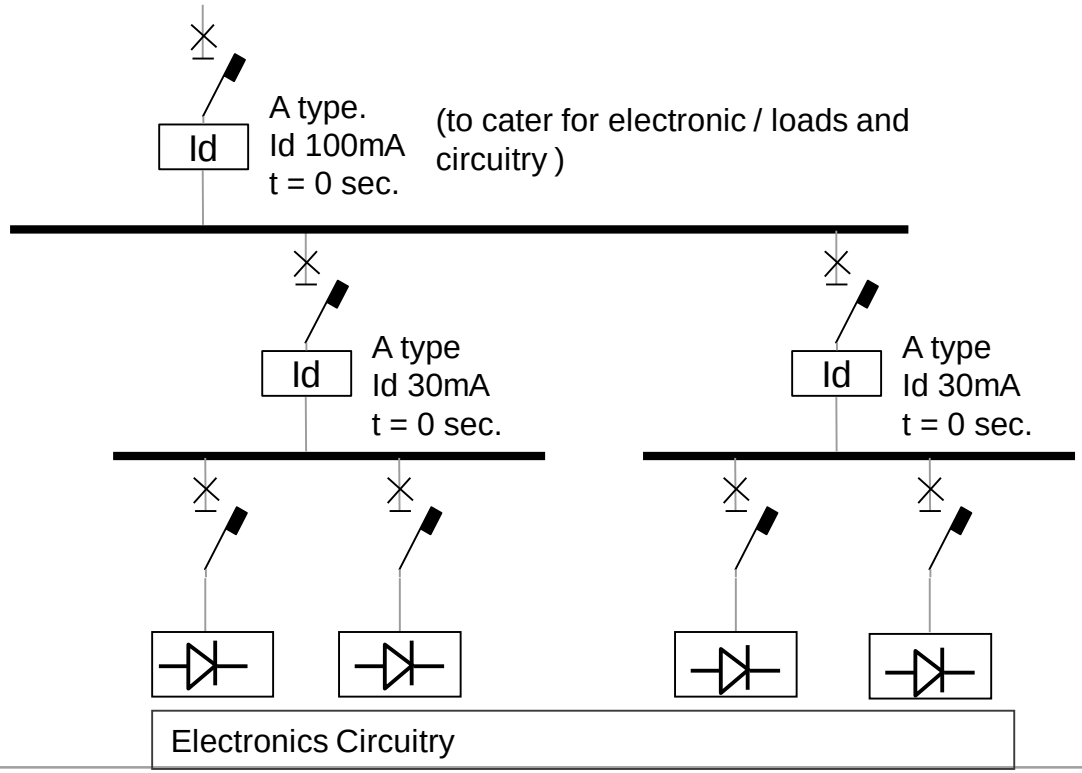


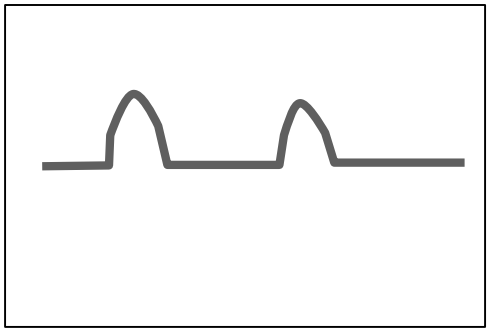
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Earthing System

Pulsation DC Leakage

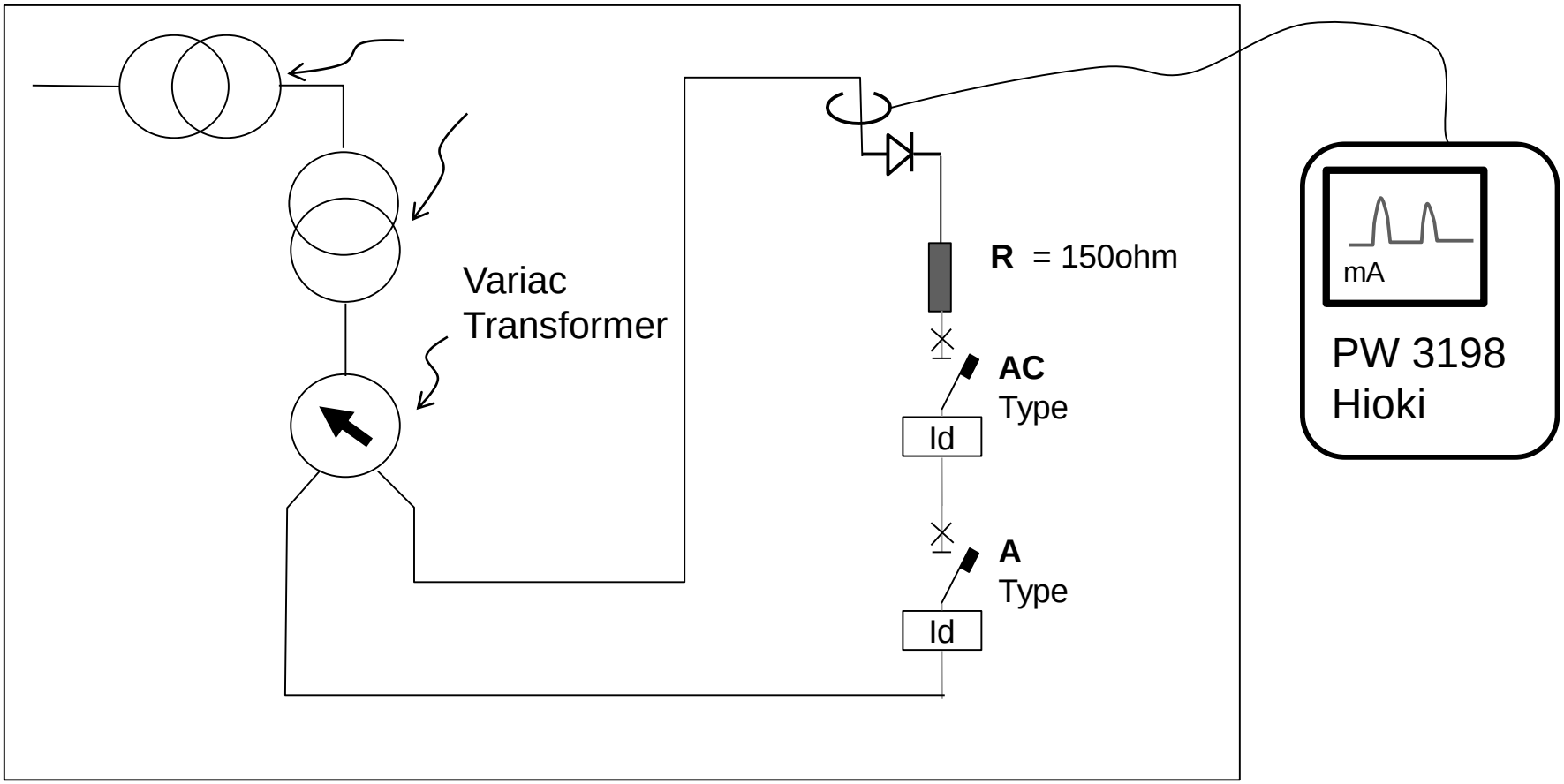
Electronics circuit with Rectifiers or PV panel, generating DC source volatge, standard AC types of RCCB or RCBO may not be sensitive enought to trip at the designed value, A and B types are available.





Earthing System

Pulsation DC Leakage – Demo



Indirect Contact and Property Protection

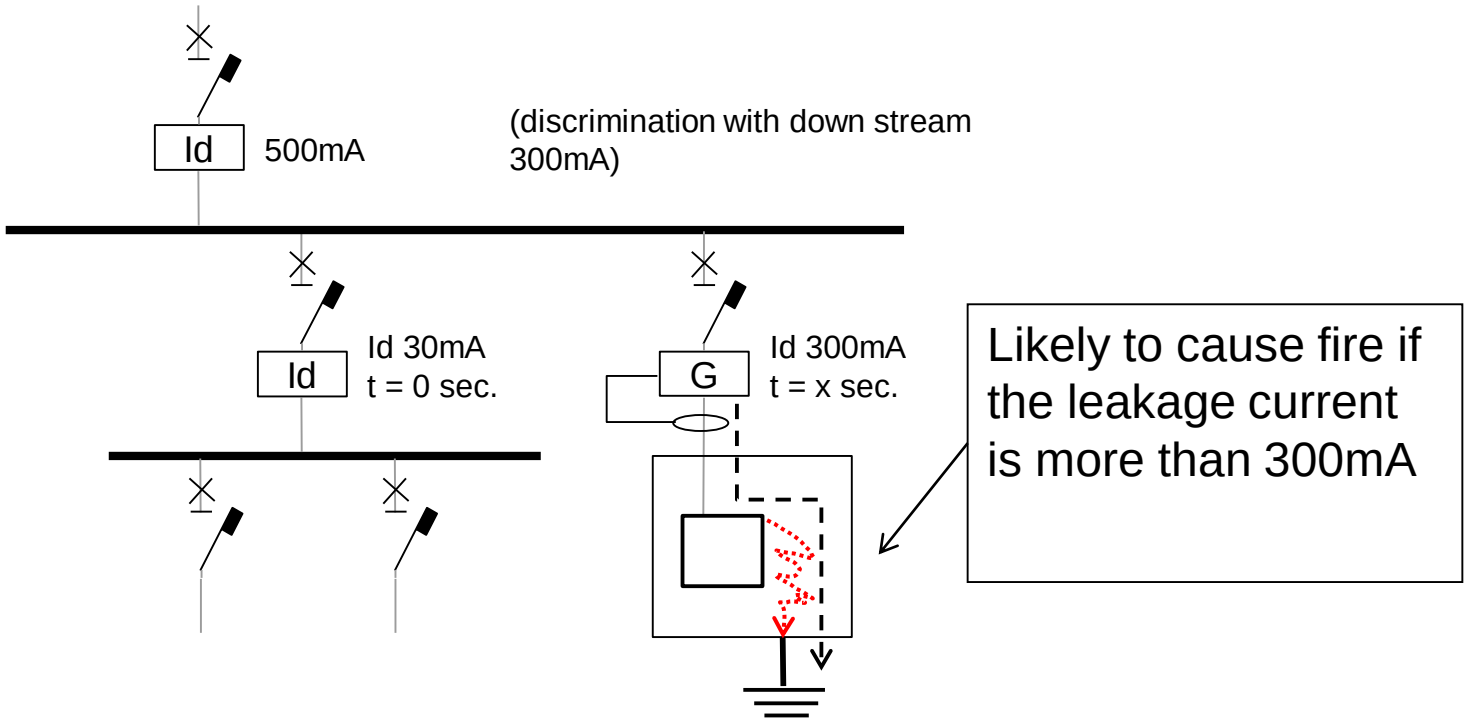
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Earthing System

