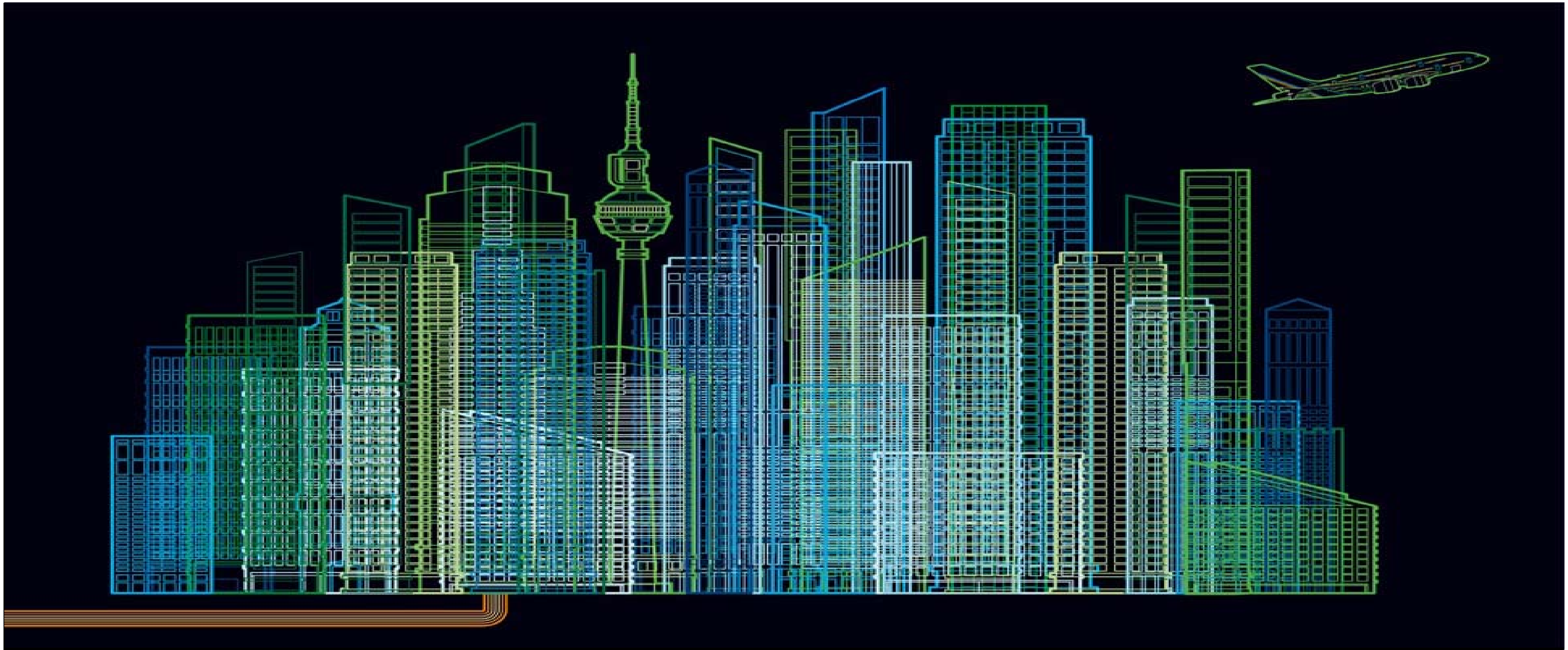


Ong Peck Seng, LP Marketing, Electric Power System Seminar, 5thJuly2011

Power System Earth Protection Protects Your Life, Protects Your Property

Electric Power System Seminar
Note of this Power Point

We would like to say a big thank you for your time attending our seminar on 5thJuly2011 at ABB premises.

This Power Point is meant for your reference only.

Please contact us if you need to verify the data or application used.

The contents of this PPT is mainly extracting from our 3rd Technical Application Paper, please refer to the booklet for more detail.

Distribution system and protection against indirect contact and earth fault.

This PPT contain 88 pages, due to time constrain, we are only able to present only 60 slides, the rest of the slides are for your info, please feel free to contact for more questions.

Hope to see you in our future programs.

Thanks

Electric Power System Seminar
Program

Agenda

1.00 pm	**Registration**	
1.15 pm	**Welcome**	
1.30 pm	**Earth leakage and earth fault protection of electrical distribution system.**	*By Ong Peck Seng, AVP Marketing, Low Voltage Products Division*
3.00 p.m.	**Break and Q&A**	
3.30 p.m.	**SS and IEC Standard requirements for over-current and earth leakage protection devices.**	*By Koh Nguang Siah, Product Marketing Manager, Low Voltage Product Division*
4.30 p.m.	**The requirement for earth leakage relay (ELR) according to IEC 60947-2 Annex M**	*By Koh Nguang Siah, Product Marketing Manager, Low Voltage Product Division*

Topic 1

Earth leakage and earth fault protection of electrical distribution system.

Earth leakage and earth fault protection of electrical distribution system.
Contents

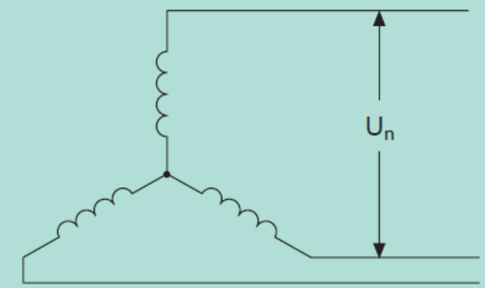
- Why Earthing System
- Indirect contact and **people** protection
- Indirect contact and **property** protection
- Earth fault protection

Earthing (Grounding) System

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?

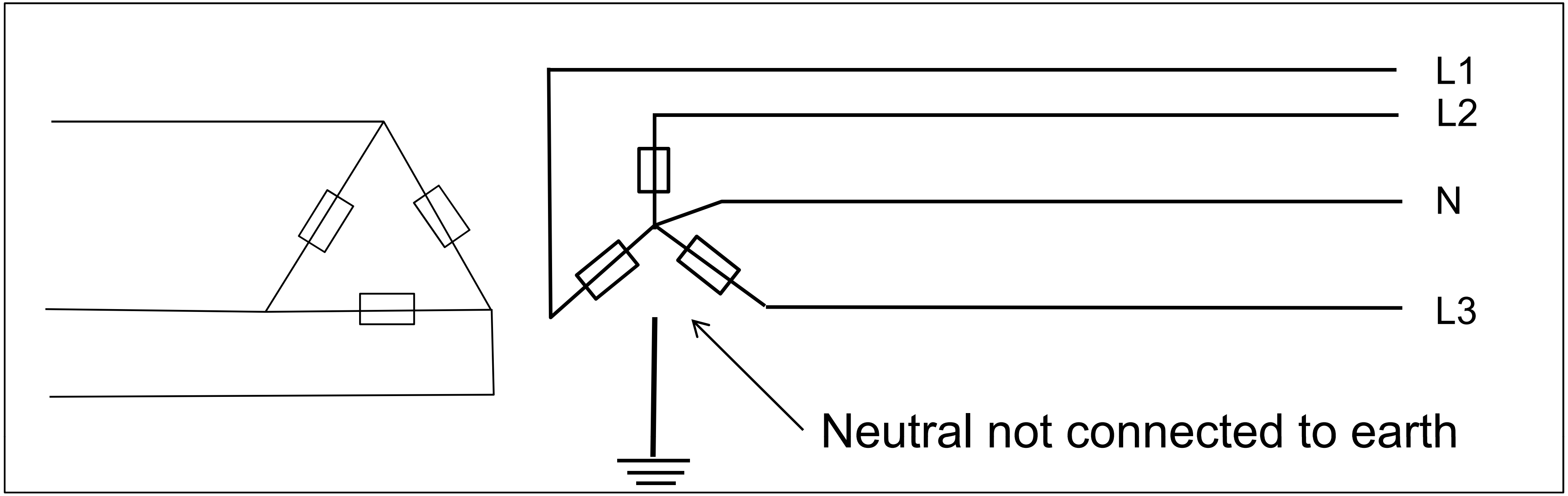
The answer is not so straight forward, please see few demo as follow:

1.) Isolated earthing

2.) Vertual earth due to stray capacitance

3.) One of the “Phase“ grounded

Earthing System Demo 1
Isolated Earthing



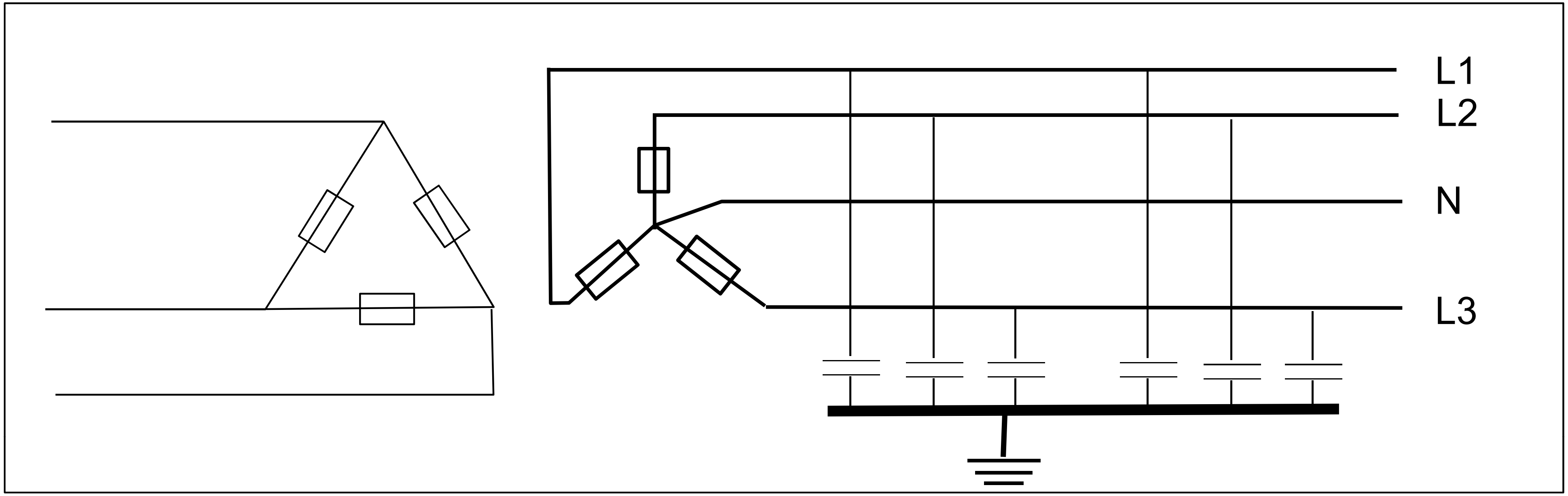
Isolated earthing

Neutral point of transformer 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 Demo 2
Virtual Earth

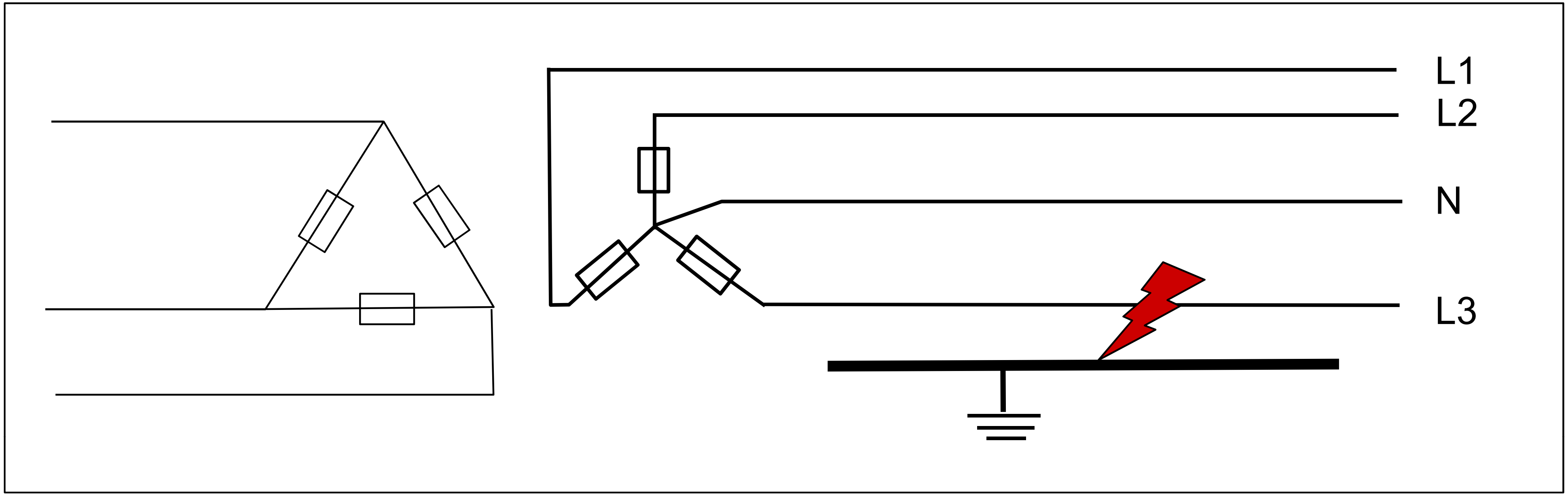


Virtual Earth will still be formed due to stray capacitence

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 Demo 3
One Phase Shorted to Earth

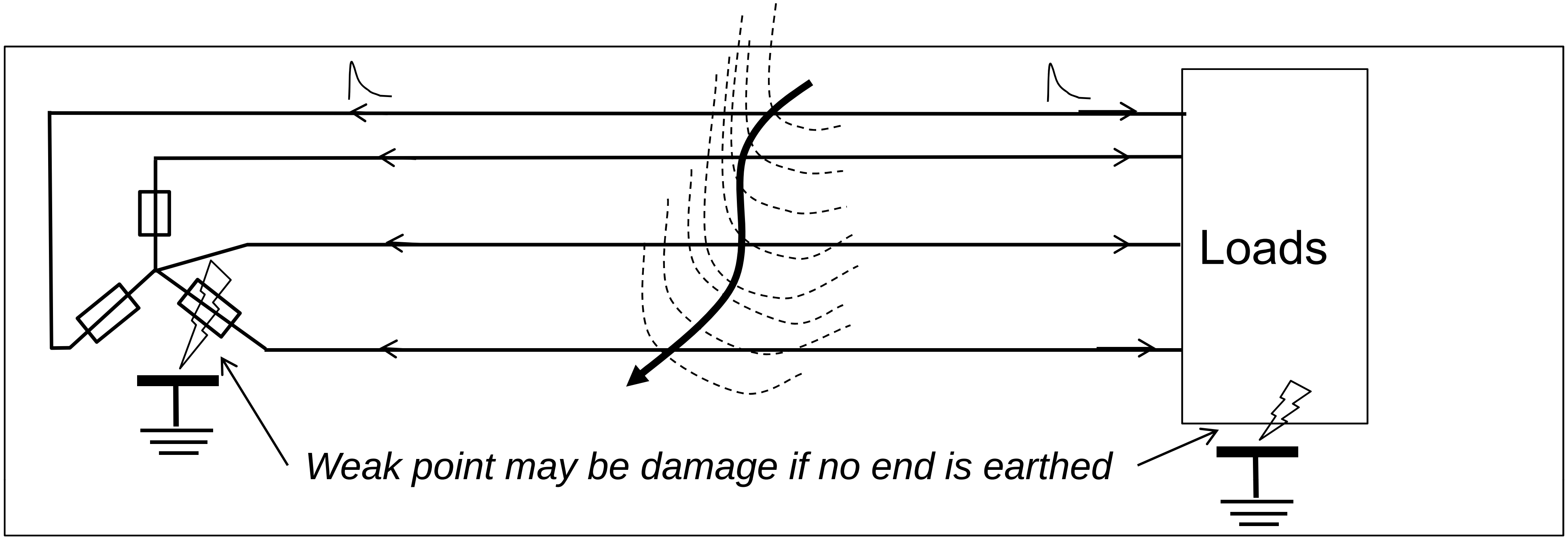


Q: What happen if one phase shorted to earth?