Selectivity 300mA

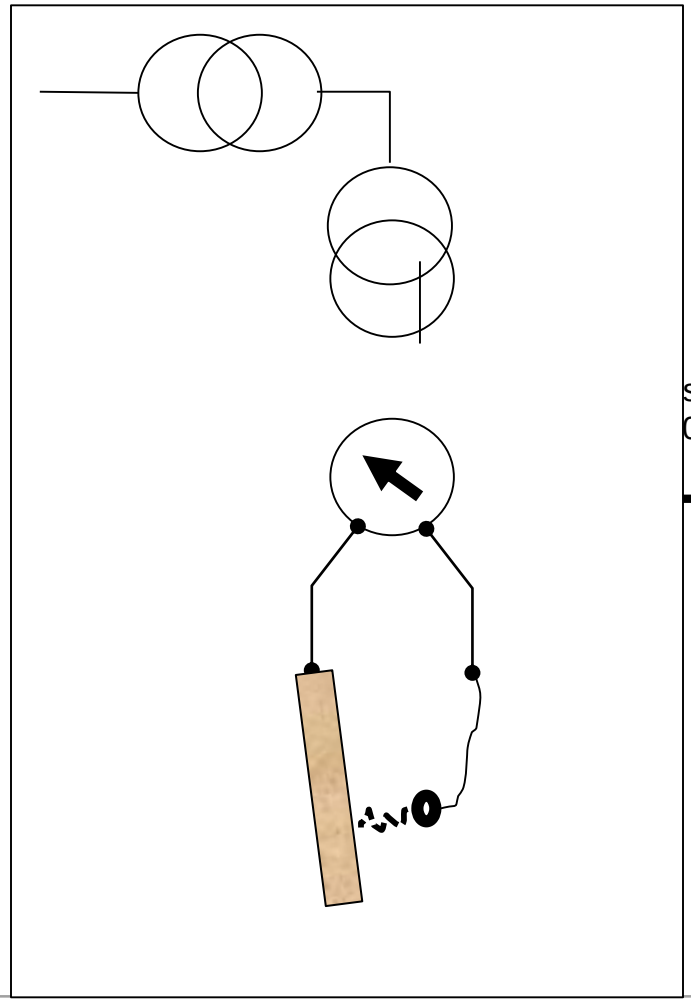
300mA:

Property protection (against fire)

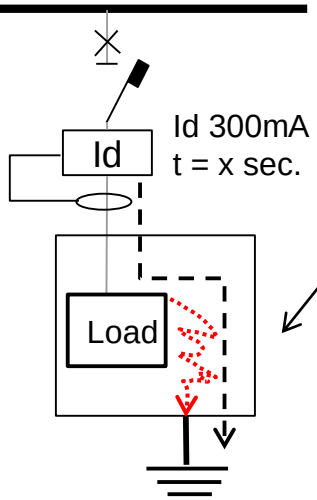


Earthing System

Leakage more than 300mA – Demo



scrimination with down stream
0mA)

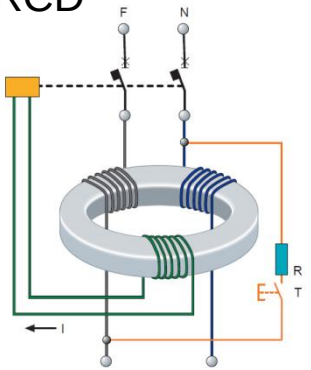


Likely to cause fire if the leakage current is more than 300mA

Earthing System

Earth Leakage or Earth Fault

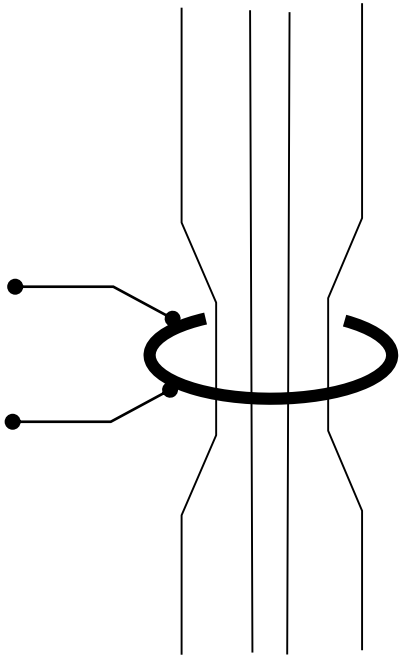
Toroid built-in the RCD



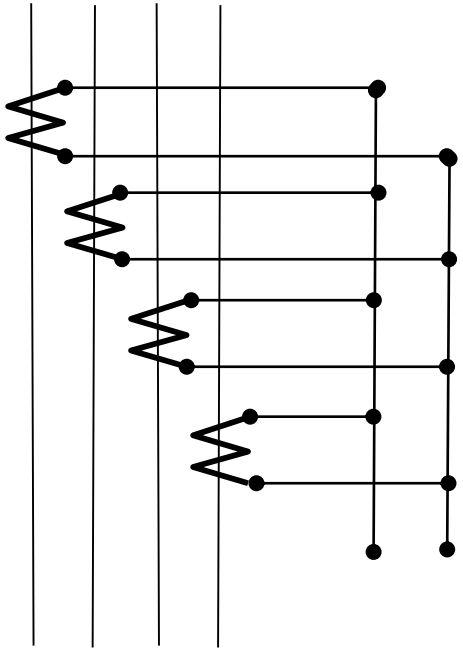
Toroid for external Relay



Earth **Leakage**
- Low current
- Measuring using **Toroid**



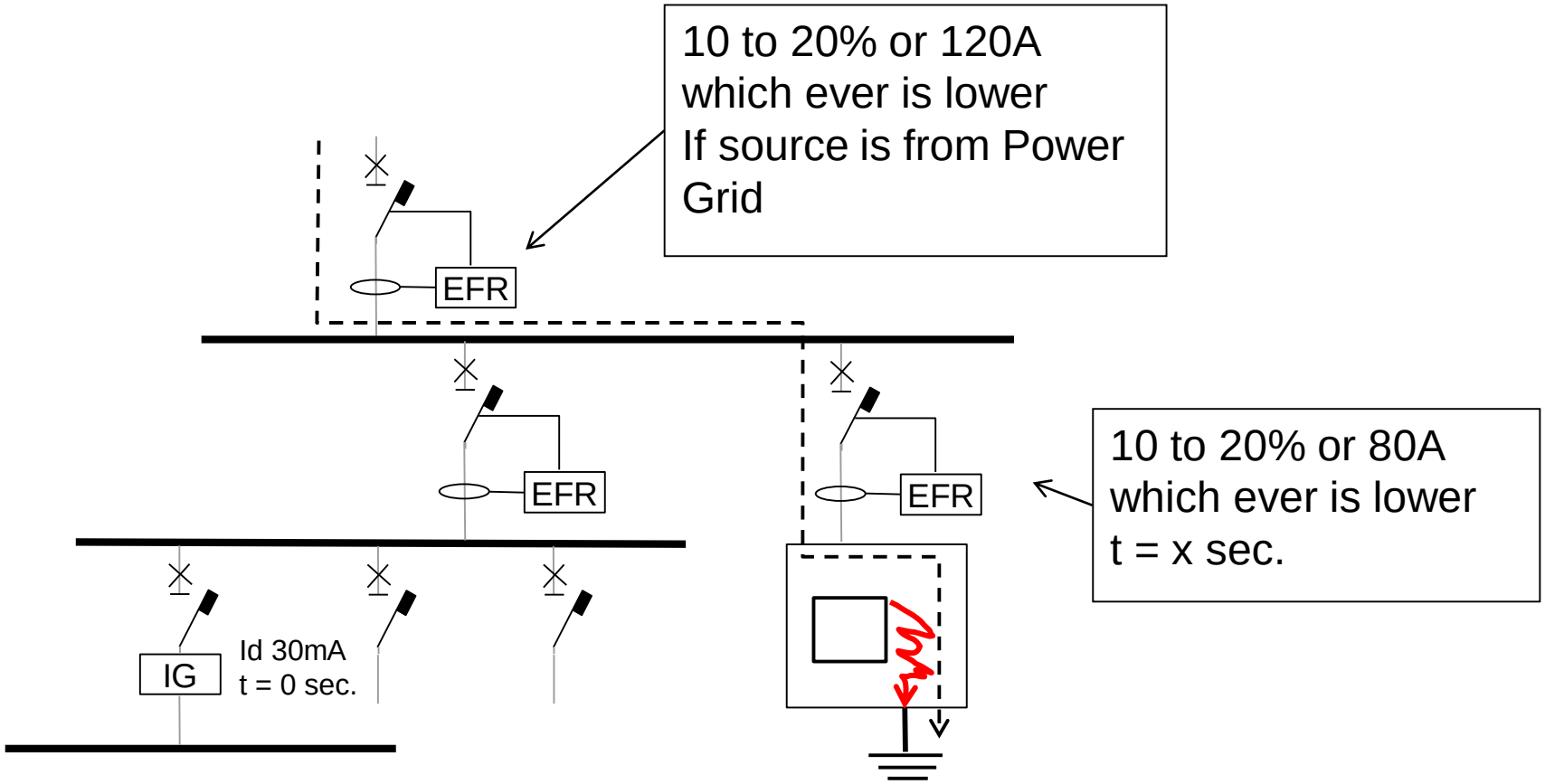
Earth **Fault**
- High current
- Measuring using **CT**



Earthing System

Earth Fault

10 to 20% of In or 120A which ever is lower



Proposed solution

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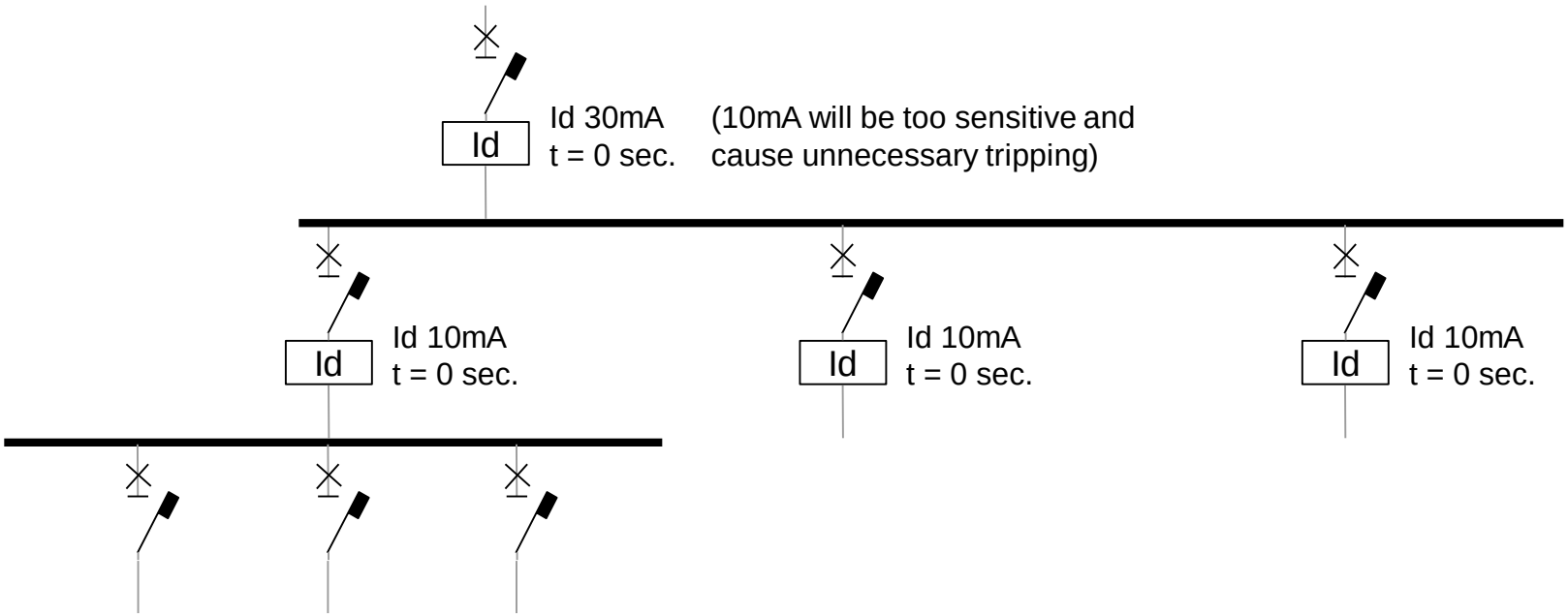
Earthing System – People Protection

Ensure Good Selectivity for 30mA and 10mA

30mA for 3 units of 10mA

Human life protection and propoer discrimination

- Consumer units e.g.



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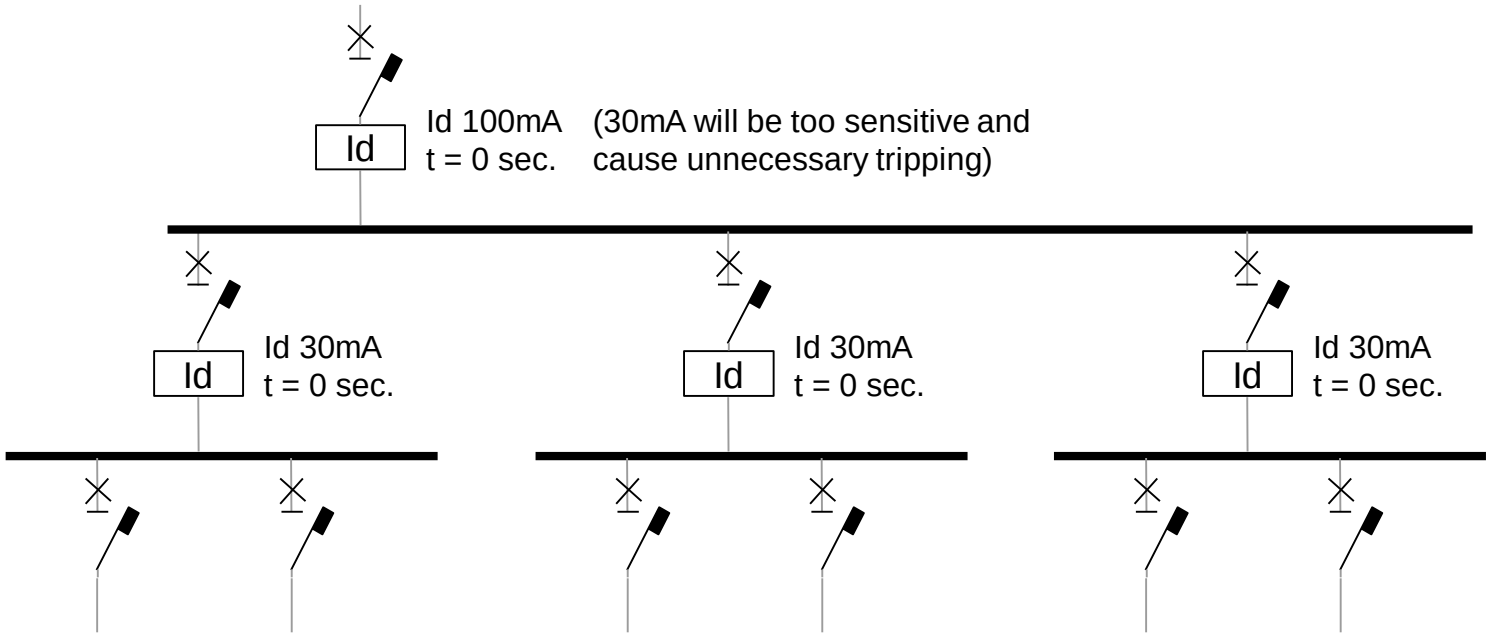
Earthing System – People protection

Ensure Good Selectivity for 100mA

100mA for 3 units of 30mA

Human life protection and propoer discrimination

- Sub-board circuit



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Earthing System – Fire Protection

Main and Feeder Circuit

10 to 20% or 120A which ever is lower with delay time at the main incoming



Earthing System – Motor Protection

Main and Feeder Circuit

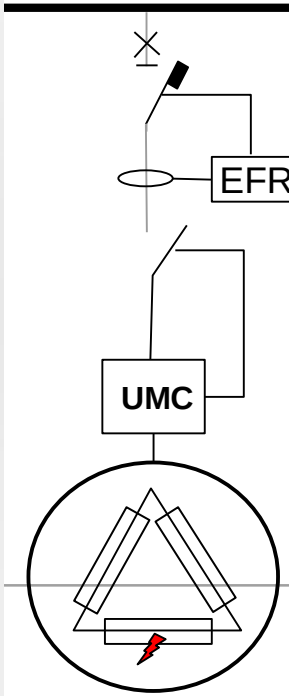
Advisible for the motor motor circuit to add ELR or EFR



LSIG

xternal Relay

5 to 10% of In
t = x sec.