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

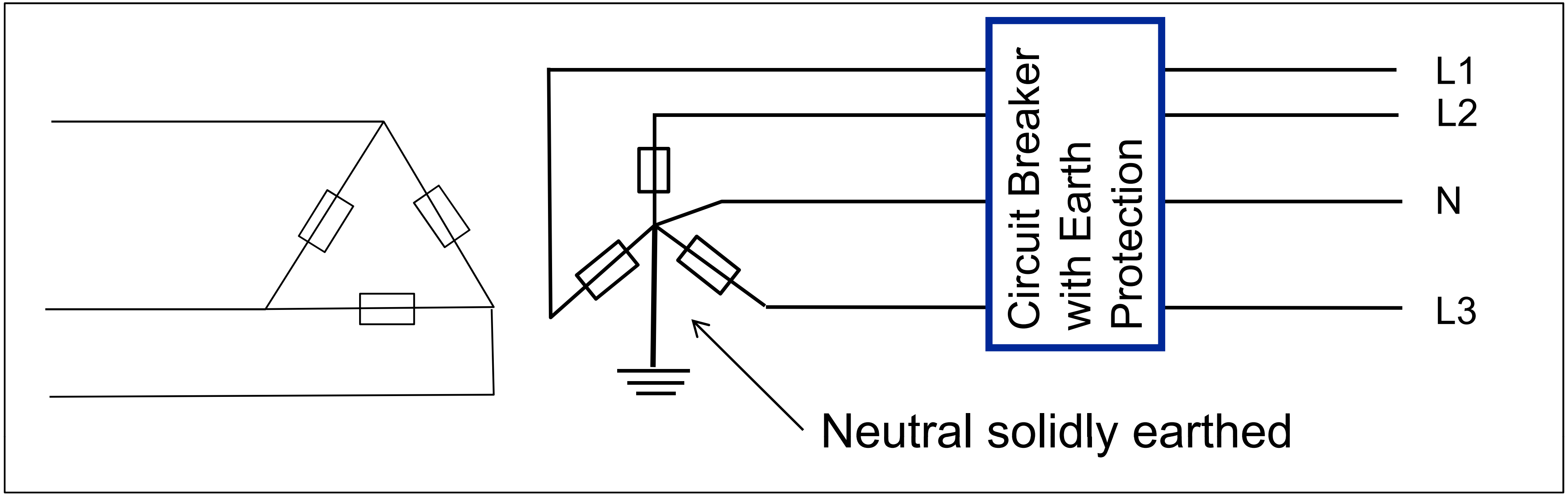
2.) The other two phases (in this case L1 & L2) will have line voltage with respect to earth, in this demo, will be 433Volts. Neutral to earth will be about 250 Volts.

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

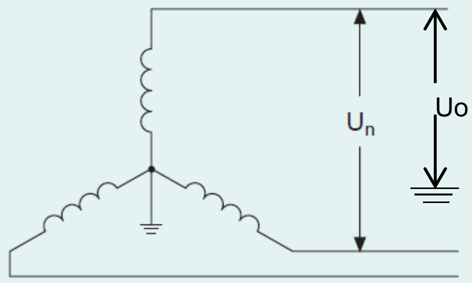


To minimze the above mentioned phenomenon, earthing of neutral is compulsary except for some special requirement like IT system.

Earthing System
Earthing for System Protection

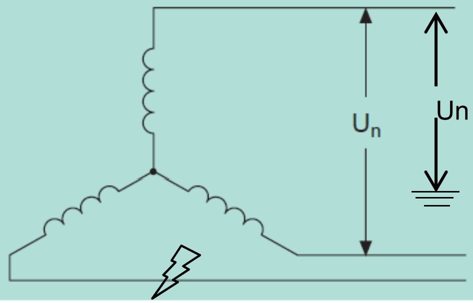
three-phase systems
with neutral connected directly to earth

$$U_{ne} = \frac{U_n}{\sqrt{3}} = U_0$$ [1]



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

$$U_{ne} = U_n$$



At least two main reasons amount many others are:

1.) Drainage of excessive high surge volatge, especially the common mode disturbances

2.) Preventing prolong high voltage of any phase become Un against earth instead of Uo as per normal working condition

Any way the **virtual earth** will still formed for large installation

Indirect Contact and People Protection

Indirect contact protection

1SDC210170F0004

1SDC210173F0004

1SDC210215F0004

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

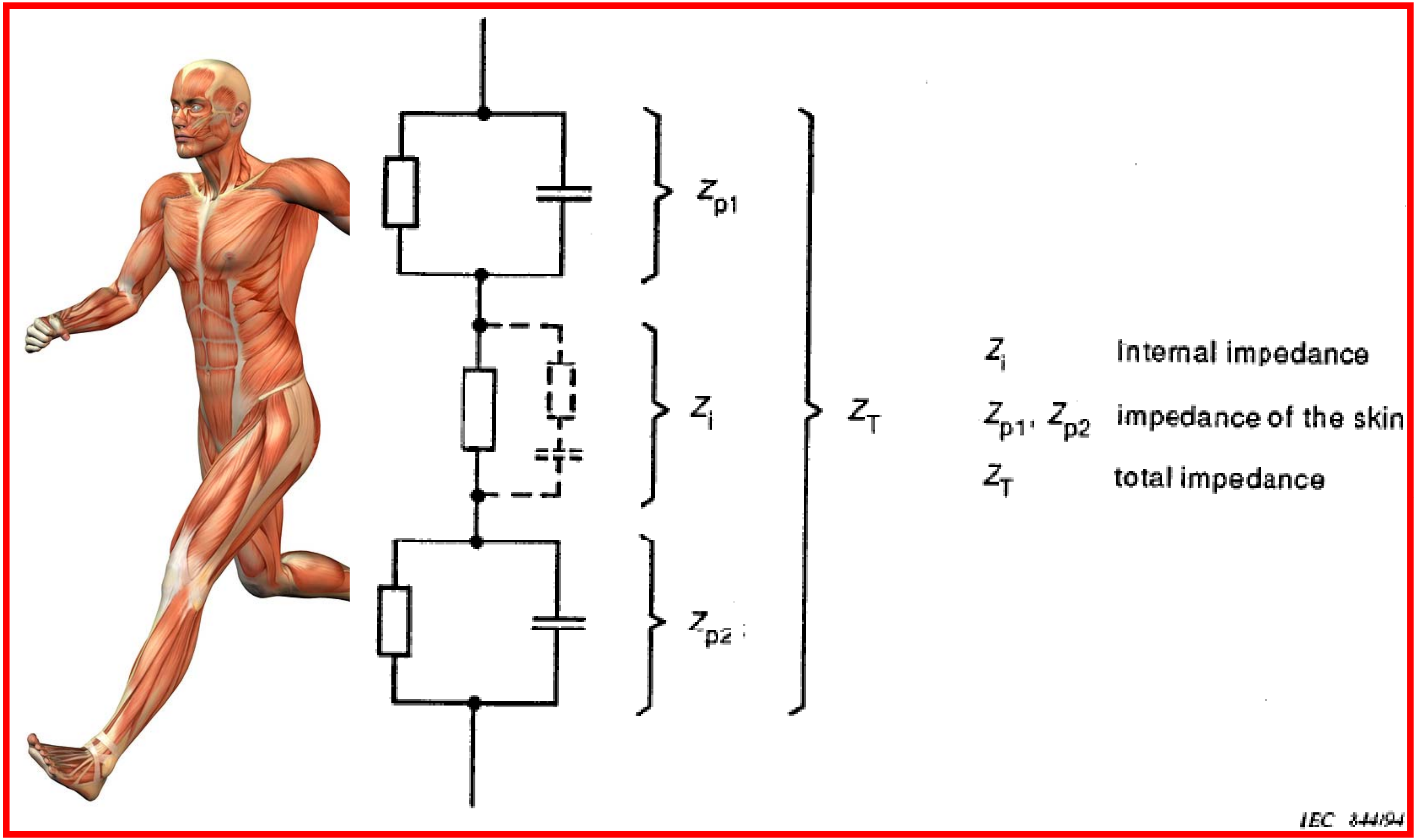
IEC

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

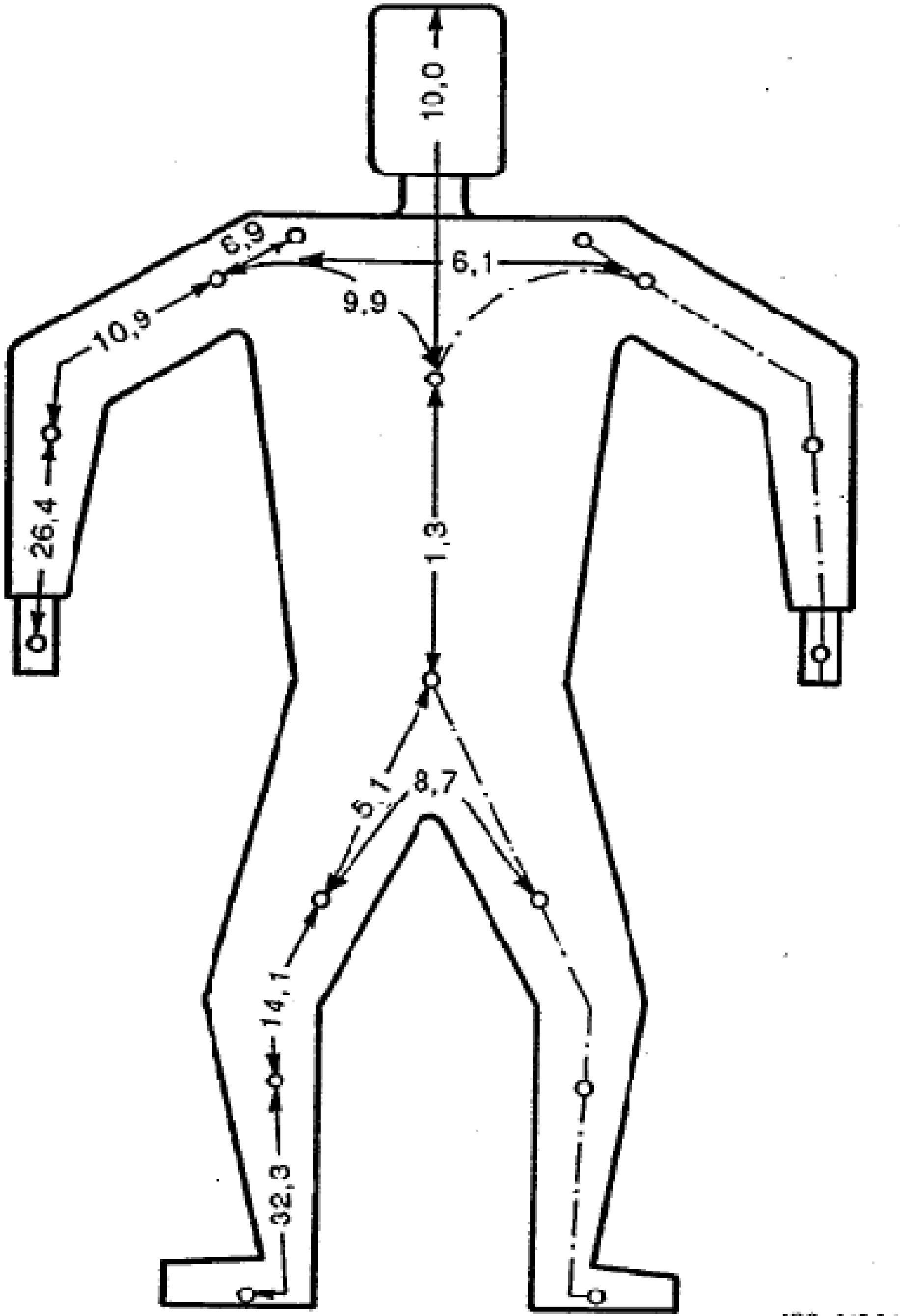
Effects of current on human beings and livestock

SS 97
IEC 61008

Impedance of the human body



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

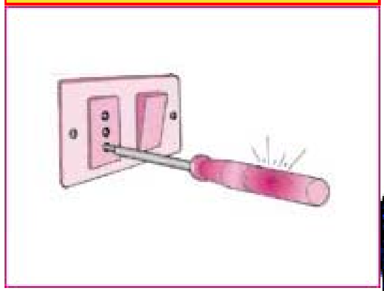
1.3.2.1 **threshold of perception:** Minimum value of current which causes any sensation for the person through which it is flowing.

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.

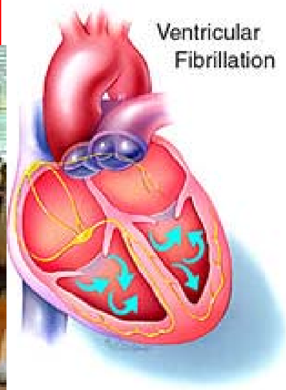
No perception



Perception

Reaction (involuntary contraction)

Let-go



ABB

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.

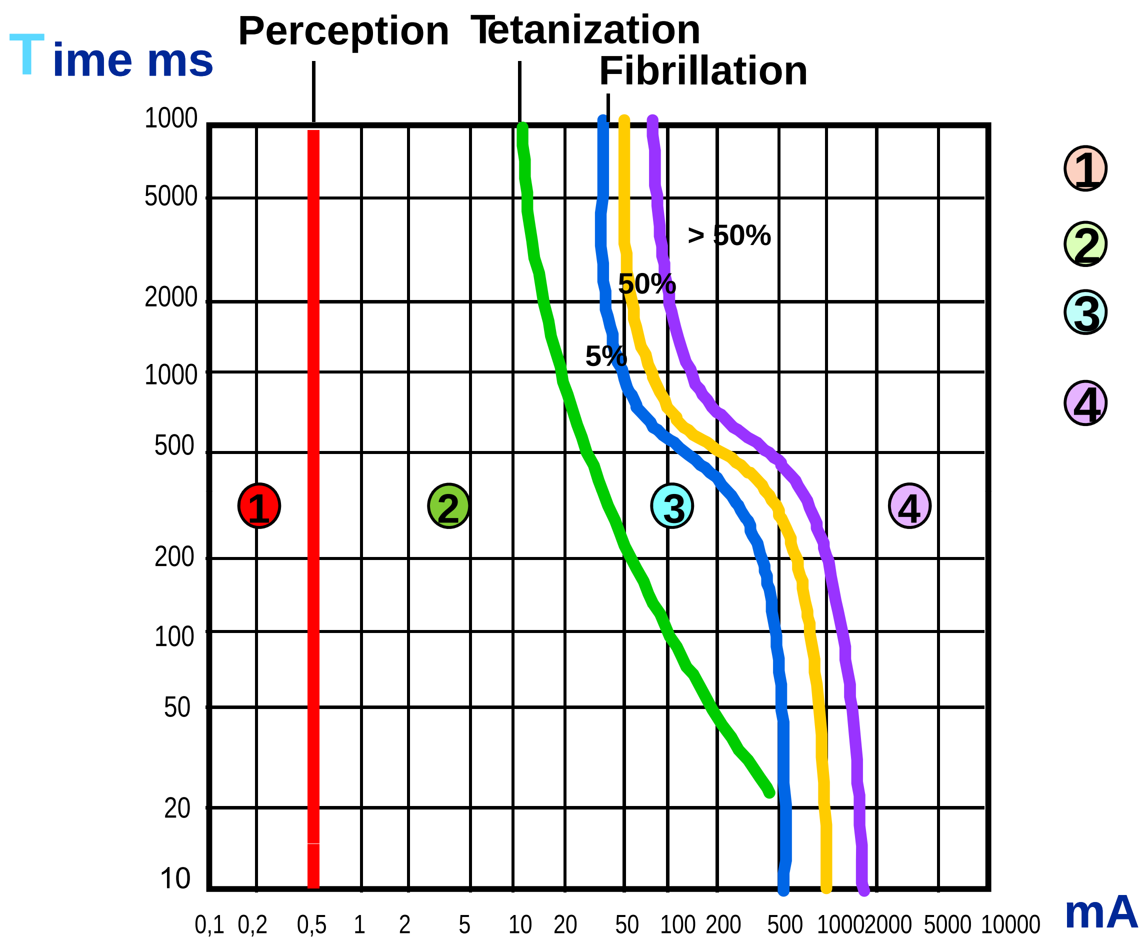
An average value of about 10 mA is assumed in this technical report.

3.3 *Threshold of ventricular fibrillation*

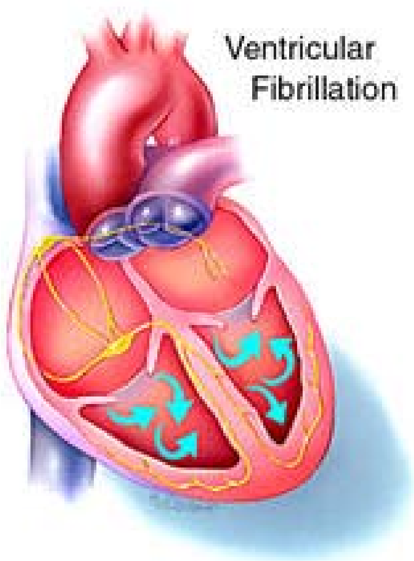
The threshold of ventricular fibrillation depends on physiological parameters (anatomy of the body, state of cardiac function, etc.) as well as on electrical parameters (duration and pathway of current flow, current parameters, etc.).