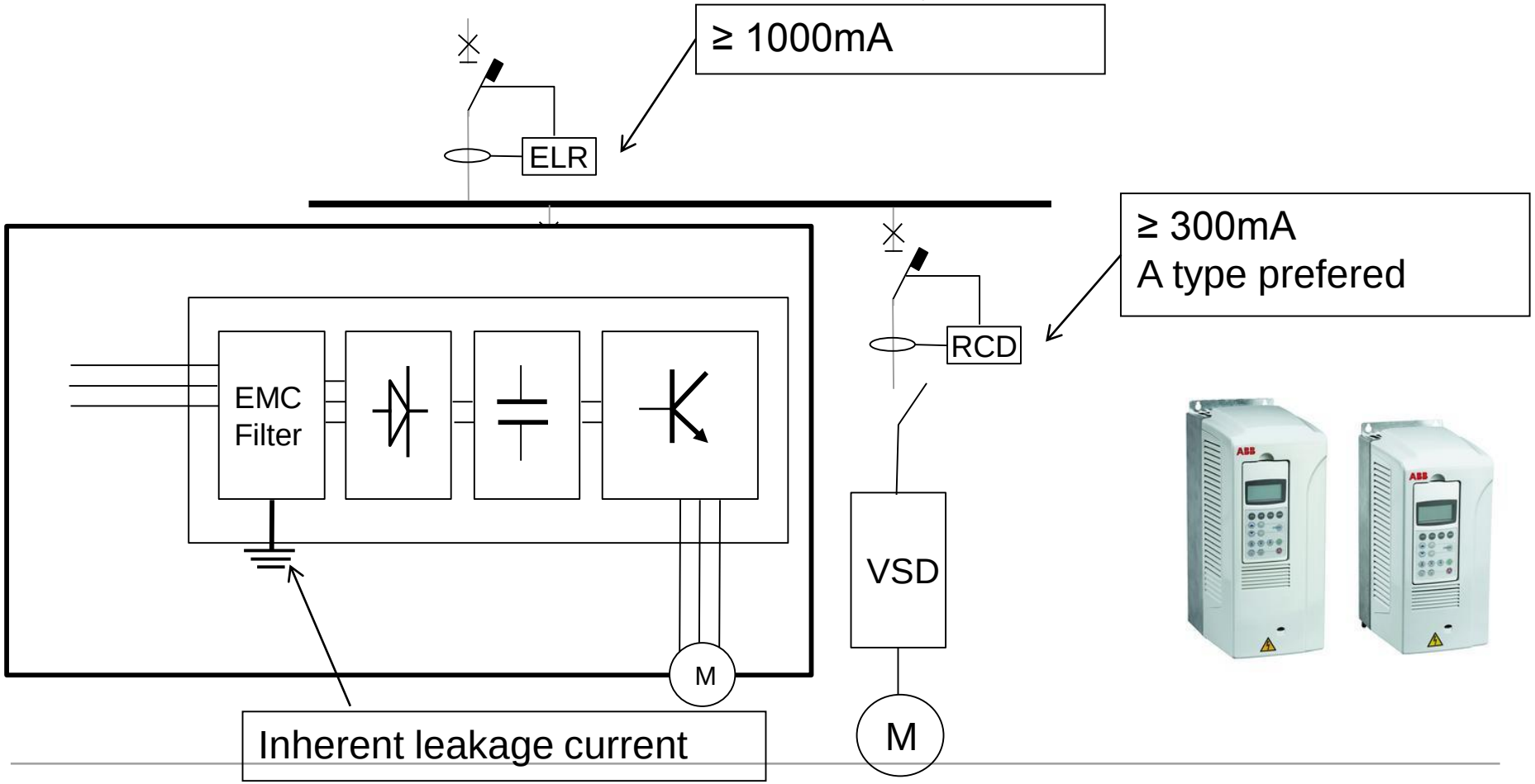


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Earthing System – VSD

Main and Feeder Circuit

Advisible for all VSD earth protection to be adjusted 300mA or more



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Earthing System – Total Solutions

RCD, RCCB, ELCB, RCBO, ELR, EFR



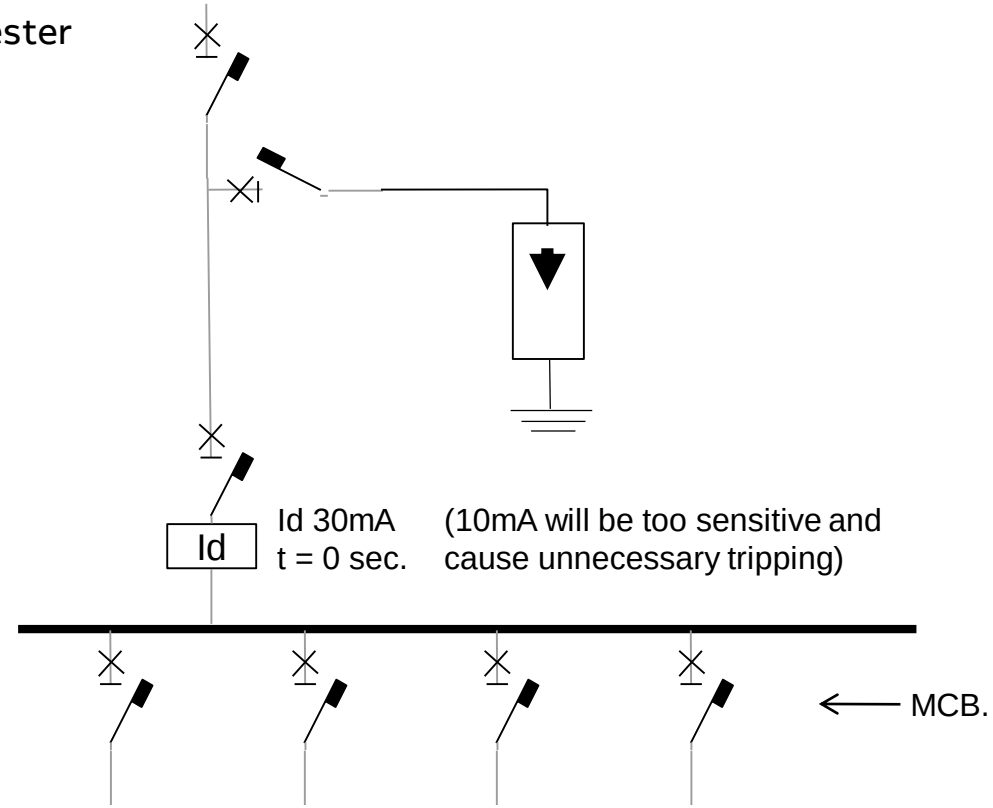


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Earthing System – Total Solutions

Avoid Nuisance Tripping

Install surge arrester



Earthing System – Total Solutions

Avoid Nuisance Tripping

Select correct type tested product with relevant standards especially the EMC compliances.

Consider using auto-reclosurer.





How 10mA RCCB improve safety & reliability of final distribution circuit ?

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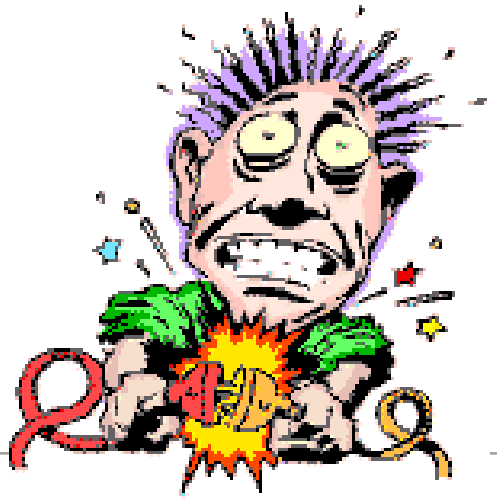
Introduction

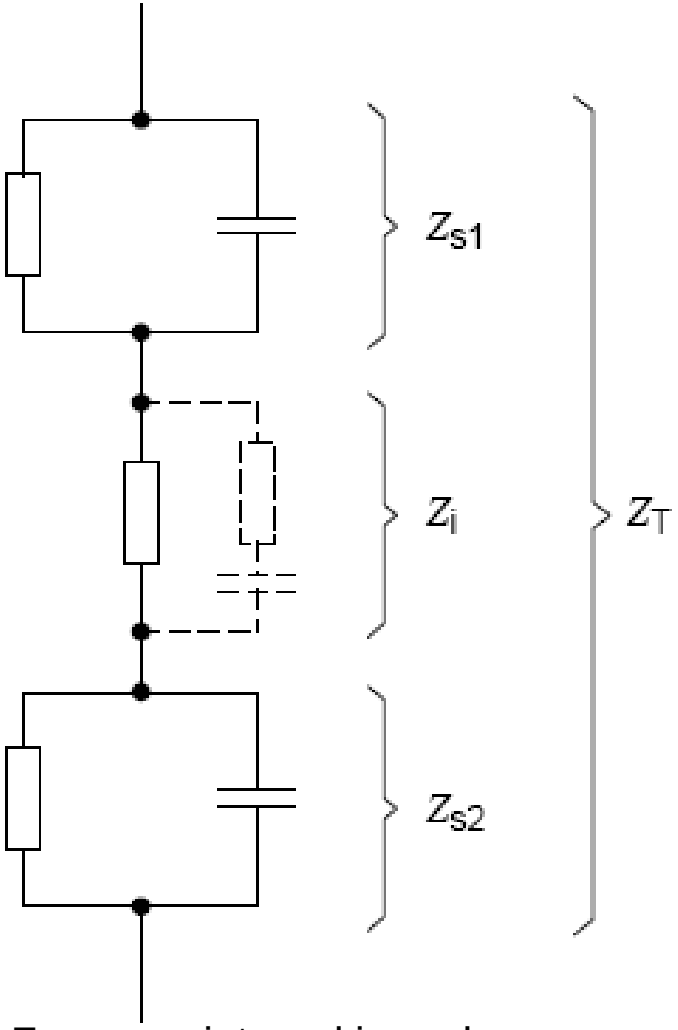
The hazards of electric shock

The danger depends mainly on the magnitude and duration of the current flow.

The human body can be considered an impedance.

This value of impedance depends on many factors.