Physiological effects

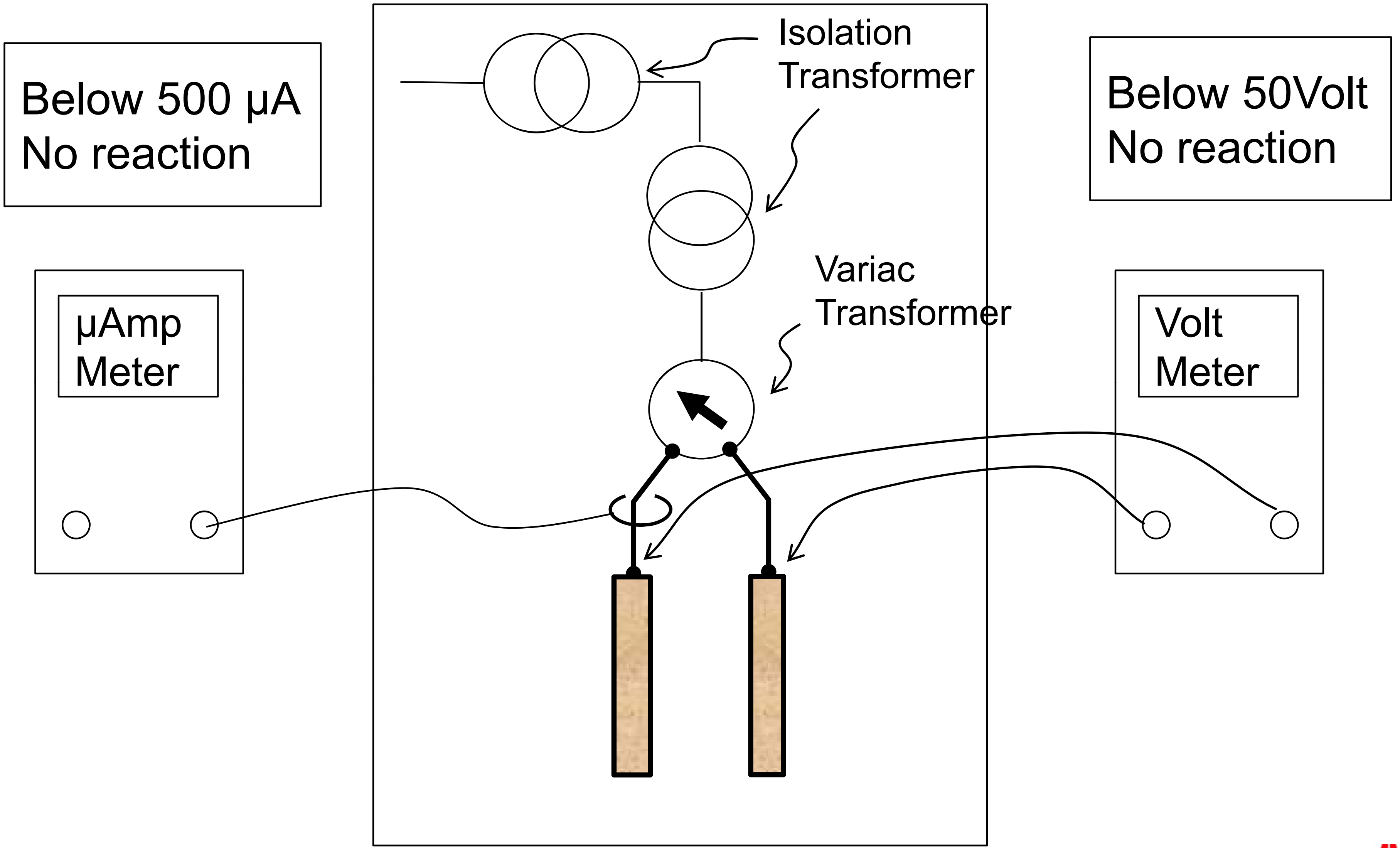
- **IEC describes as follow the current effects:**



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



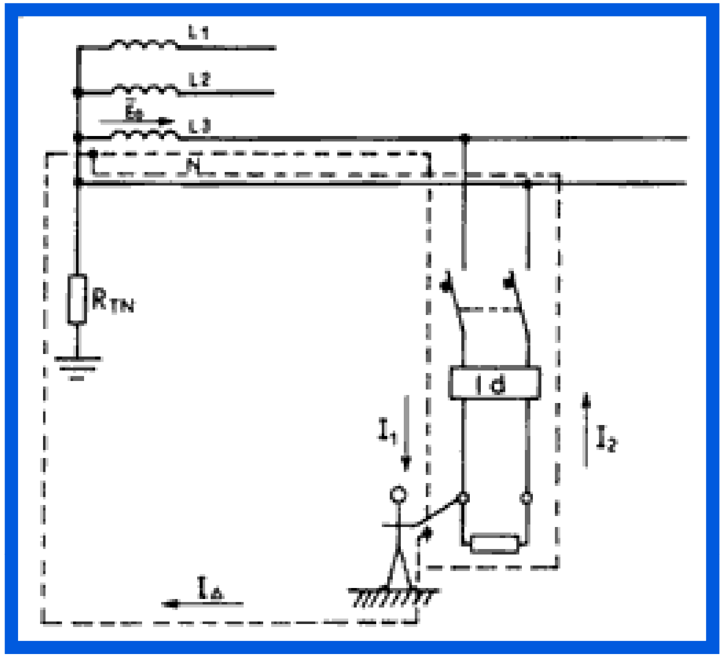
Earthing System Demo 4
Physiological Effect

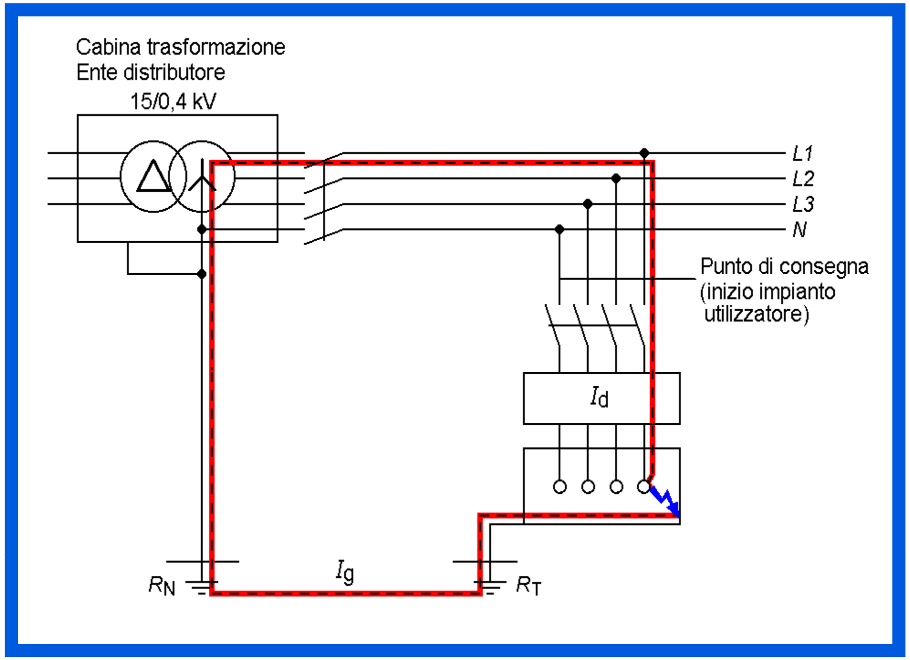


Earthing System
Direct Contact

- Most common shock-related injury
- Occurs when you touch electrical wiring or equipment that is improperly used or maintained
- Typically occurs on hands
- Very serious injury that needs immediate attention

Earthing System
Selectivity

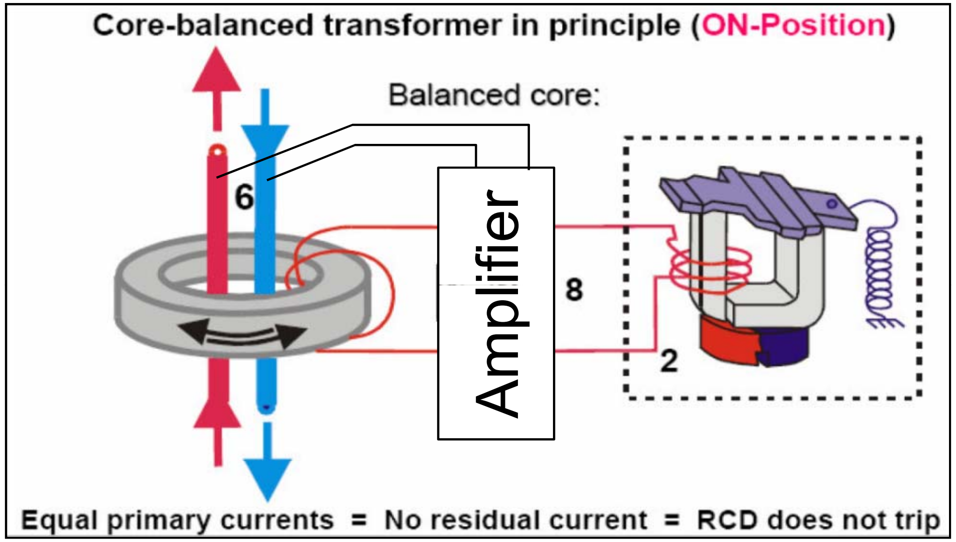


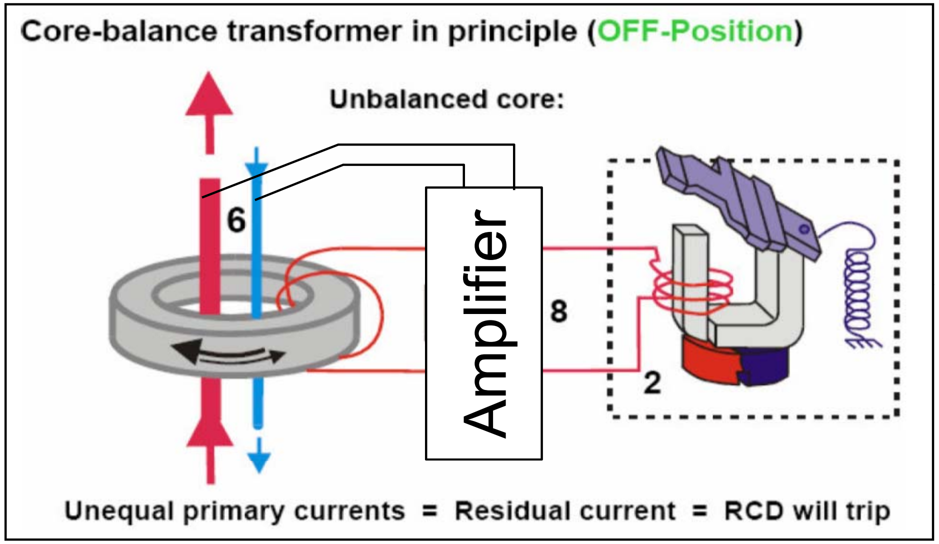


- **10mA, 30mA, 100mA**, → Human Life Protection, protection against indirect contact by the automatic disconnection of supply
- **300mA, 500mA, 1000mA**, → Fire Protection
- Higher that the above value is consider earth fault.

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.



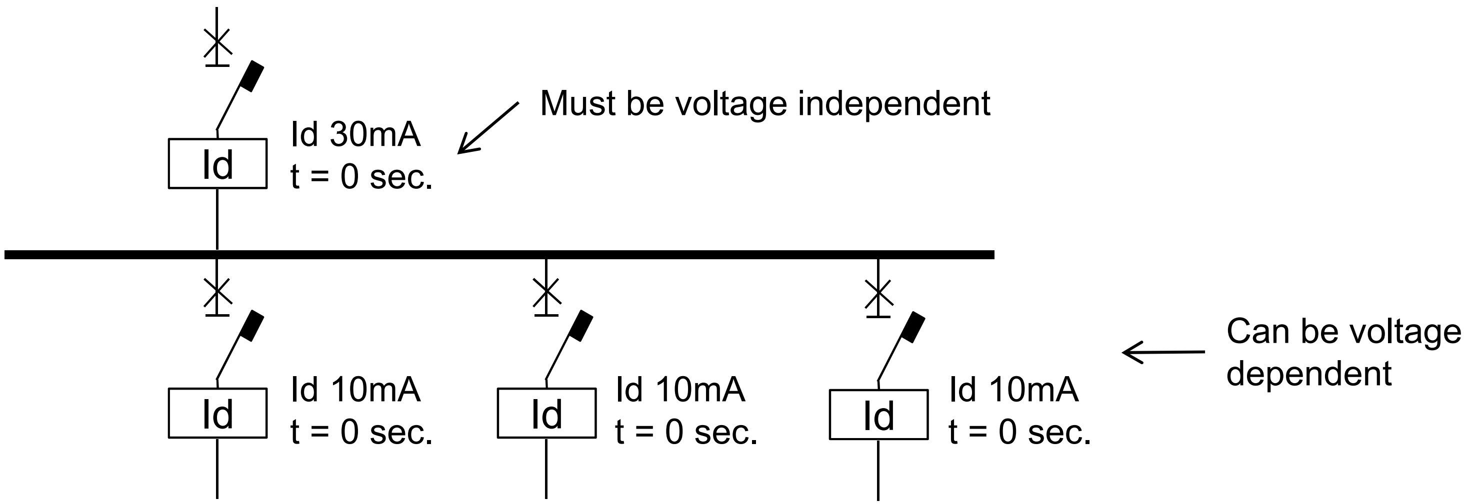


- RCBO – A device with the combination of RCD and Circuit Breaker
- ELR/EFR, A measurement device giving output contact to trip the shunt trip coil of a circuit breaker

Earthing System
Selectivity 10mA

10mA:

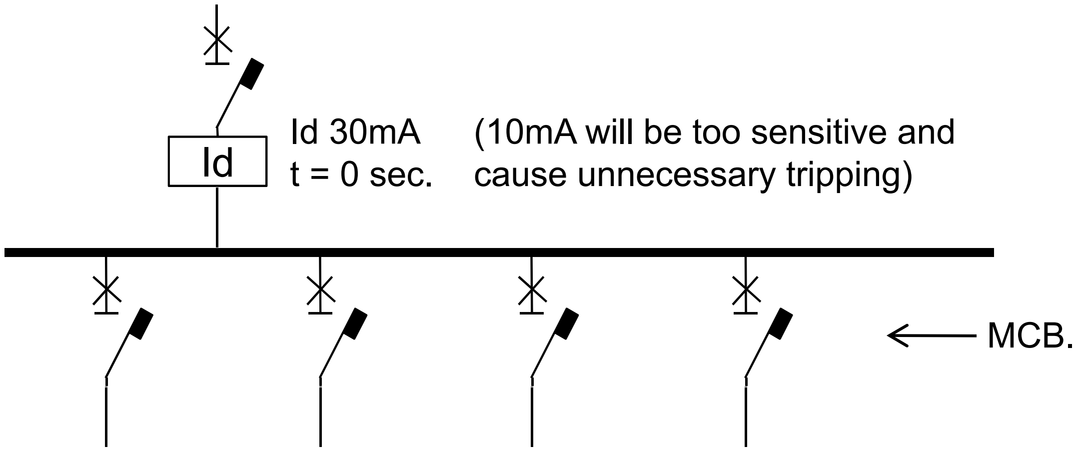
- Sensitive human life protection
  - Hospital
  - Kindergarten, etc
- Final distribution circuit for better discrimination



Earthing System
Selectivity 30mA

30mA:

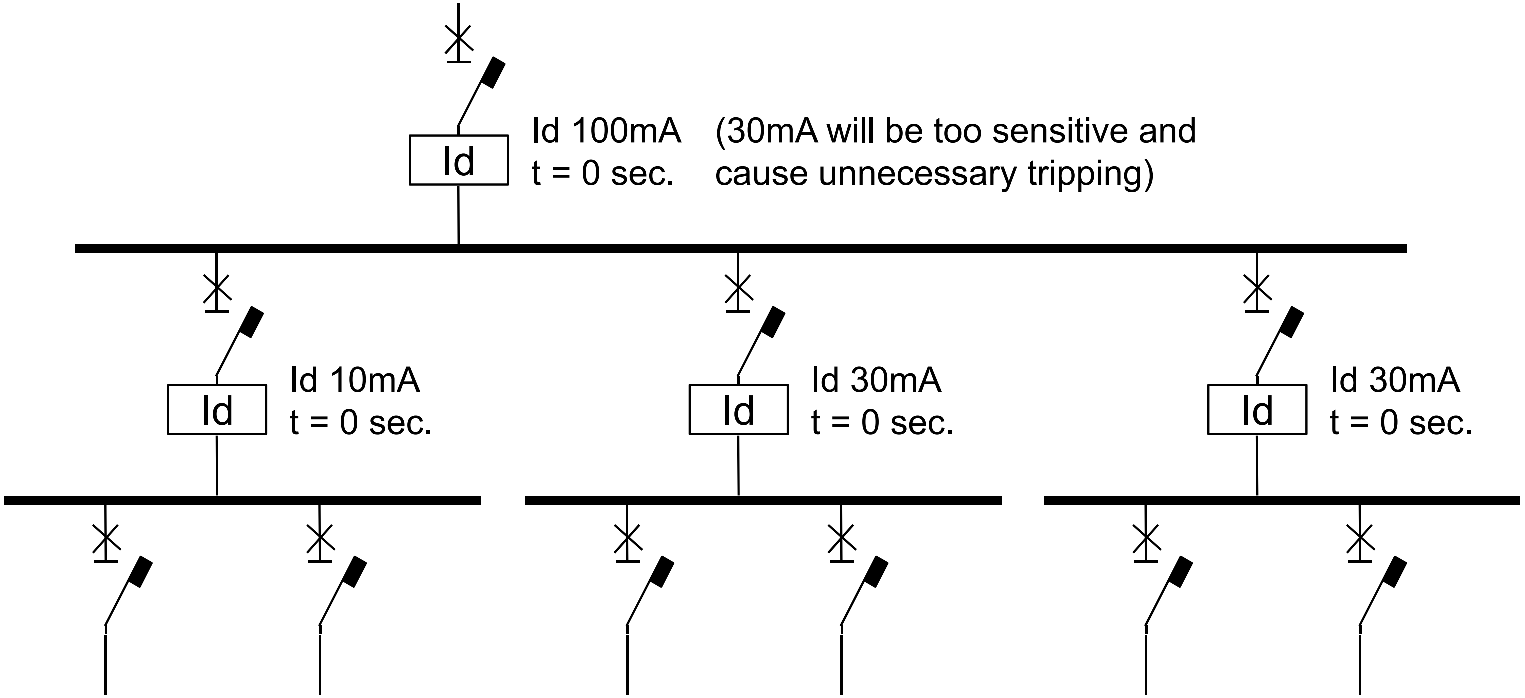
- Human life protection
  - Household, office
- Consumer unit



Earthing System
Selectivity 100mA

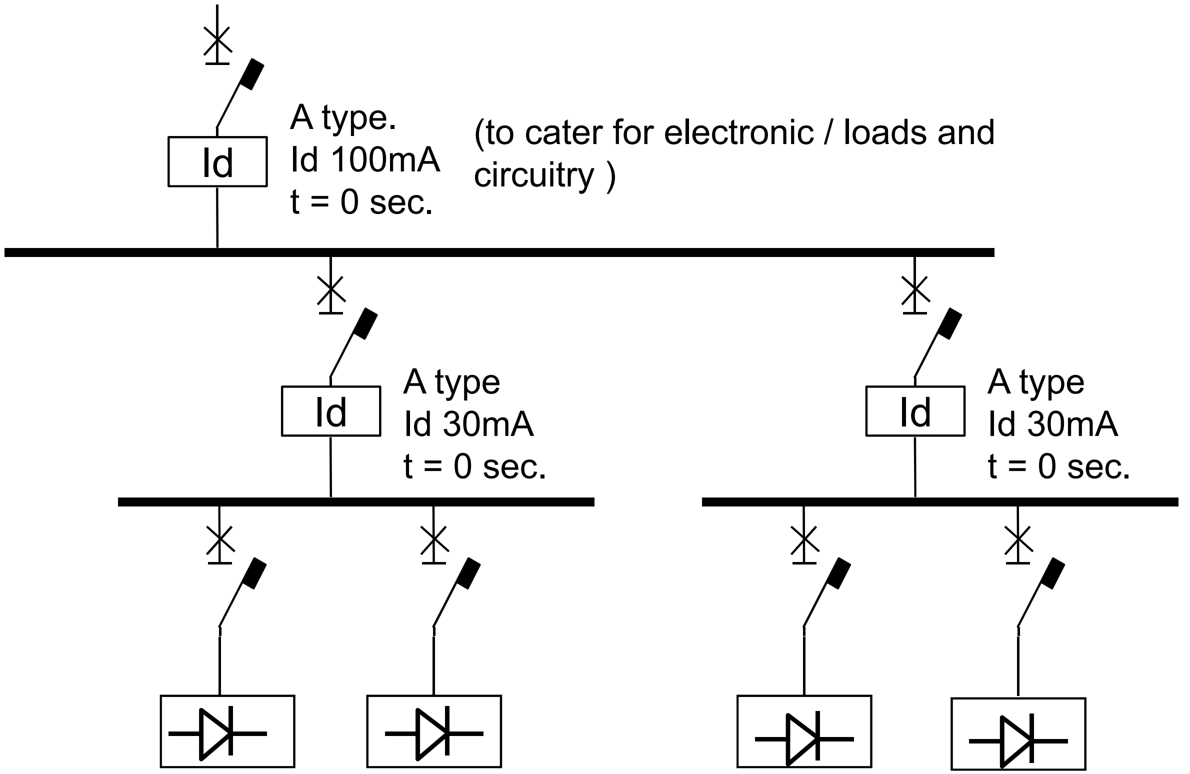
100mA:

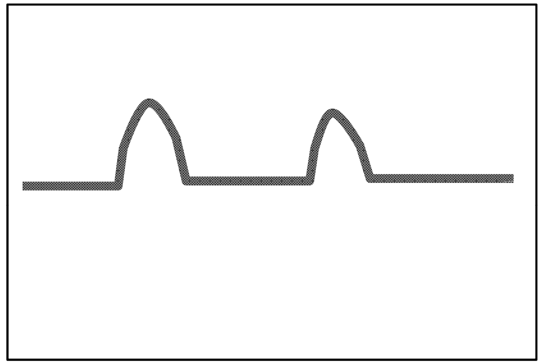
- Human life protection and propoer discrimination
  - Sub-board circuit



Earthing System
Pulsation DC Leakage

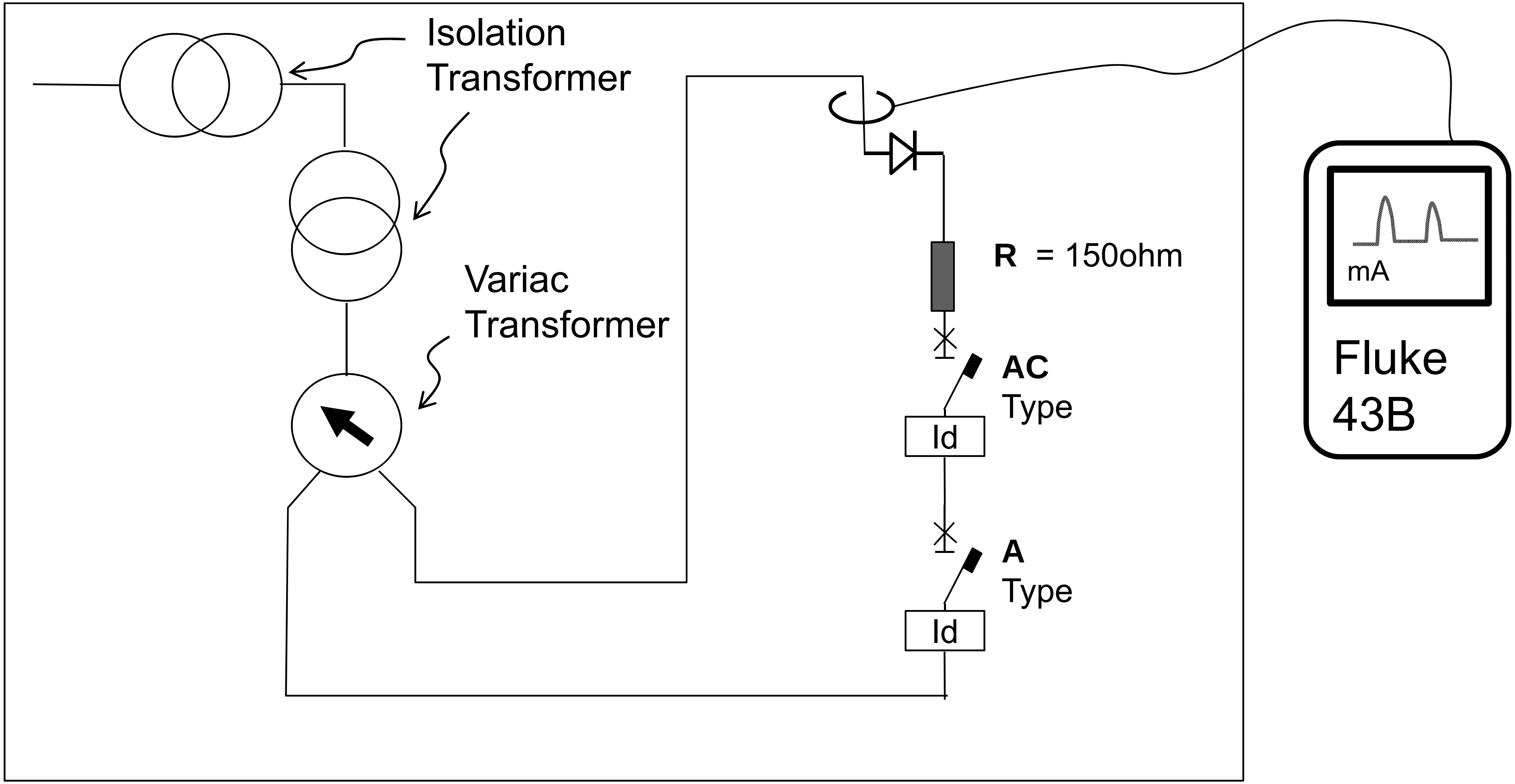
Electronics circuit with Rectifiers or PV panel, generating DC source volatge, standard AC types of RCCB or RCBO may not be sensitive enought to trip at the designed value, A and B types are available.





Electronics Circuitry

Earthing System
Pulsation DC Leakage – Demo 5

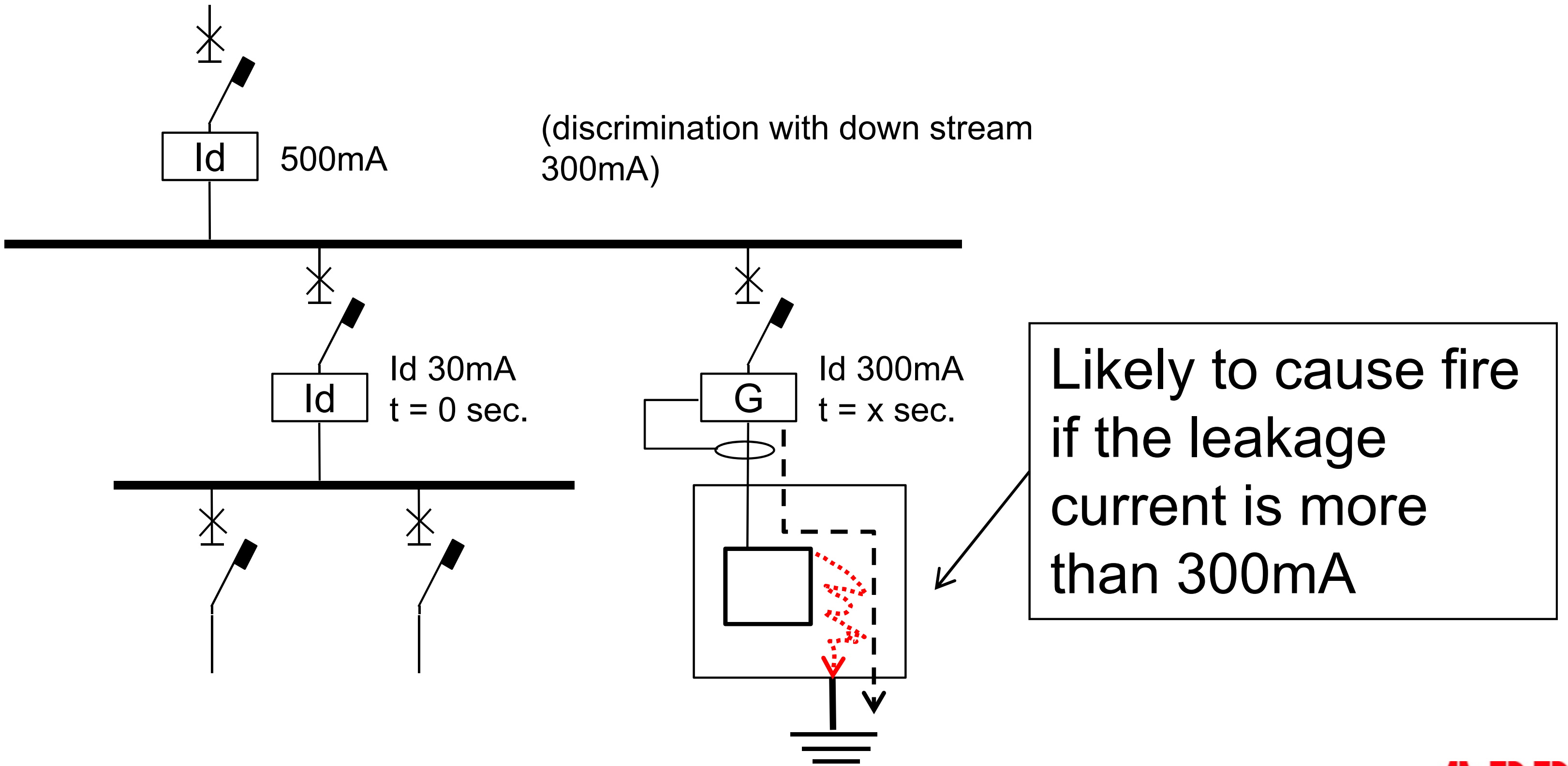


Indirect Contact and Property Protection

Earthing System
Selectivity 300mA

300mA:

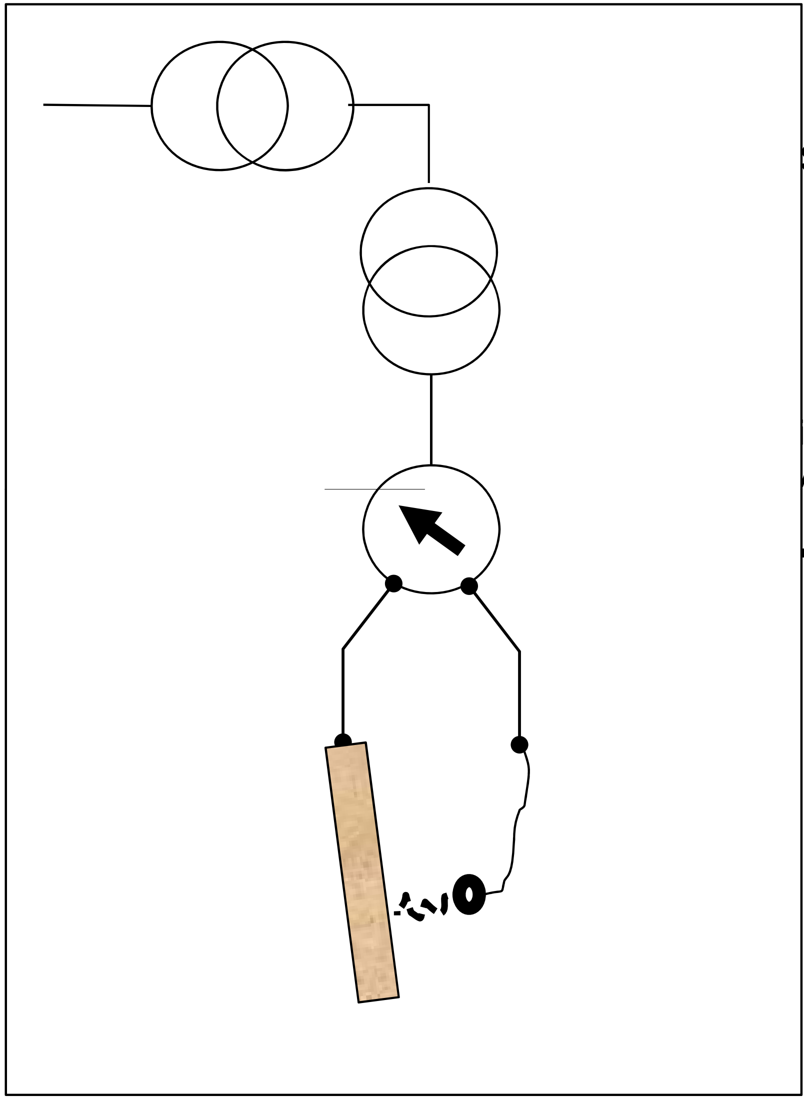
- Property protection (against fire)

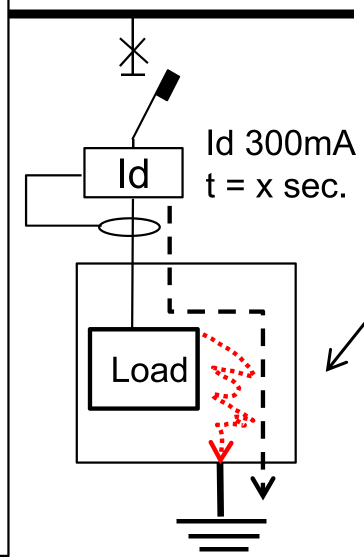


Earthing System
Leakage more than 300mA – Demo 6

st fire)

mination with down stream
A)

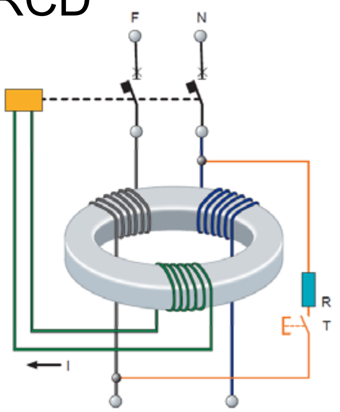




Likely to cause fire if the leakage current is more than 300mA

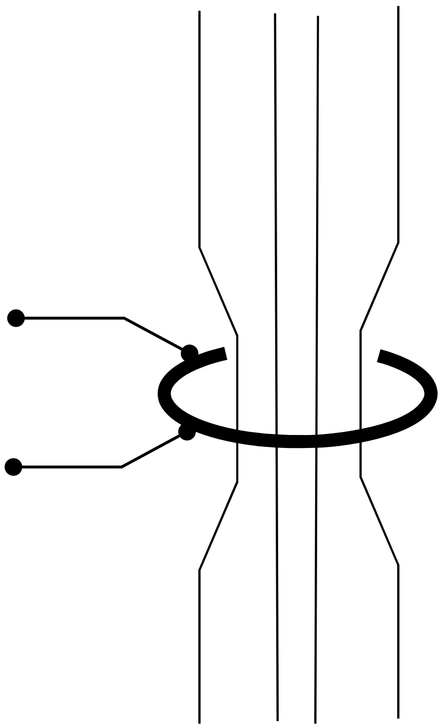
Earthing System
Earth Leakage or Earth Fault

Toroid built-in the RCD

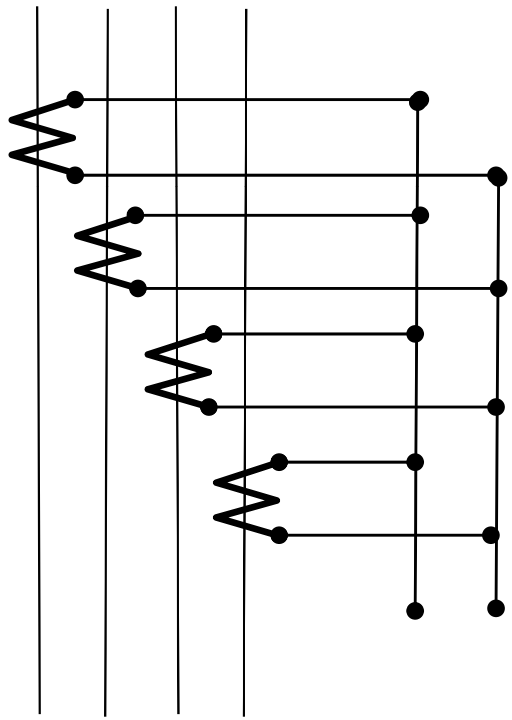


Toroid for external Relay

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

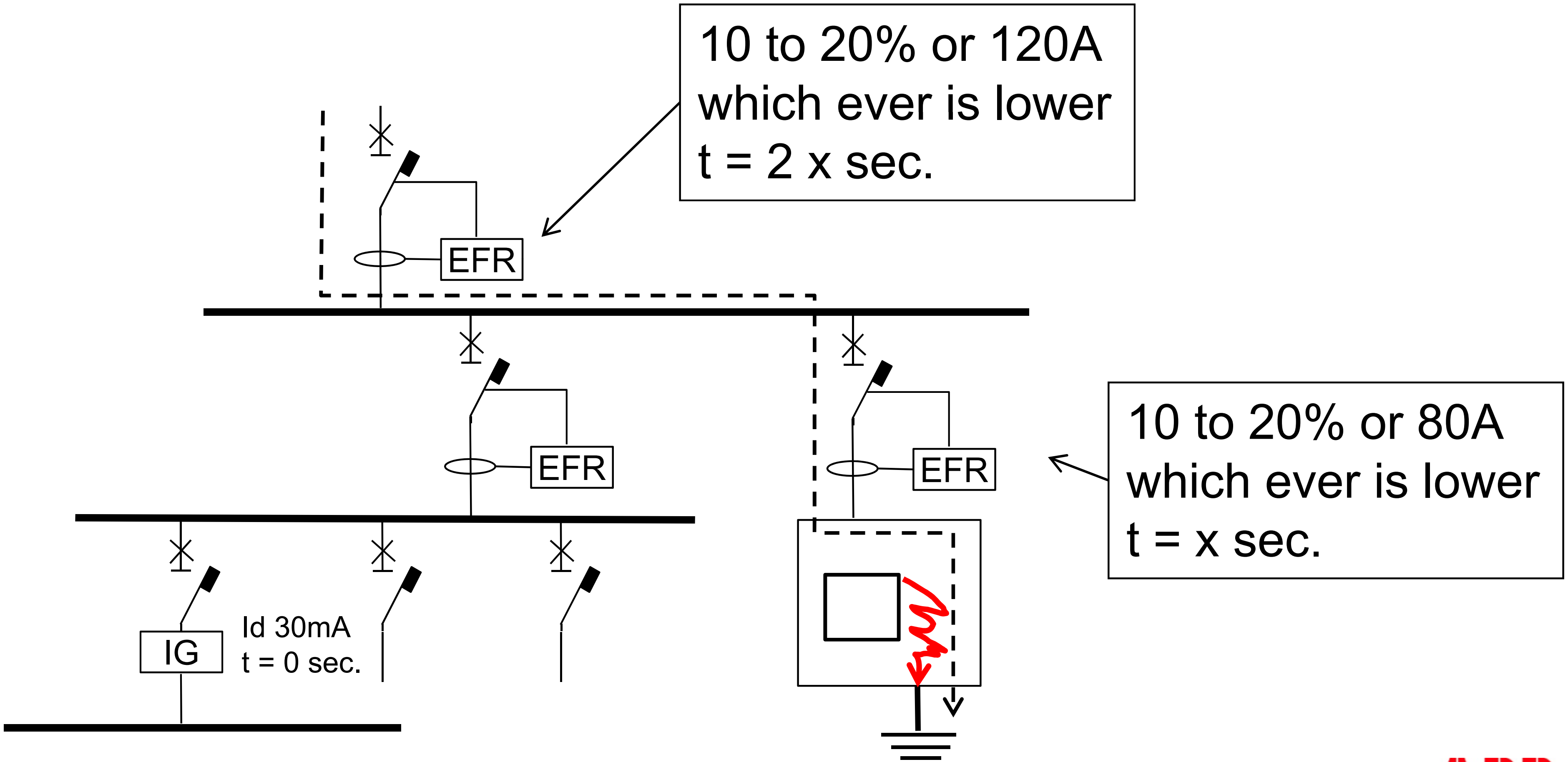


Earth Fault
- High current
- Measuring using **CT**



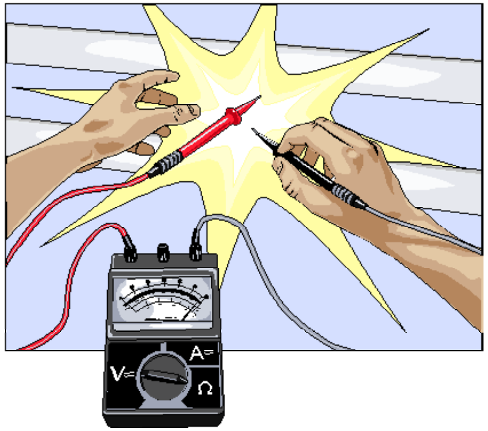
Earthing System
Earth Fault

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



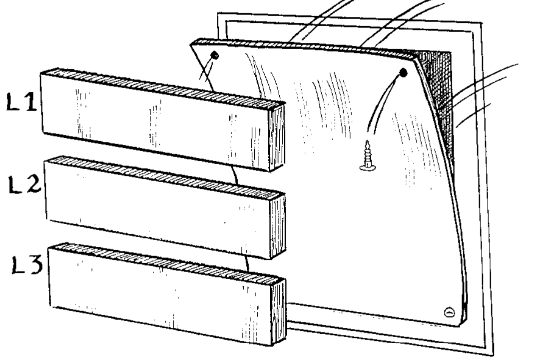
Earthing System
What causes the Fault

Human Errors

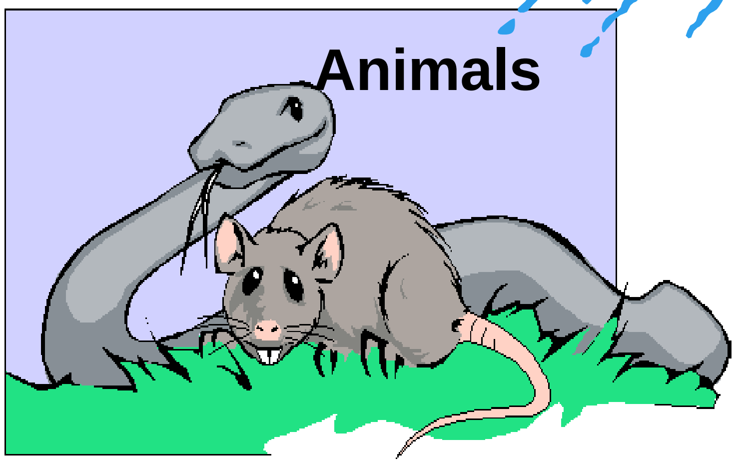


Pollution

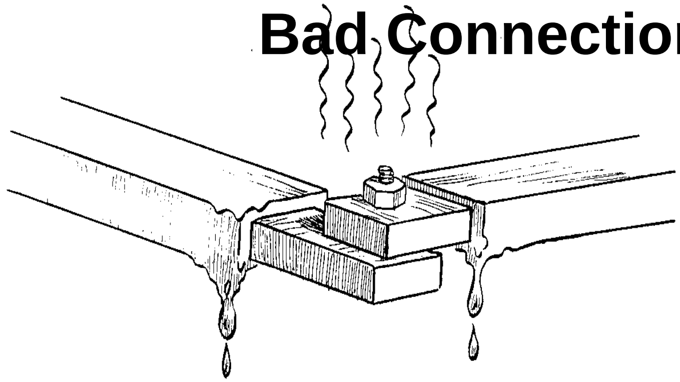
Mechanical faults



Animals



Bad Connections



Outdoor Substation

Transformer Arcing Fault >>> develops into a major fire

Earthing 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

ABB

Letter code meanings:

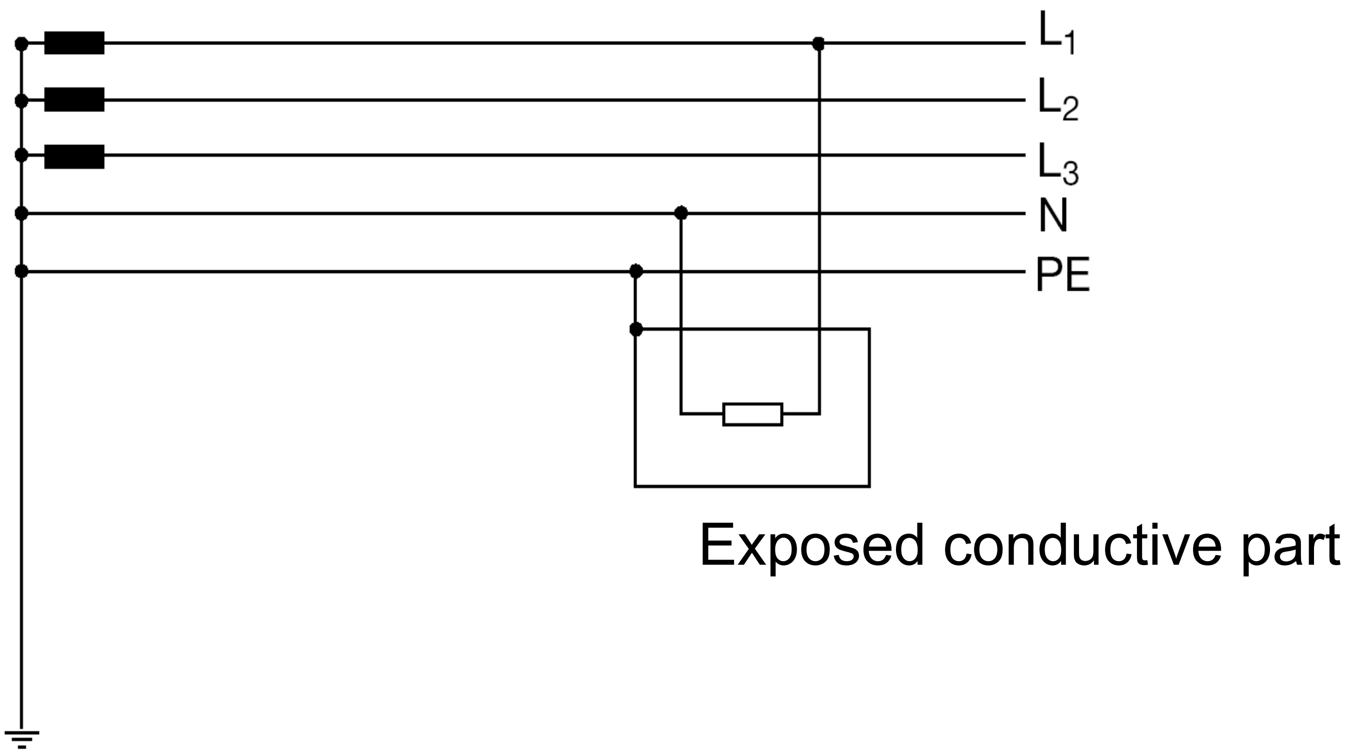
Subsequent letter (if any): N and PE conductors arrangement