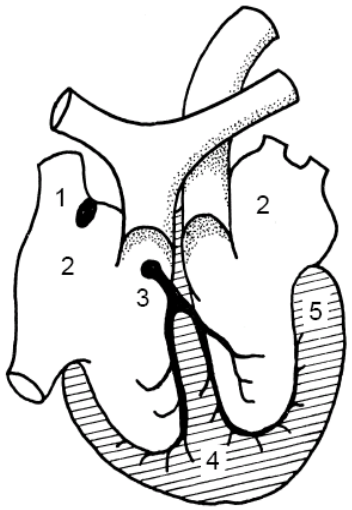


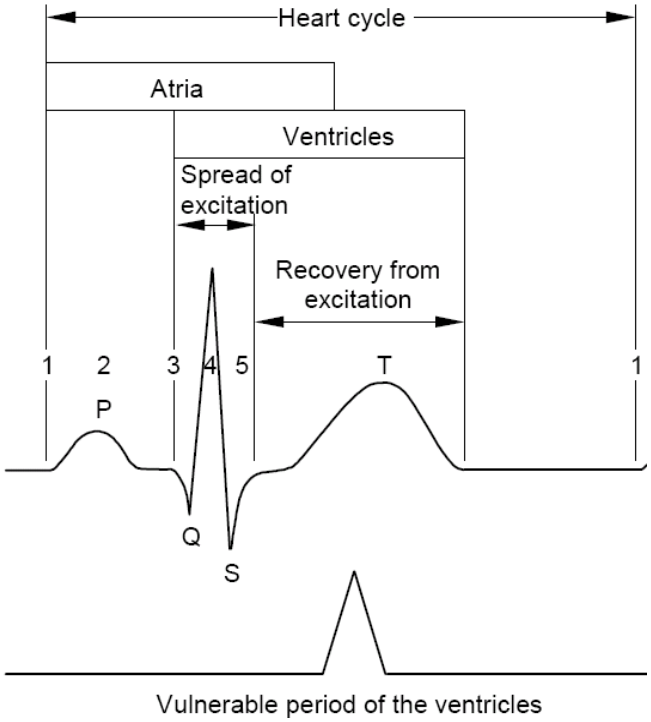
Z_i	internal impedance
Z_{s1}, Z_{s2}	impedances of the skin
Z_T	total impedance

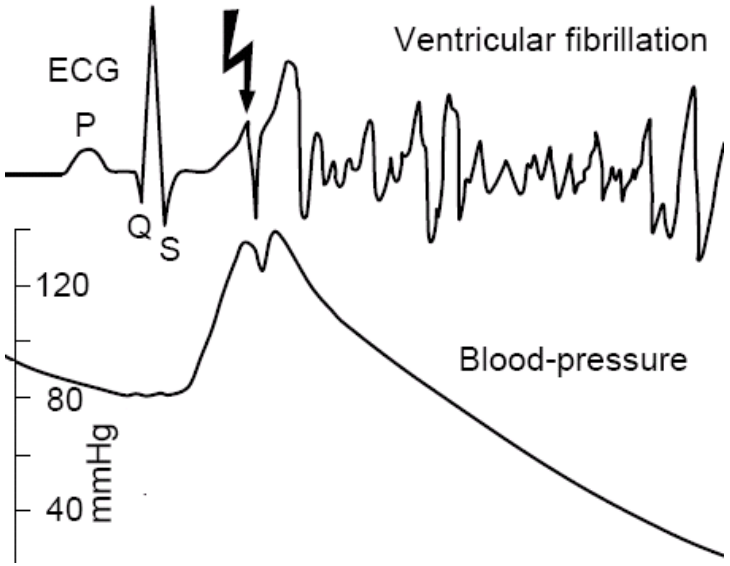
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Effects of current on the human body

General effects of current







Standards overview

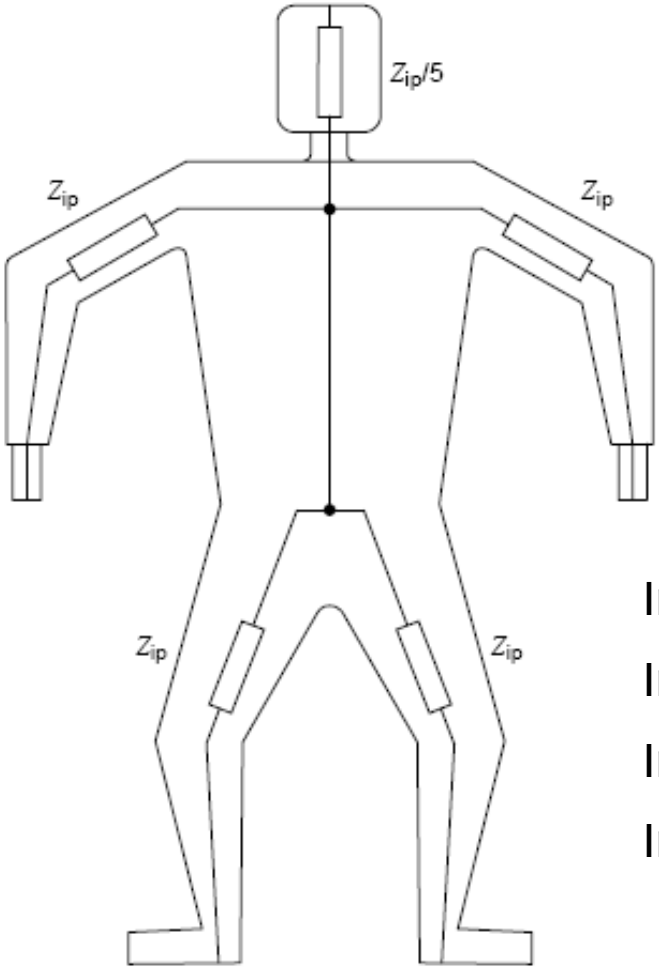
Reference standards panorama

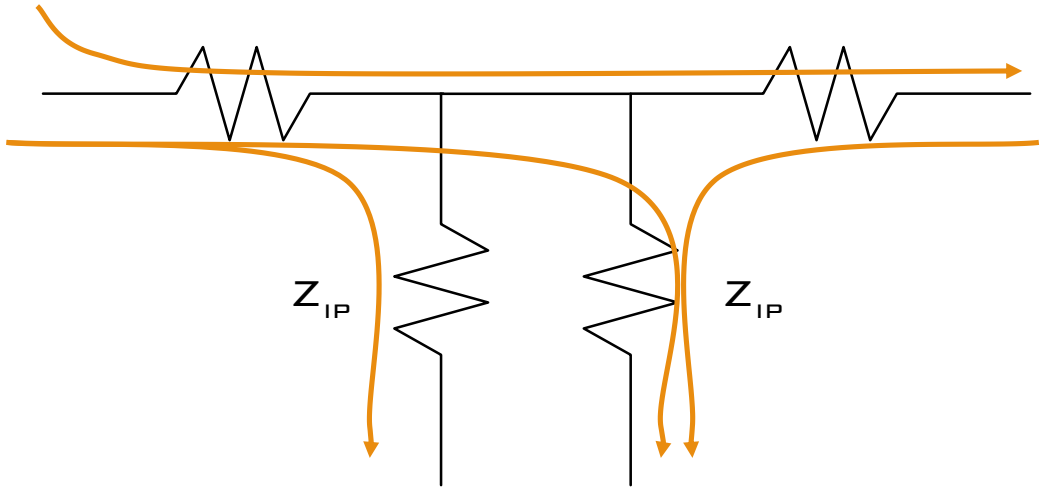
IEC/TS 60479
- Effects of current
on human beings and livestock
Part 1: general aspects
Part 2: special aspects
Part 3: effects of currents passing through the body of livestock
Part 4: effects of lightning strokes on human beings and livestock
Part 5: touch voltage threshold values for physiological effects



The impedance of the human body

The human body





Impedance hand to hand is 2 Z_{ip}

Impedance hand to foot is 2 Z_{ip}

Impedance from one hand to both feet is 3/2 Z_{ip}

Impedance from both hands to both feet is Z_{ip}

Z_{IP} = internal partial impedance of one extremity

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The impedance of the human body

Values of total body impedances (IEC

Touch voltage V	Values for the total body impedances Z_T (Ω) that are not exceeded for		
	5 % of the population	50 % of the population	95 % of the population
25	1 750	3 250	6 100
50	1 375	2 500	4 600
75	1 125	2 000	3 600
100	990	1 725	3 125
125	900	1 550	2 675
150	850	1 400	2 350
175	825	1 325	2 175
200	800	1 275	2 050
225	775	1 225	1 900
400	700	950	1 275
500	625	850	1 150
700	575	775	1 050
1 000	575	775	1 050
Asymptotic value	575	775	1 050

The impedance of the cow body

Values of total cow body impedances (IEC 60479-3)

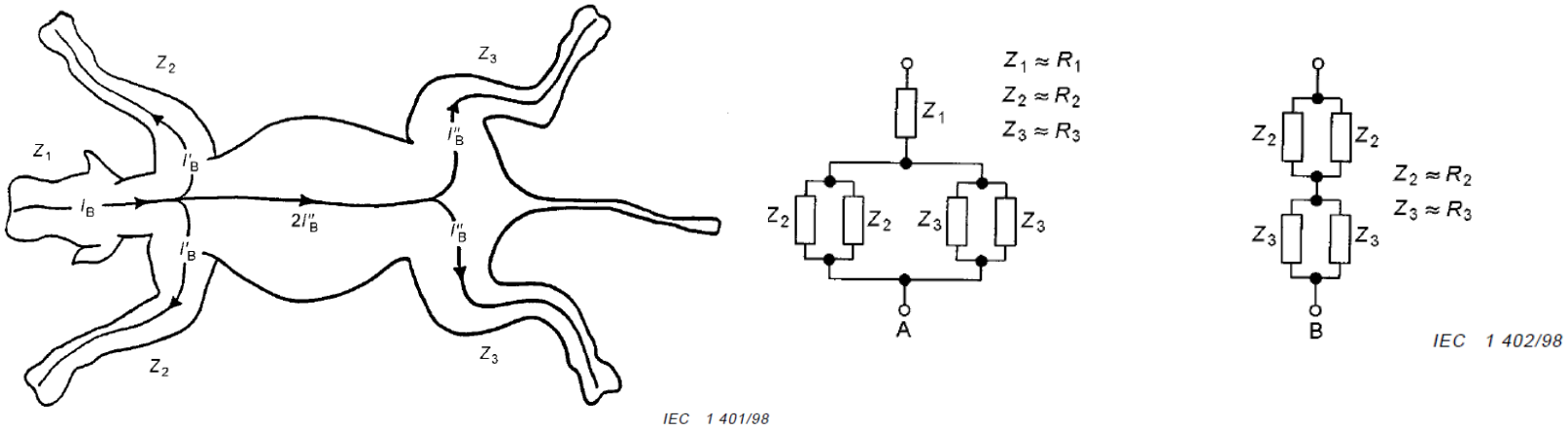


Figure 1 – Current flow and impedances of the relevant parts of the body of a cow for current path from the nose to the legs

Table 2 – Total body impedances Z_T for a.c. 50/60 Hz for cattle for touch voltages up to 230 V

Current path	Values for total body impedance (Ω) that are not exceeded for a percentage of the population		
	5 %	50 %	95 %
Nose to four legs	220	300	425
Forelegs to hindlegs	600	850	1 250
NOTE – The values are rounded off from statistical analysis of 80 cattle measured.			