S ⇨ N and PE conductors separated

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

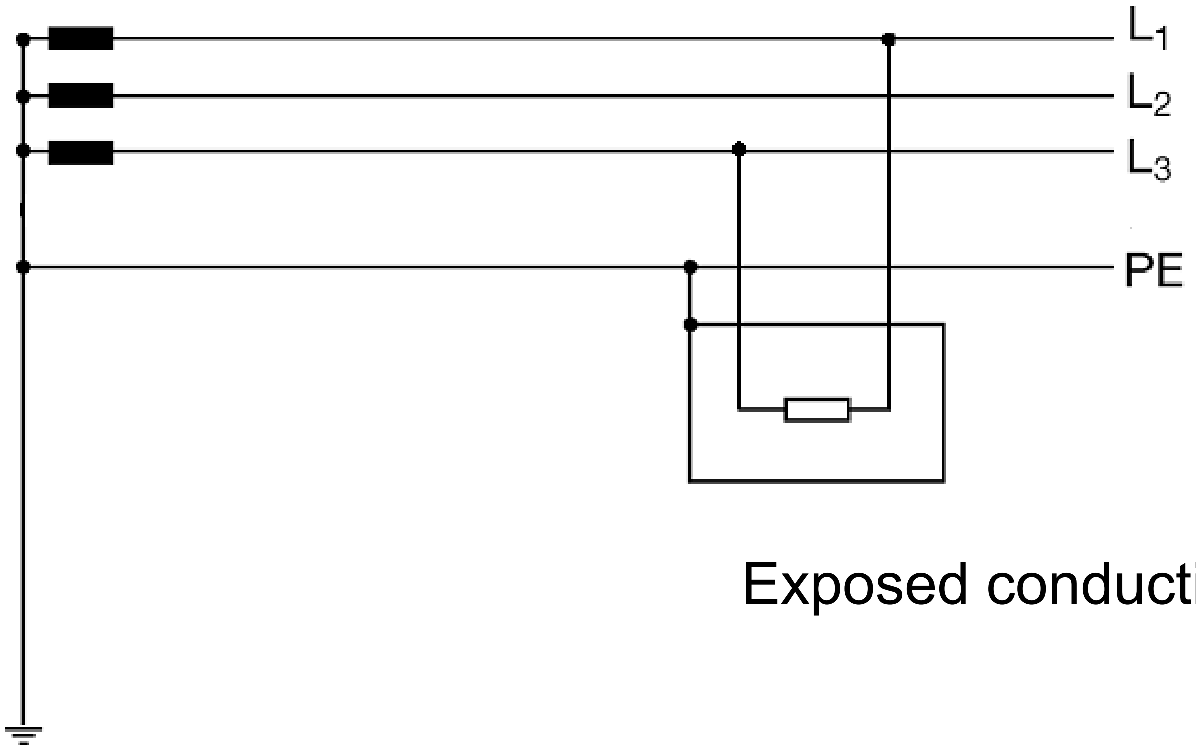
Earthing Systems: TN SYSTEM

TN-S system
5 wires



Earthing Systems: TN SYSTEM

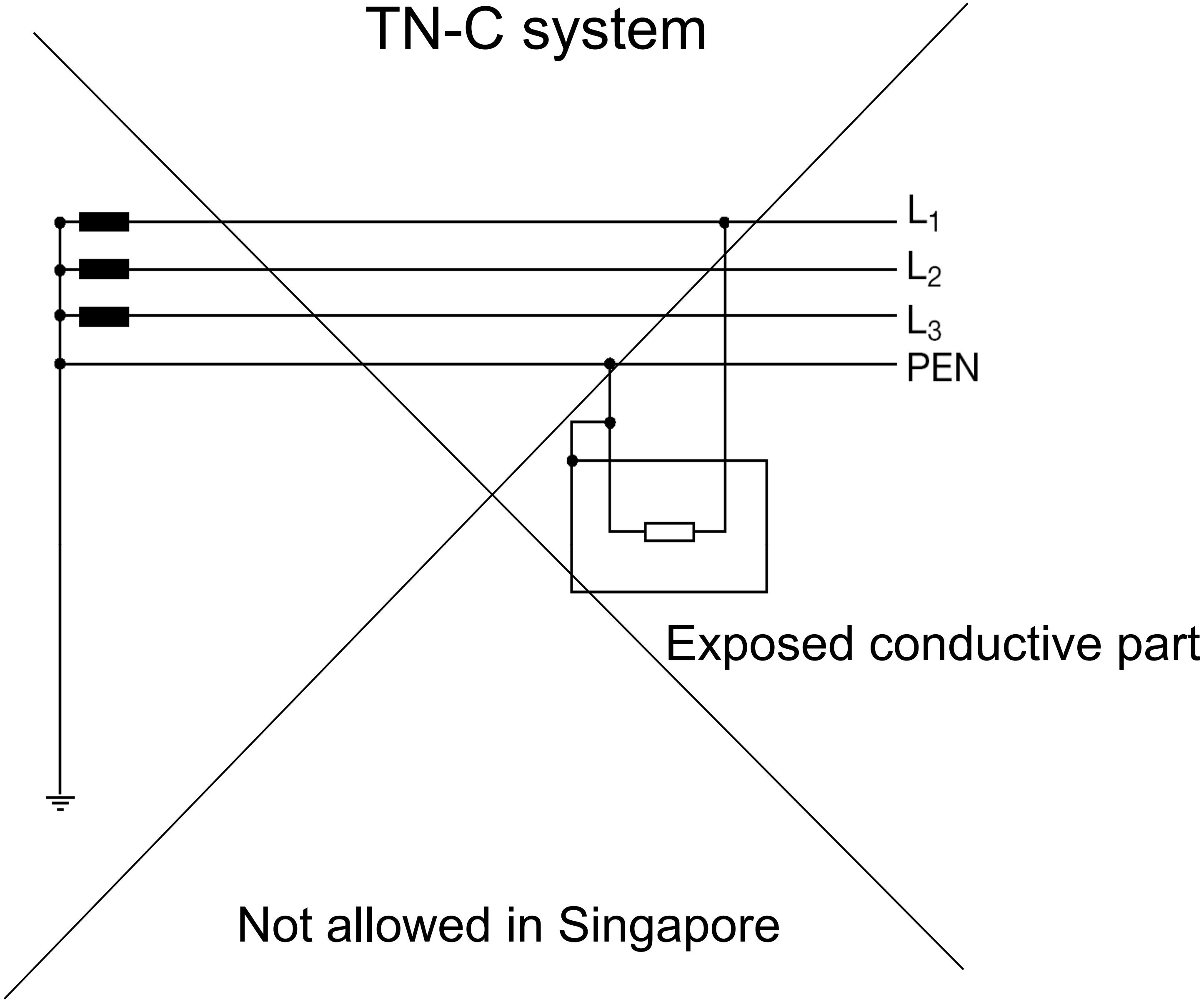
TN-S system
4 wires



Exposed conductive part

Earthing Systems: TN SYSTEM

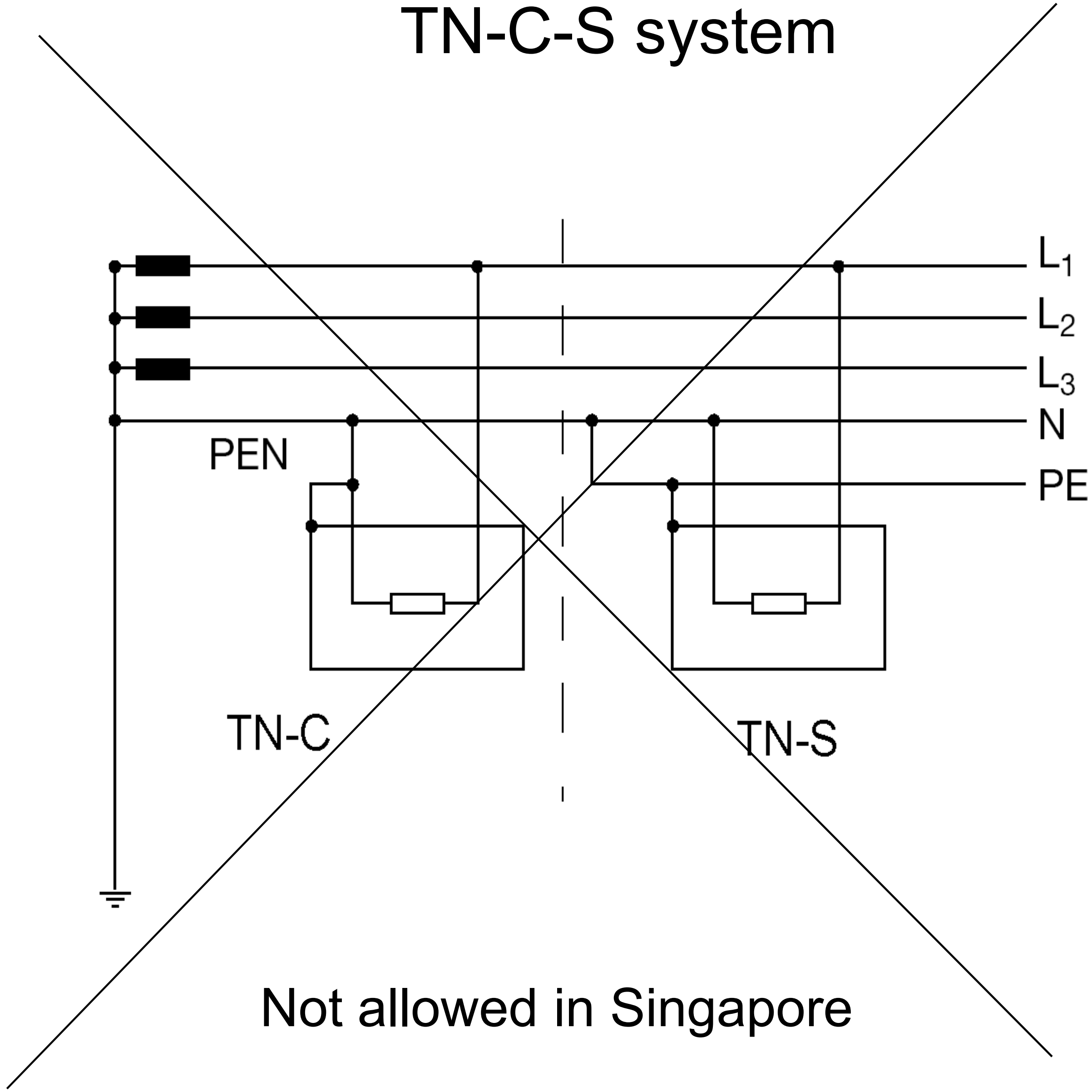
TN-C system



Not allowed in Singapore

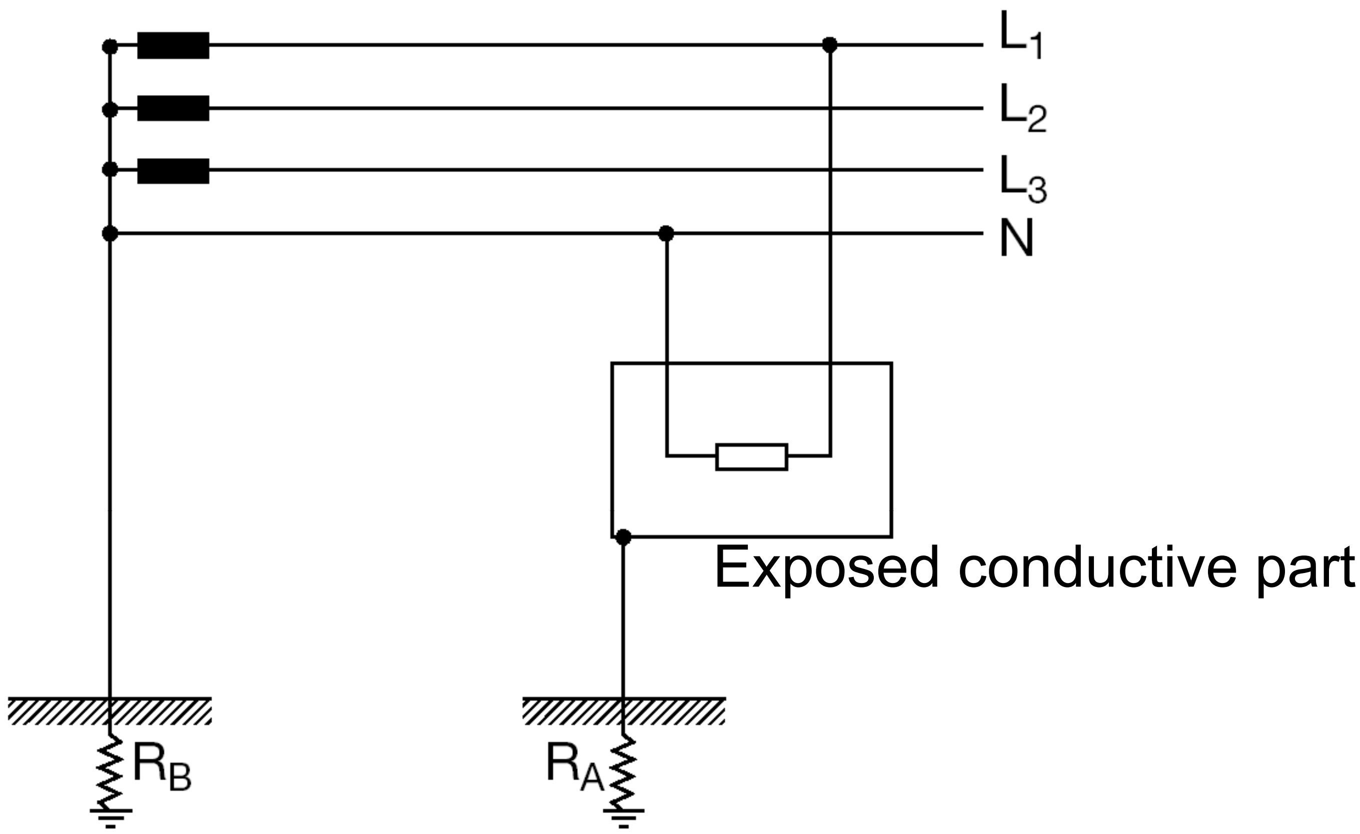
Earthing Systems: TN SYSTEM

TN-C-S system



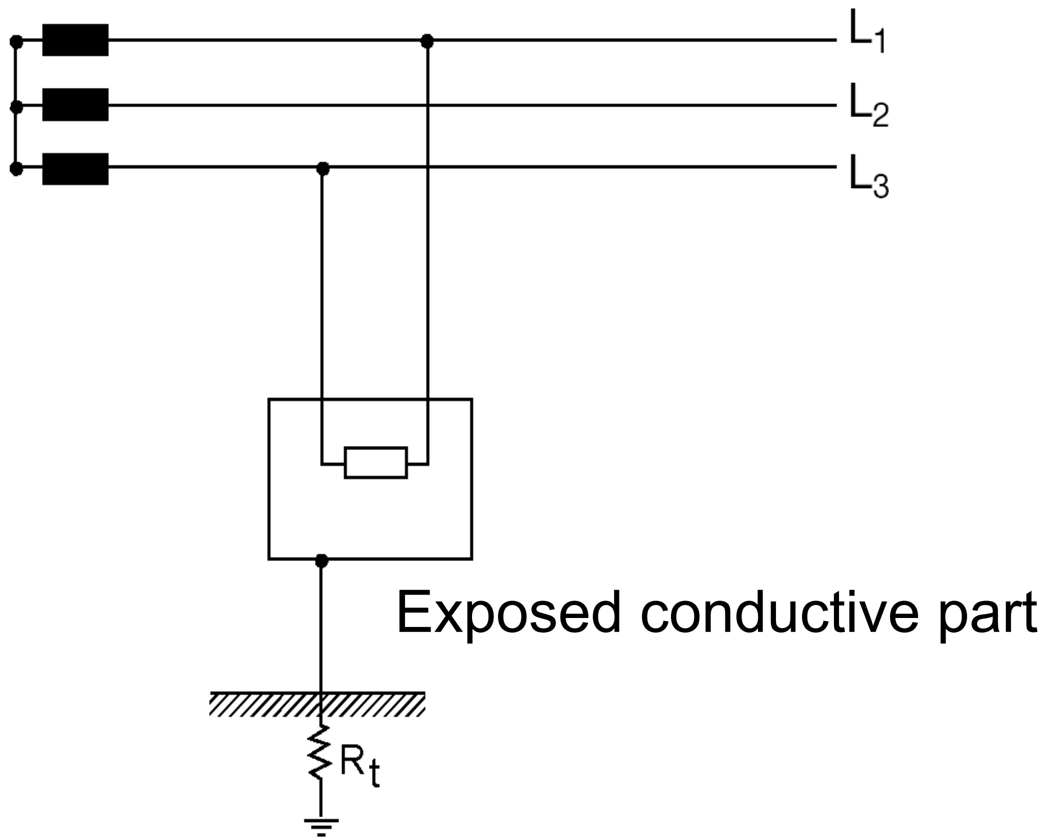
Not allowed in Singapore

Earthing Systems: TT SYSTEM



Earthing Systems: IT SYSTEM

IT system



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:

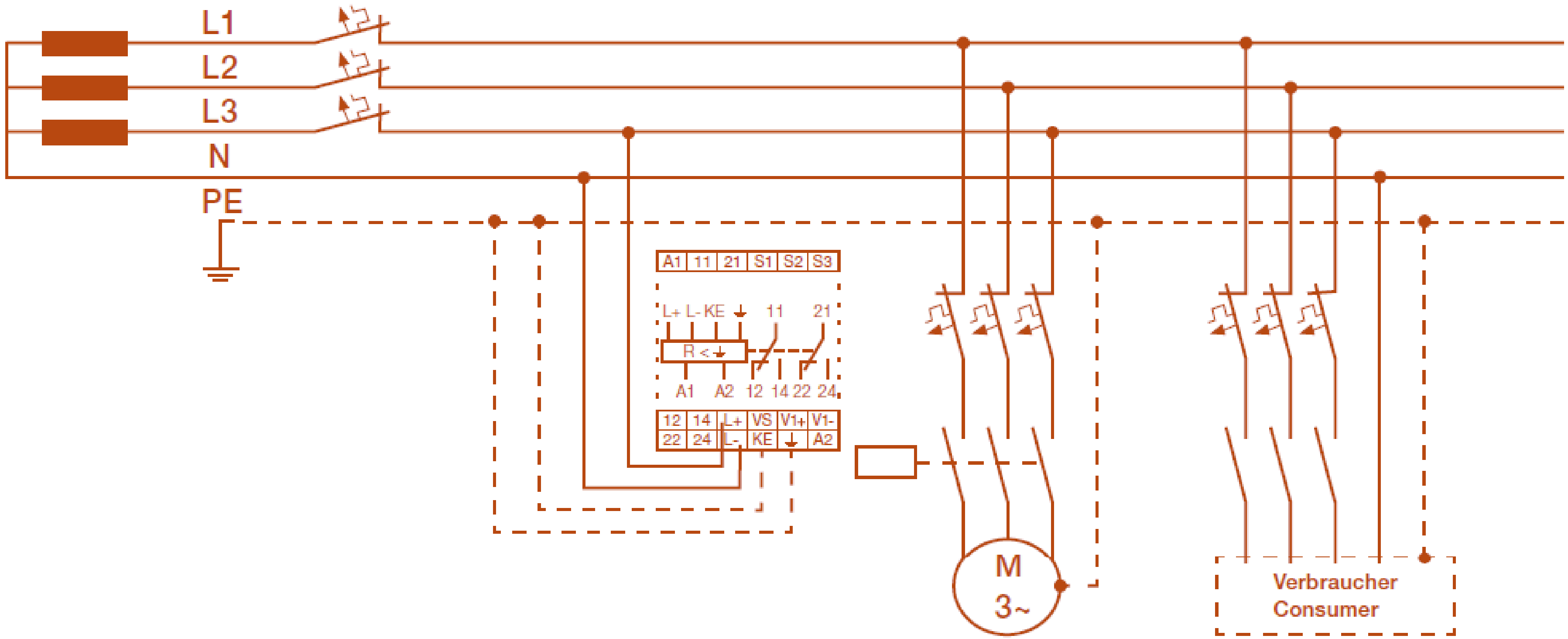
- industrial or utilities installations (especially chemical, petrochemical and telecommunications) for which a very high level of service continuity is required;
- installations for IT apparatuses fed by UPS