©AE

Effects of AC current in the range of 15Hz to 100Hz

Threshold of let-go

Why we need 10mA RCCB to improve safety?

It is Because IEC 60479 - 1, clause:

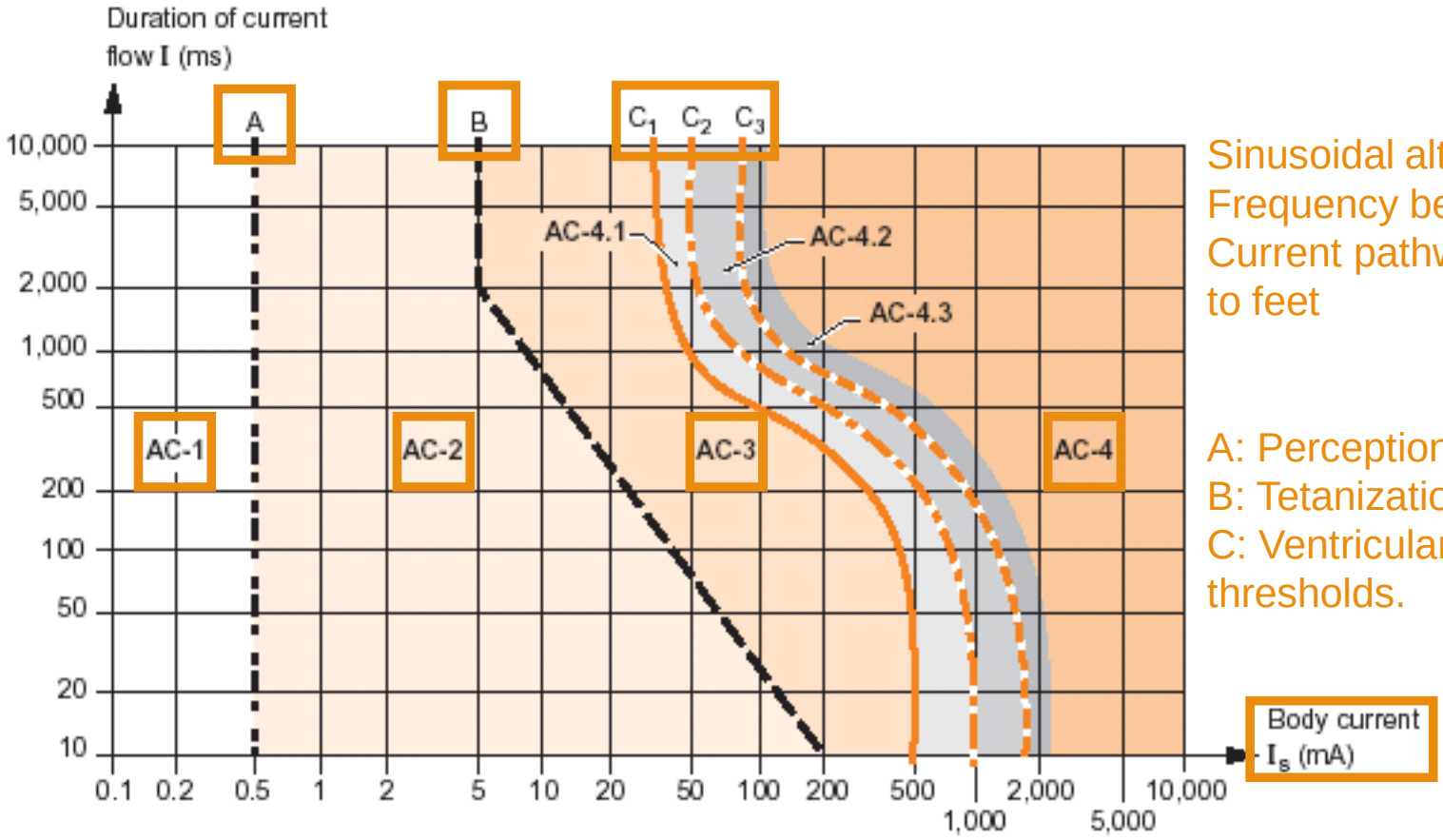
5.4 Threshold of let-go

The threshold of let-go depends on several parameters, such as the contact area, the shape and size of the electrodes and also on the physiological characteristics of the individual.

A value of about 10 mA is assumed for adult males in this technical specification.

In this document a value of about 5 mA covers the entire population (for additional information, see Figure 23).

Time - current diagram



Sinusoidal alternating current
Frequency between 15 - 100Hz
Current pathway from one hand to feet

A: Perception threshold
B: Tetanization threshold
C: Ventricular fibrillation thresholds.

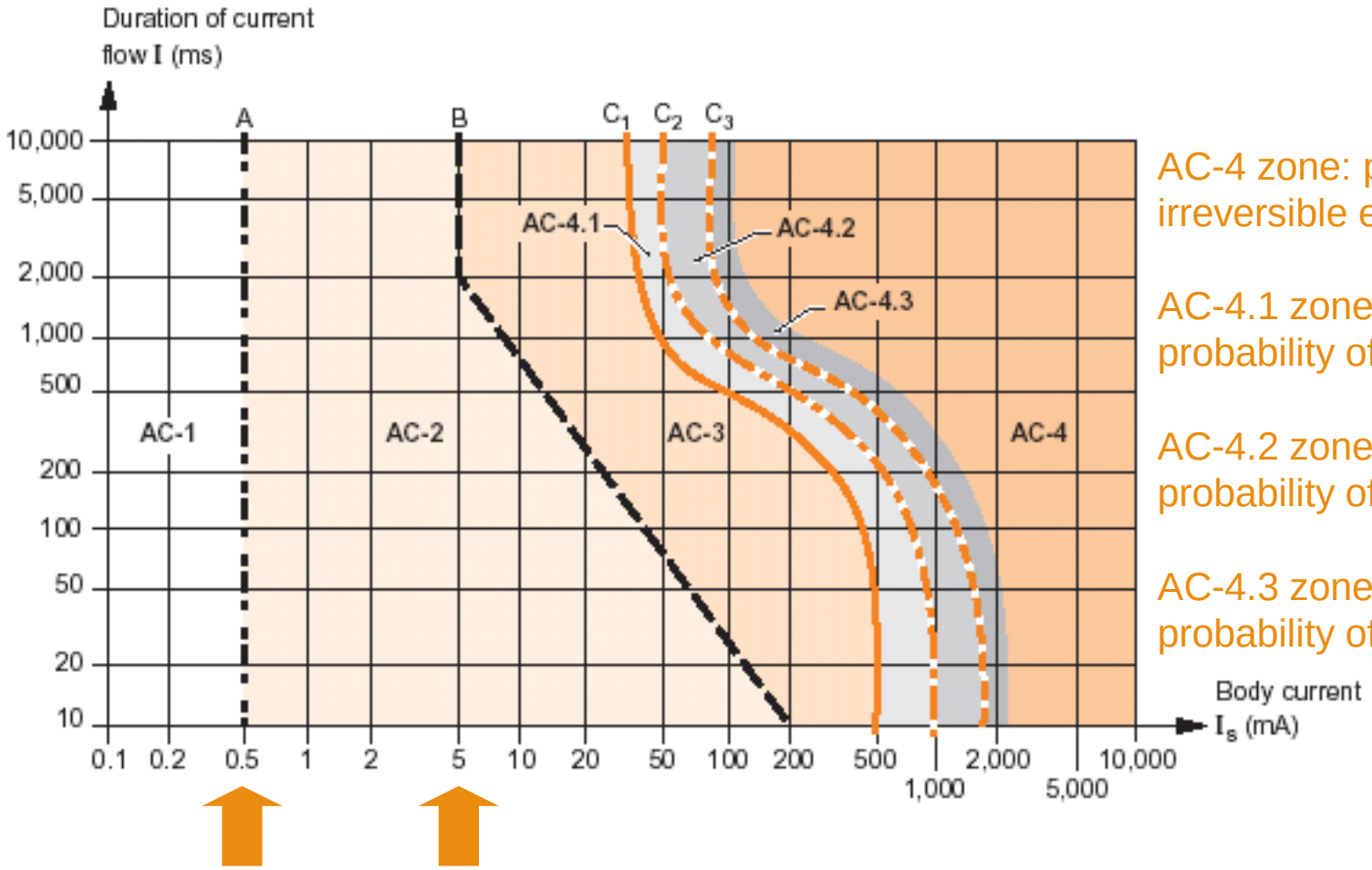
Time - current zones

Table 11 – Time/current zones for a.c. 15 Hz to 100 Hz for hand to feet pathway – Summary of zones of Figure 20

Zones	Boundaries	Physiological effects
AC-1	Up to 0,5 mA curve a	Perception possible but usually no 'startled' reaction
AC-2	0,5 mA up to curve b	Perception and involuntary muscular contractions likely but usually no harmful electrical physiological effects
AC-3	Curve b and above	Strong involuntary muscular contractions. Difficulty in breathing. Reversible disturbances of heart function. Immobilization may occur. Effects increasing with current magnitude. Usually no organic damage to be expected
AC-4 [1)]	Above curve c_1	Patho-physiological effects may occur such as cardiac arrest, breathing arrest, and burns or other cellular damage. Probability of ventricular fibrillation increasing with current magnitude and time
	c_1-c_2	AC-4.1 Probability of ventricular fibrillation increasing up to about 5 %
	c_2-c_3	AC-4.2 Probability of ventricular fibrillation up to about 50 %
	Beyond curve c_3	AC-4.3 Probability of ventricular fibrillation above 50 %

[1)] For durations of current flow below 200 ms, ventricular fibrillation is only initiated within the vulnerable period if the relevant thresholds are surpassed. As regards ventricular fibrillation, this figure relates to the effects of current which flows in the path left hand to feet. For other current paths, the heart current factor has to be considered.