- 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

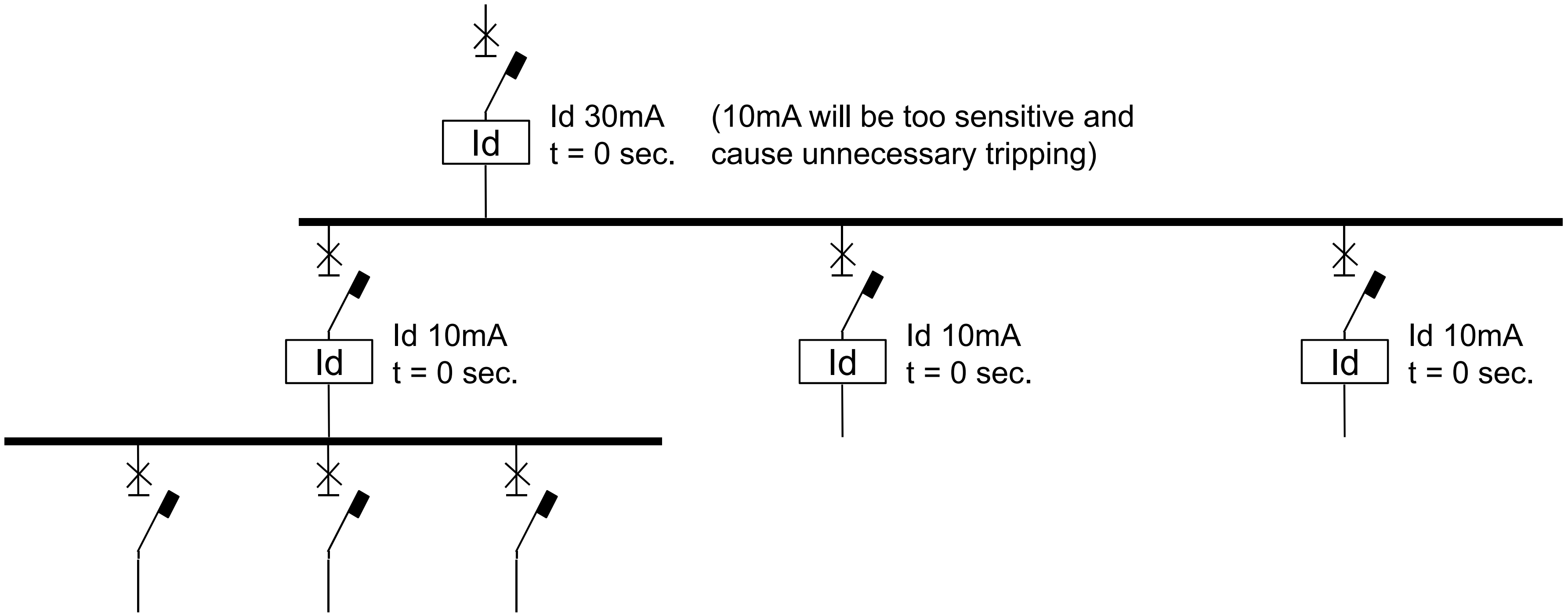


Proposed solution

Earthing System – People Protection
Ensure Good Selectivity for 30mA and 10mA

30mA for 3 units of 10mA

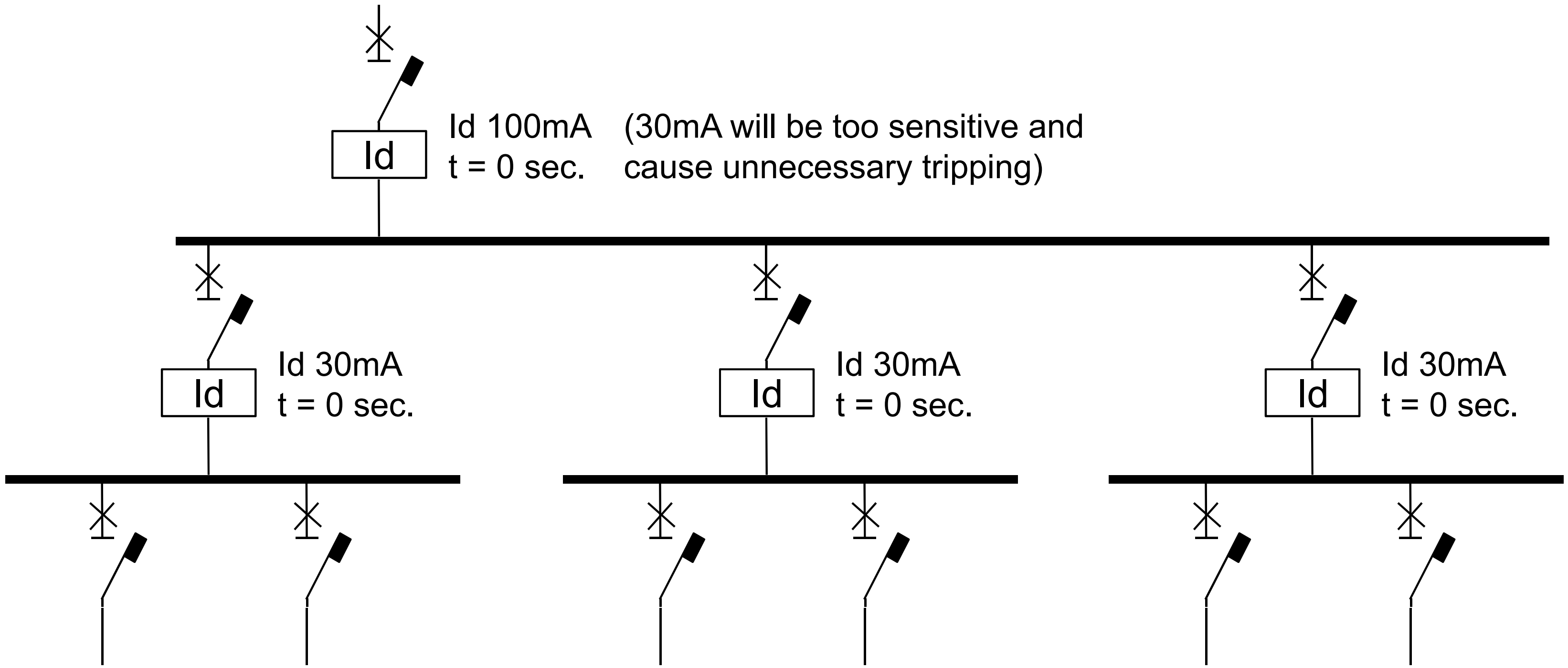
- Human life protection and propoer discrimination
  - Consumer units e.g.



Earthing System – People protection
Ensure Good Selectivity for 100mA

100mA for 3 units of 30mA

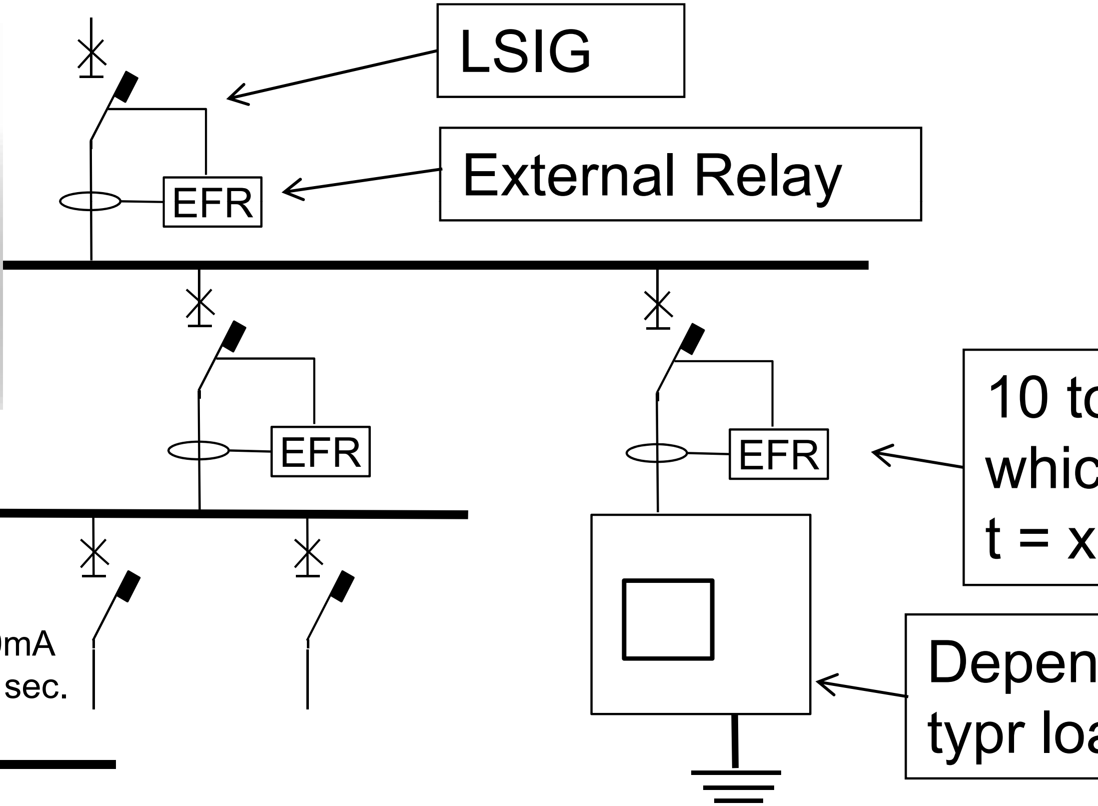
- Human life protection and propoer discrimination
  - Sub-board circuit



Earthing System – Fire Protection
Main and Feeder Circuit

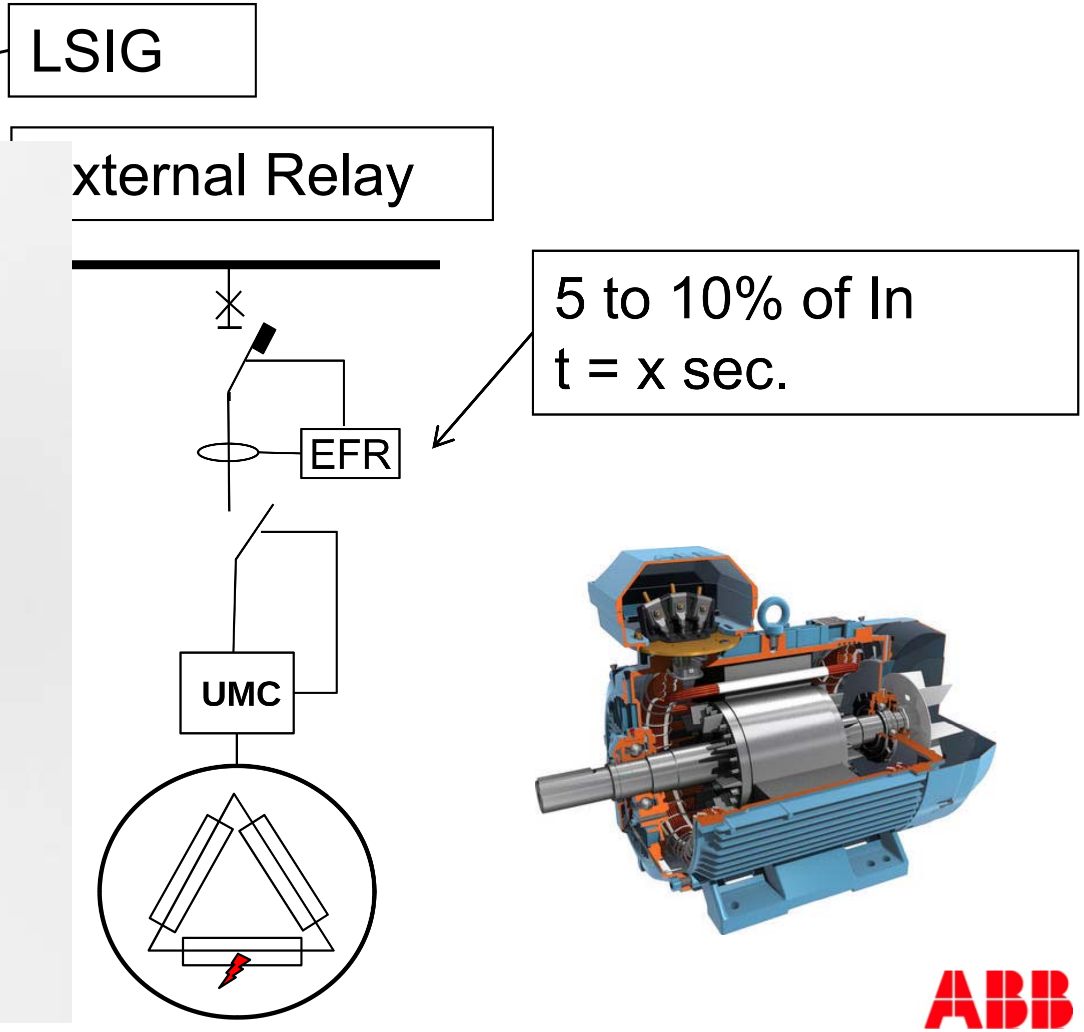
10 to 20% or 120A which ever is lower with delay time at the main

- Mian incoming



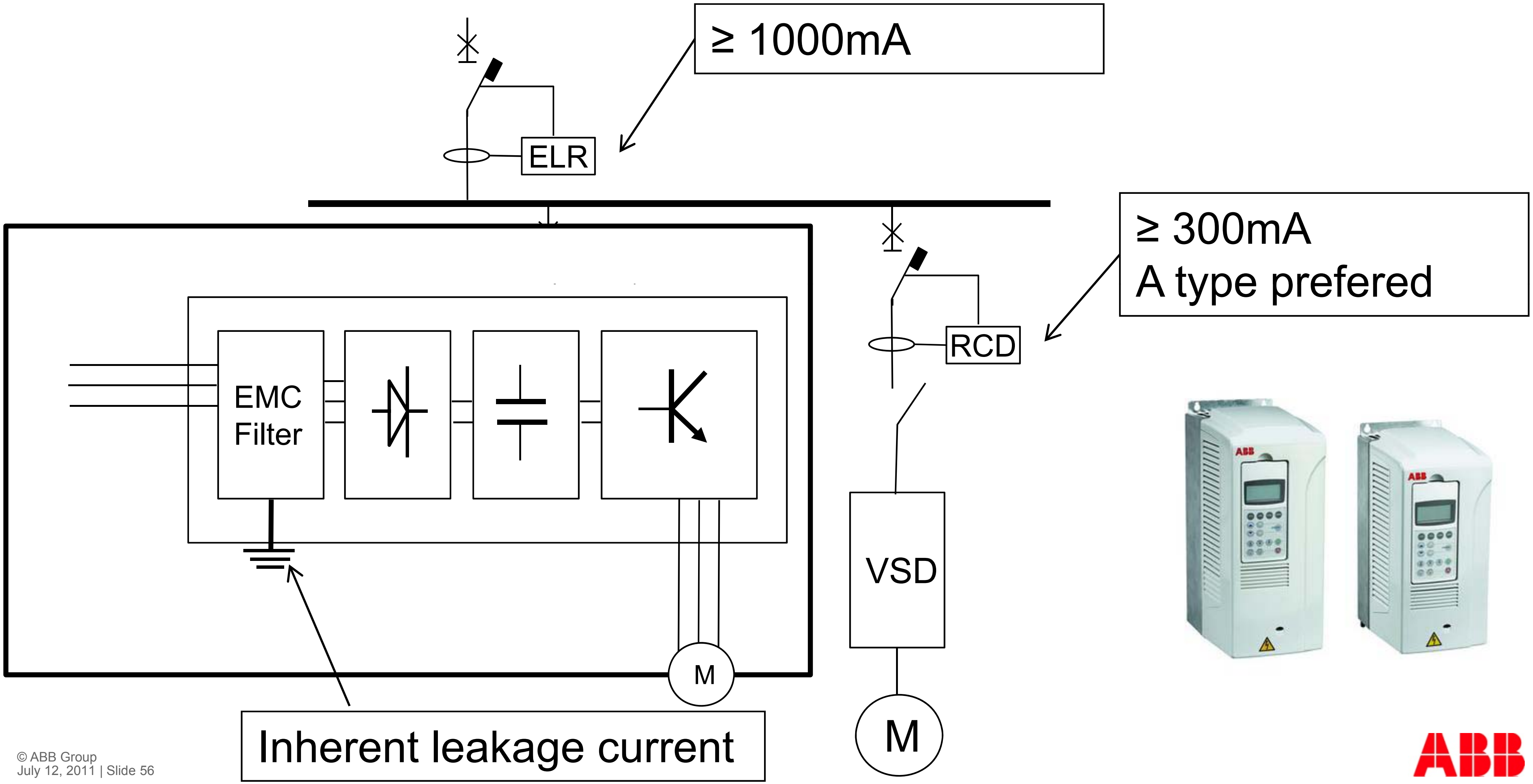
Earthing System – Motor Protection
Main and Feeder Circuit

Advisible for the motor motor circuit to add ELR or EFR



Earthing System – VSD
Main and Feeder Circuit

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



Earthing System – Total Solutions
RCD, RCCB, ELCB, RCBO, ELR, EFR

Earthing System – Total Solutions
Avoid Nuisance Tripping

- Select correct type tested product with relevant standards especially the EMC compliances.
- Consider using auto-reclosurer.