Time - current diagram



AC-4 zone: possibility of irreversible effects

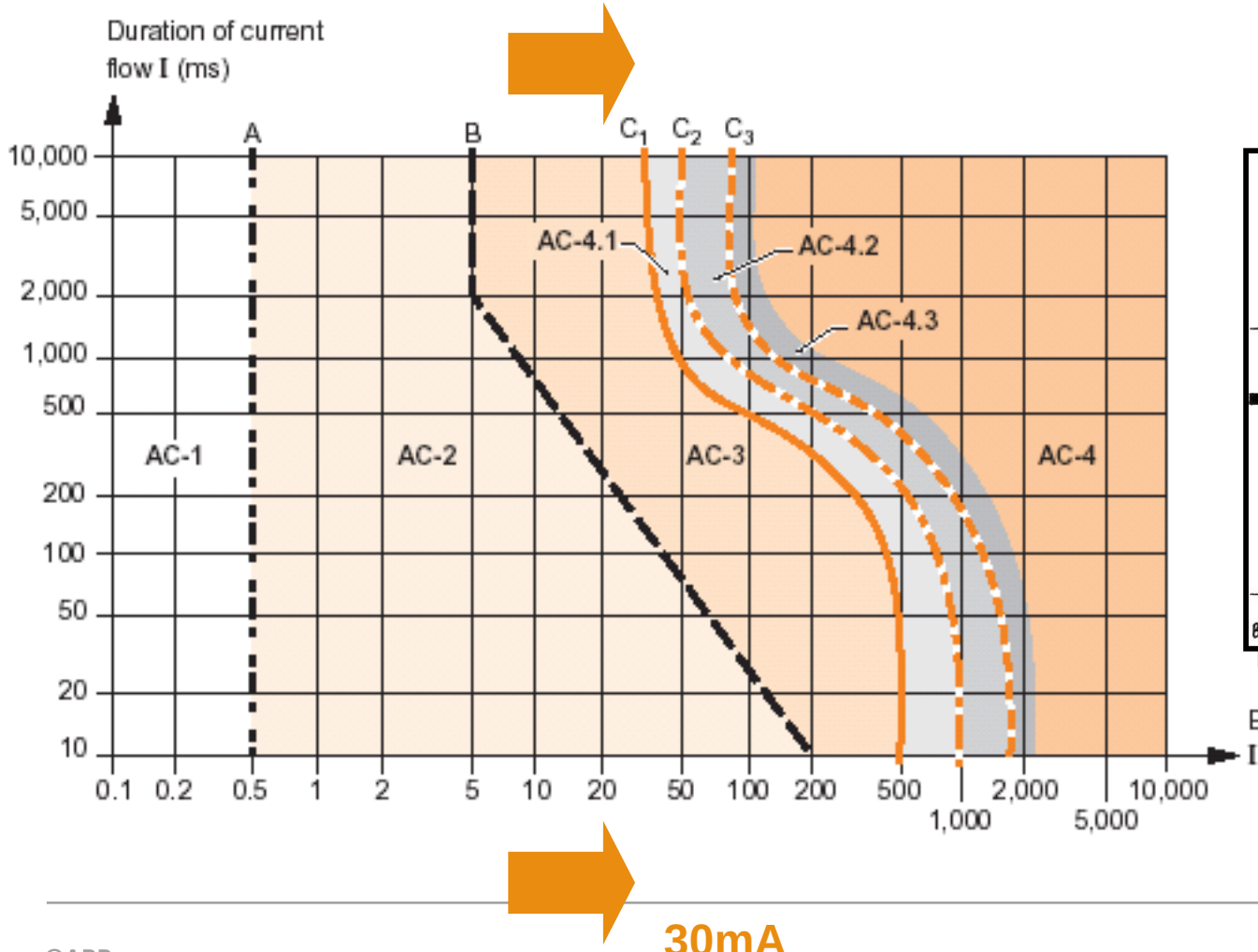
AC-4.1 zone: up to 5% probability of heart fibrillation

AC-4.2 zone: up to 50% probability of heart fibrillation

AC-4.3 zone: above 50% probability of heart fibrillation

Time - current diagram

30mA threshold

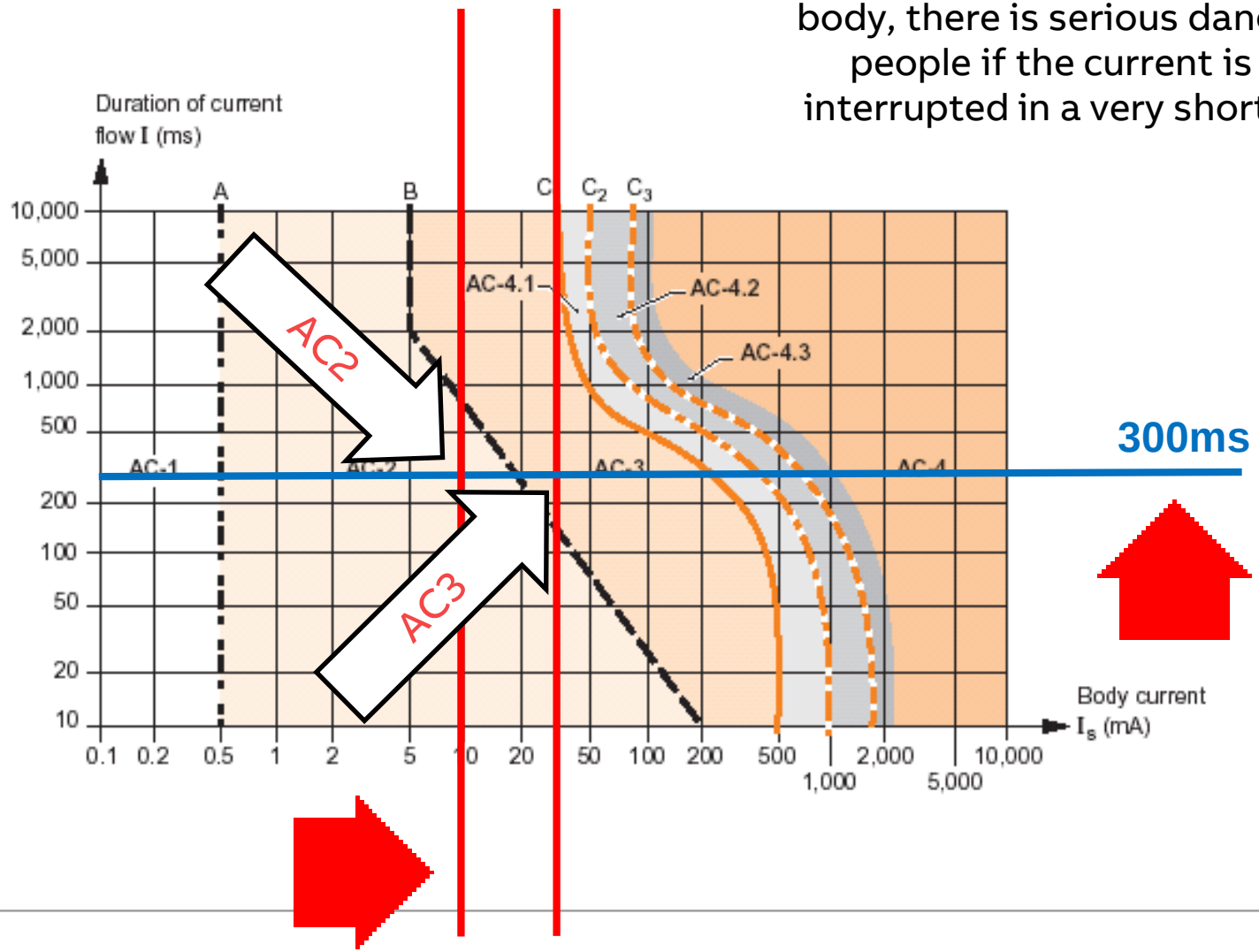




30mA

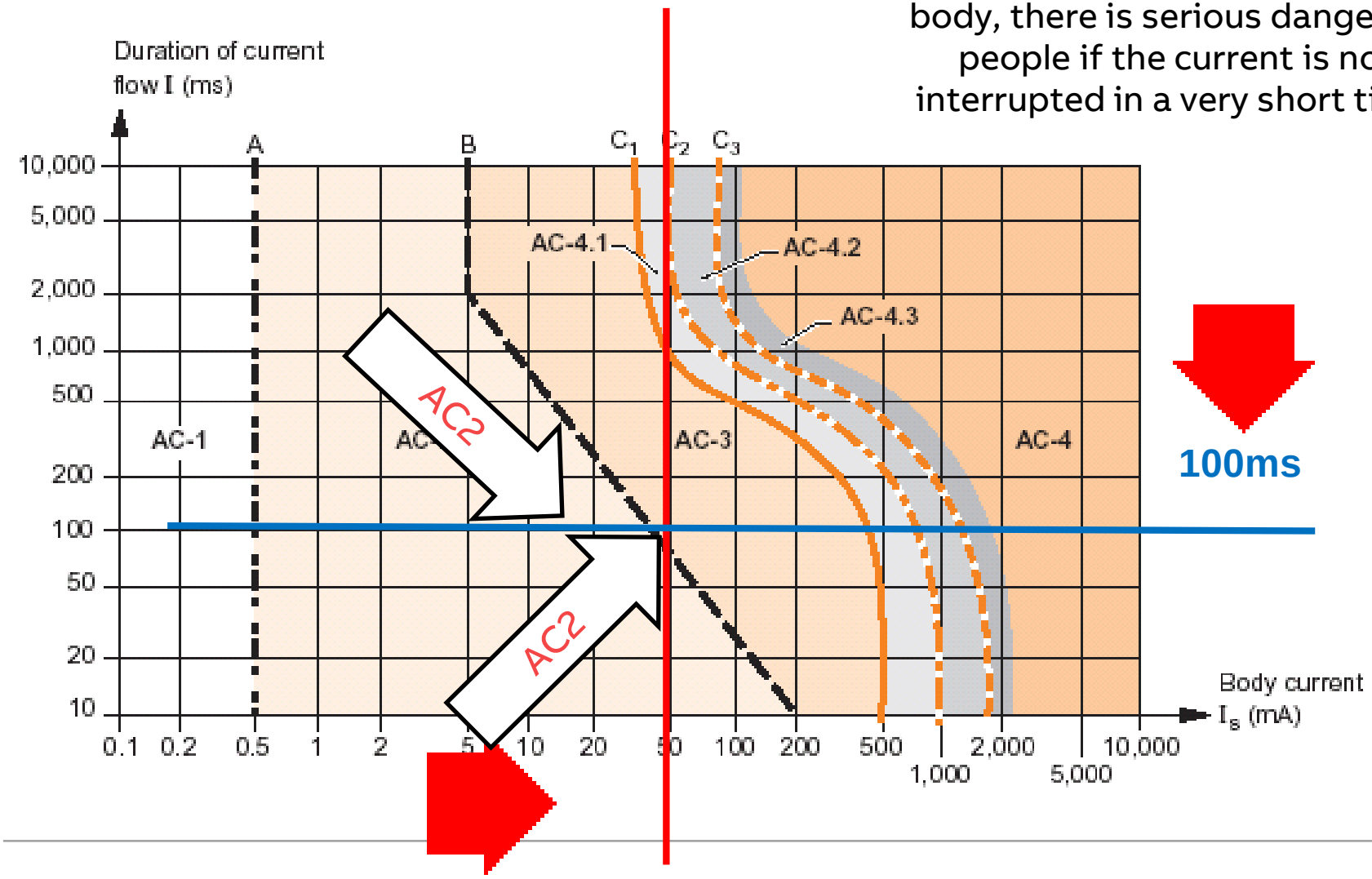
IEC 61008 requirement

When a current higher than 30 mA passes through a part of a human body, there is serious danger for people if the current is not interrupted in a very short time.



SS97 requirement

When a current higher than 30 mA passes through a part of a human body, there is serious danger for people if the current is not interrupted in a very short time.



RCD selectivity with 10mA RCD

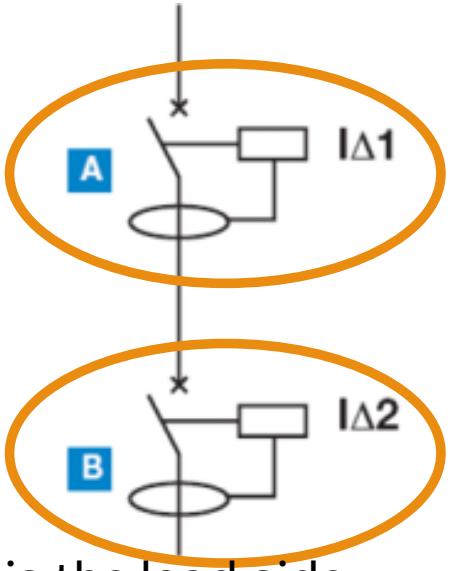
What is selectivity?

Selectivity (

is a type of coordination of two, or more, protective devices in series.

Selectivity is done between one residual current device on the supply side and one residual current device, or more than one, on the load side.

A is the supply side (or upstream) RCD

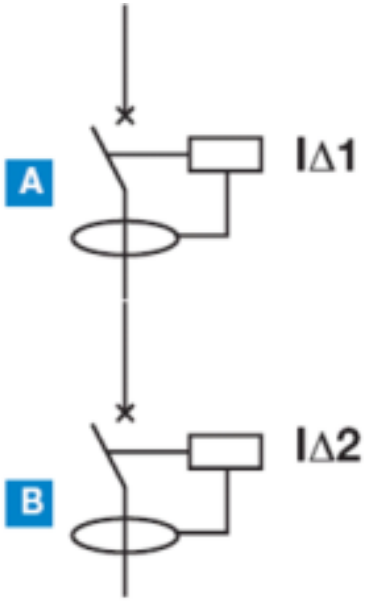


B is the load side (or downstream) RCD

RCD selectivity

Residual Current Device selectivity

The normal purpose of selectivity is to ensure that an earth fault current causes only the RCD protecting the downstream circuit to trip and does not cause the tripping of the upstream one.



Two types of RCD selectivity exist:

- amperometric selectivity
- chronometric selectivity

RCD amperometric selectivity

Amperometric selectivity

Amperometric selectivity

is strictly based on the residual current values;

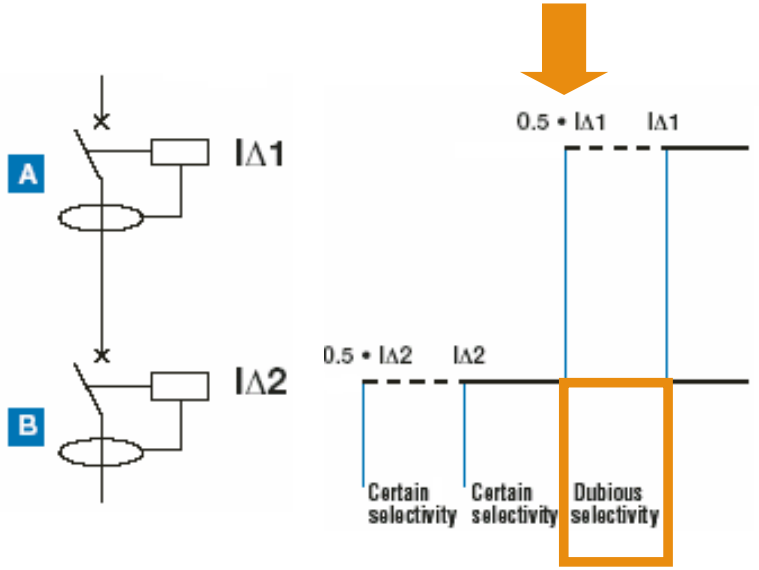
may be created by placing low-sensitivity RCDs upstream and higher-sensitivity RCDs downstream.

The operative rule to obtain an amperometric selectivity is

$I_{\Delta 1} = 3 \times I_{\Delta 2}$

F 202, 30mA upstream;

F 202, 10mA downstream.



Amperometric selectivity is a partial selectivity!!

10mA Switched Socket Outlet

Household Appliances with Higher Risk



Delicate Loads

Fish tanks 	Washing machines 	Instant water heater 
Computers 	Hand tools 	Refrigerators 
Appliances that presence with water or closed contact with people		

10mA Switched Socket Outlet

Other Conditions



Vulnerable conditions

Infant and baby  Lower resistance and lower immunity	Pets  Lower resistance and highly destructive	Outdoor  Highly subject to water ingression
Old folk  Lower mobility and lower immunity	Work at height  Not injured by electrocuted but by fallen	Swimming Pool  Subject to water ingress and risk of swimmers

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10mA Switched Socket Outlet

Infrastructure and Industry



Work Site power supply  PDL elimit 10ma rcd adaptor **Mandatorily** for all tools and equipment	Lab equipment  Close contact with technicians	Power on vehicle  Tire is well insulated, vehicle is not grounded
AC vehicle chargers  Lower mobility and lower immunity	Site equipment  Not injured by electrocuted but by fallen	Hospital  Delicate environment
There are many many more applications		

Earthing System

Sensitivity 10mA

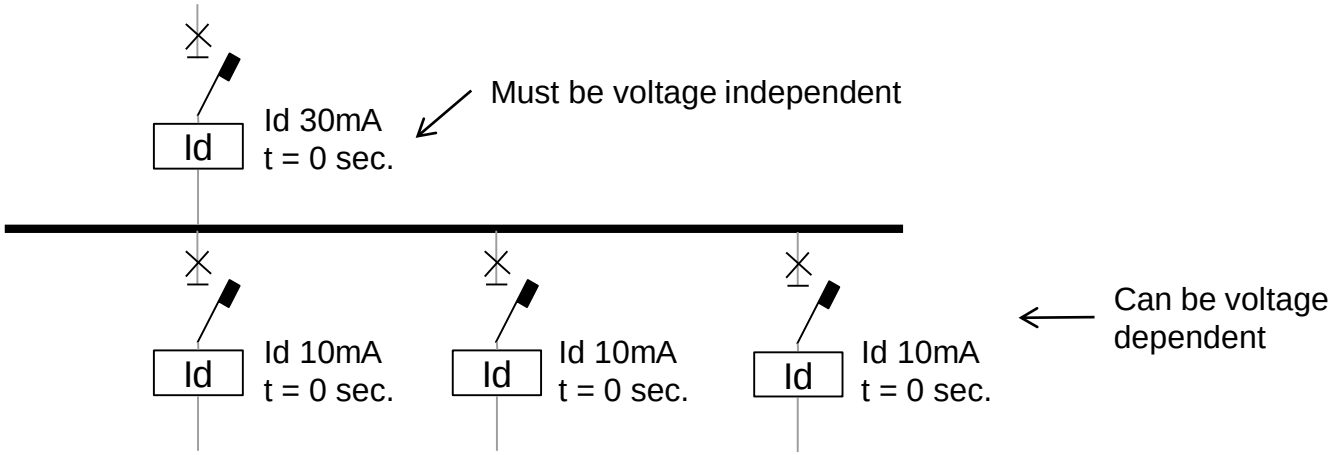


10mA:

Sensitive human life protection

- Household
- Hospital
- Kindergarten, etc

Final distribution circuit for better discrimination



10mA Switched Socket Outlet Offers

Substitute Standard Switched Socket outlet

Single and double 10mA RCD SSO