Power and productivity
for a better world™

Additional Info

Protection of lines

■ Protection against indirect contact

Verification about the Max Length protected against indirect contact for TN systems with neutral conductor not distributed

$$L_{max} = \frac{0.8 \cdot U \cdot S}{1.5 \cdot \rho \cdot 2 \cdot I_{min}}$$

U = rated voltage of the system (V)

I_{min} = minimum short circuit current value (A)

S = Phase conductor cross-section (mm^2)

ρ = conductor resistivity @ 20 °C ($\Omega \cdot mm^2/m$) [0.018-copper/0.027-aluminium]

Protection of lines

■ Protection against indirect contact

Verification about the Max Length protected against indirect contact for TN systems with neutral conductor distributed

$$L_{max} = \frac{0.8 \cdot U_0 \cdot S}{1.5 \cdot \rho \cdot (1+m) \cdot I_{min}}$$

U_0 = phase to ground voltage of the system (V)

I_{min} = minimum short circuit current value (A)

S = Phase conductor cross-section (mm^2)

ρ = conductor resistivity @ 20 °C ($\Omega \cdot mm^2/m$) [0.018-copper/0.027-aluminium]

m = ratio between neutral conductor resistance and phase conductor resistance

Protection of lines

■ **Protection against indirect contact**

The protection of the cable is assured if:

$$I_{\min} \geq 1.2 \cdot I3$$

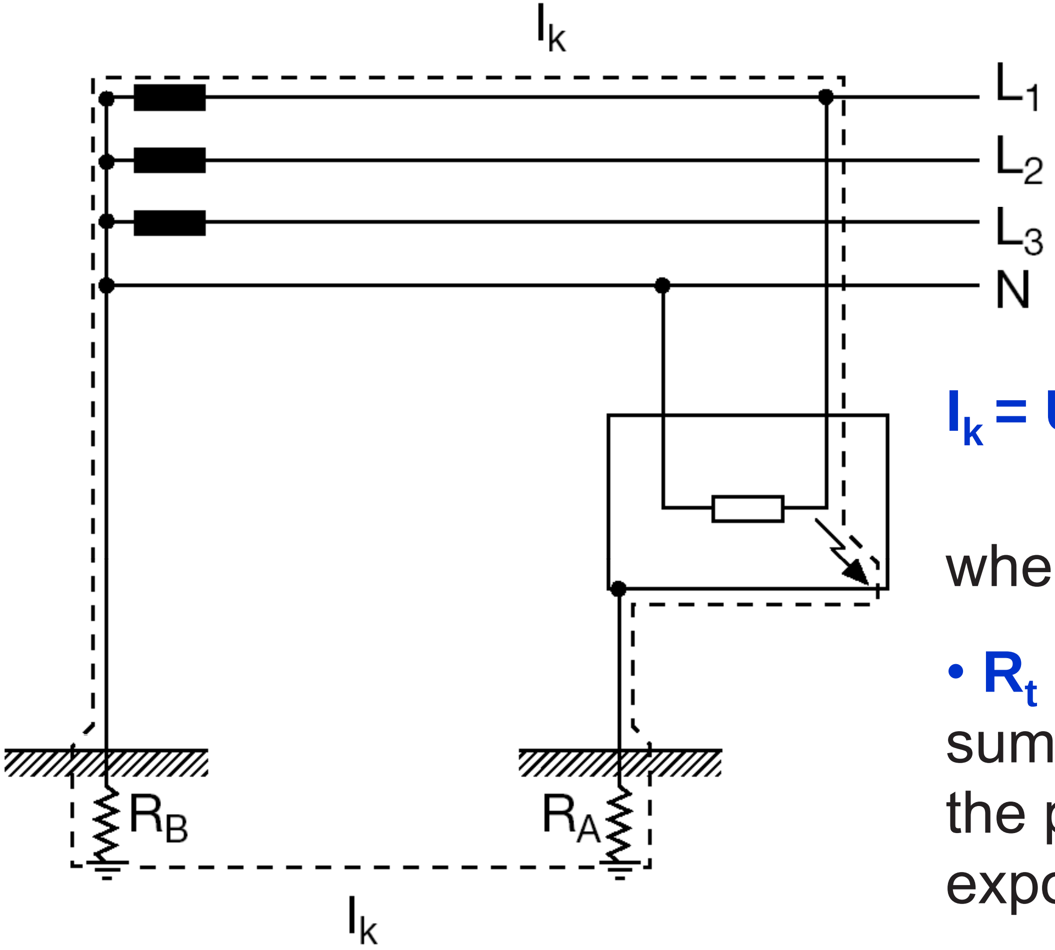
Magnetic threshold

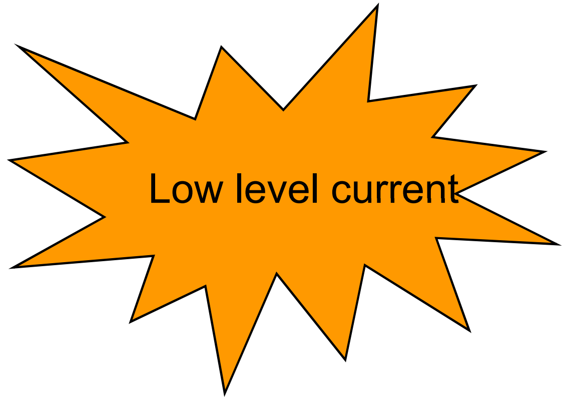
Max magnetic threshold tolerance

ABB

Indirect Contacts TT system

Fault current in TT





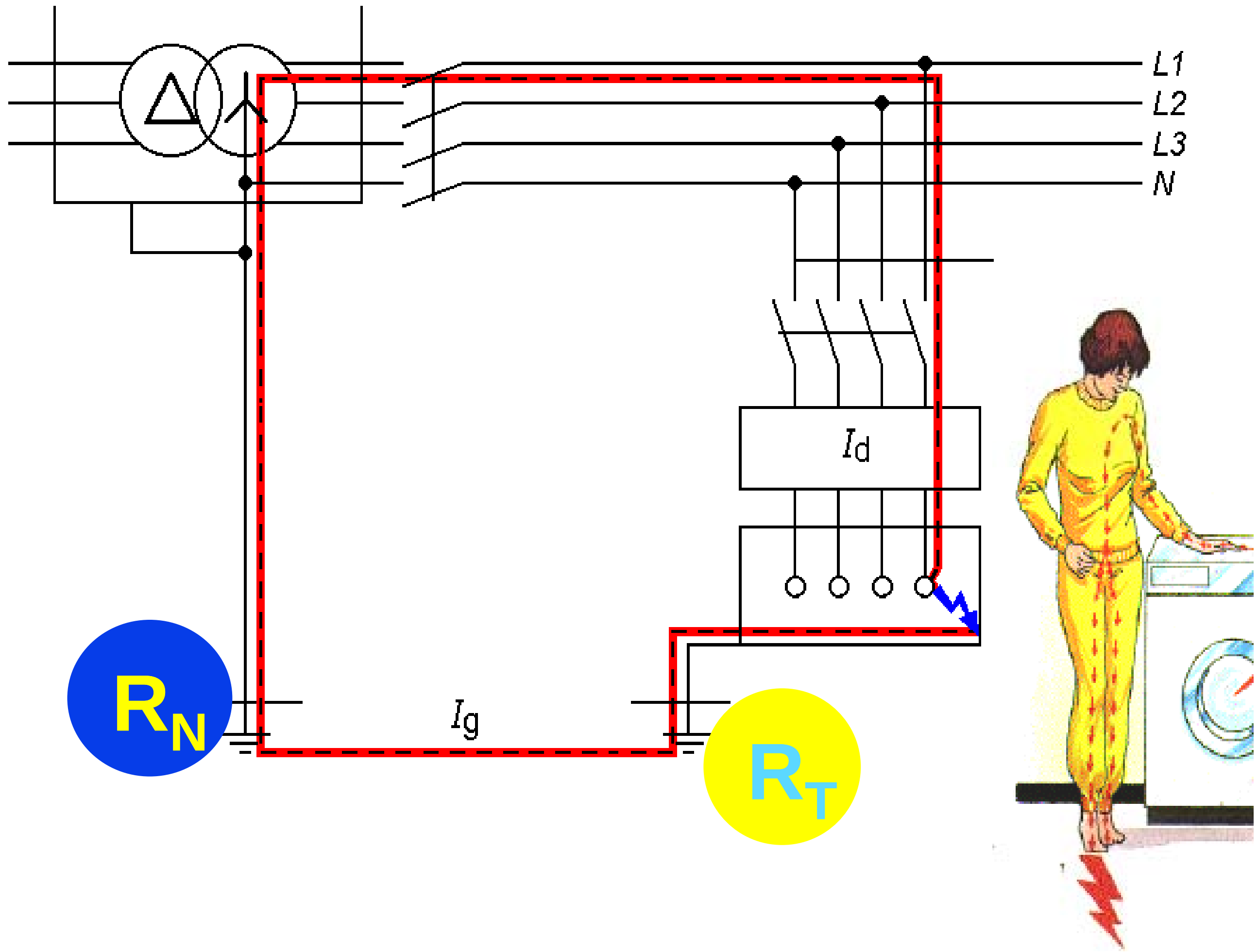
$I_k = U_0 / R_t$

where:

- R_t is the total resistance, equal to the sum of the earth electrode (RA) and the protective conductor for the exposed conductive parts [Ω];
- U_0 is the rated voltage between phase and ground

Max admissible voltage in TT system

MV/LV Transformer



$$R_T \leq \frac{50}{Id}$$

R_T Ground resistance

I_d Tripping differential current

- G or S type

~~**- Max delay 1 sec distribution circ.**~~

50 V normal environment

→**25 V** shipyard, ambulatory, stable

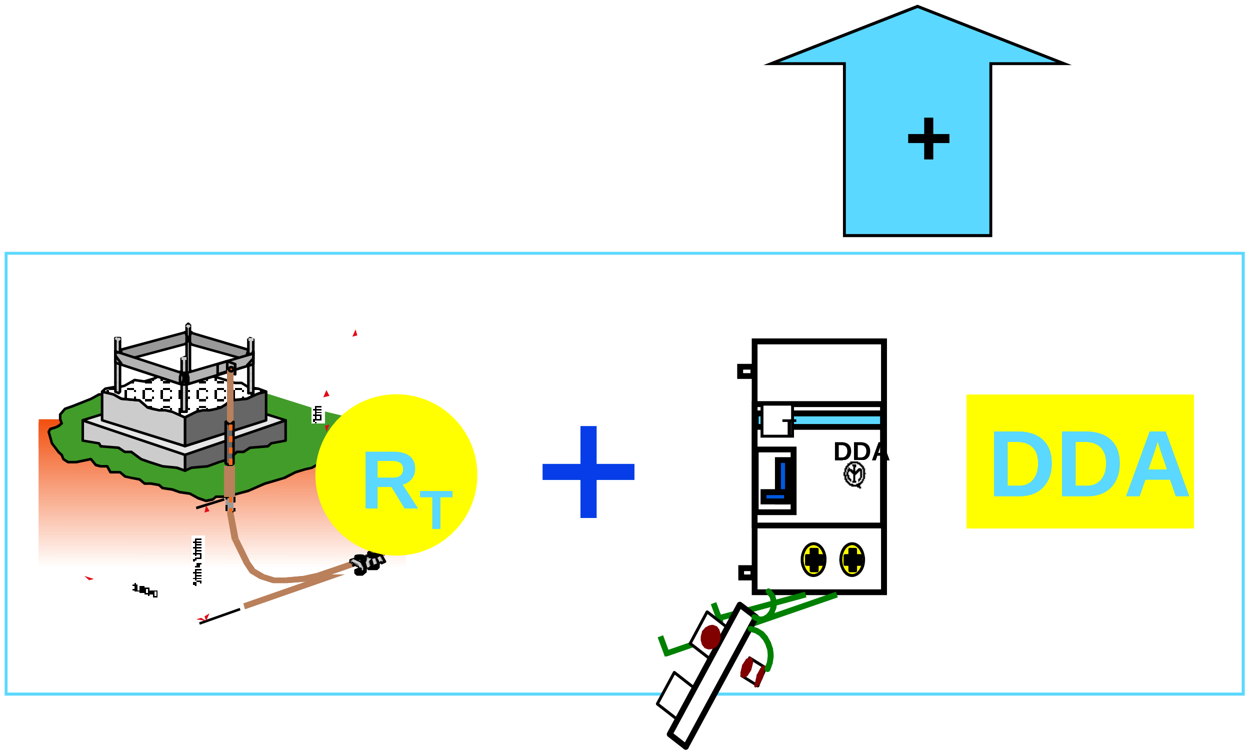
TT Sistems

Nominal currents $I_{\Delta n}$		Ground resistance R_t	
5	mA	10	kΩ
10	mA	5	kΩ
30	mA	1666	Ω
100	mA	500	Ω
300	mA	166	Ω
500	mA	100	Ω
1	A	50	Ω
3	A	16,6	Ω
5	A	10	Ω
10	A	5	Ω
20	A	2,5	Ω

Indirect protection normally done with a RCD + a coordination with Ground resistance

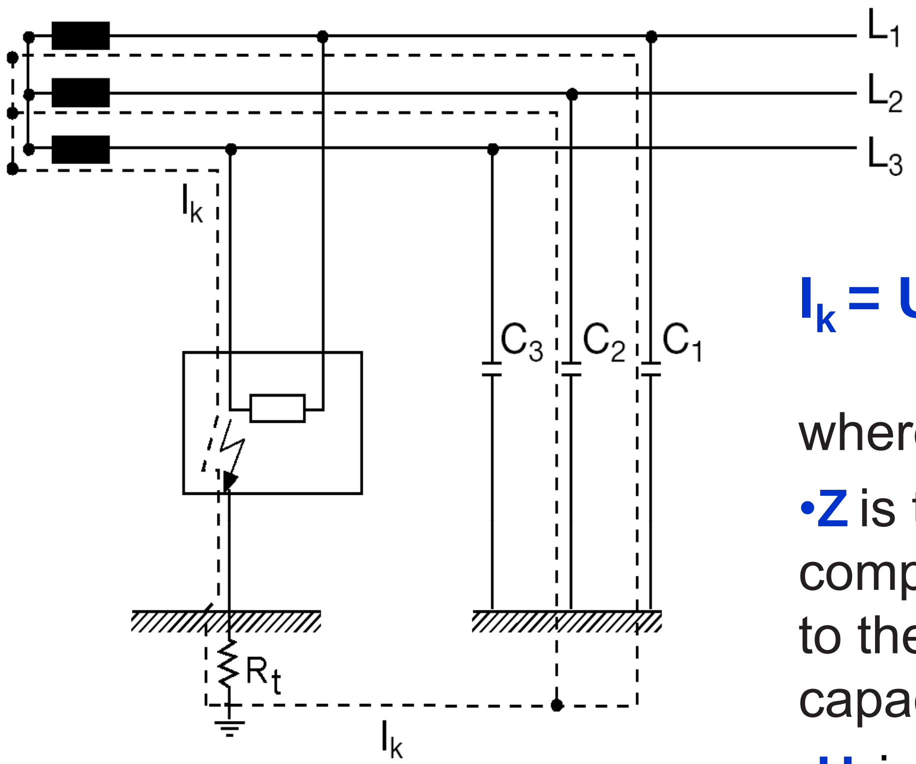
Security

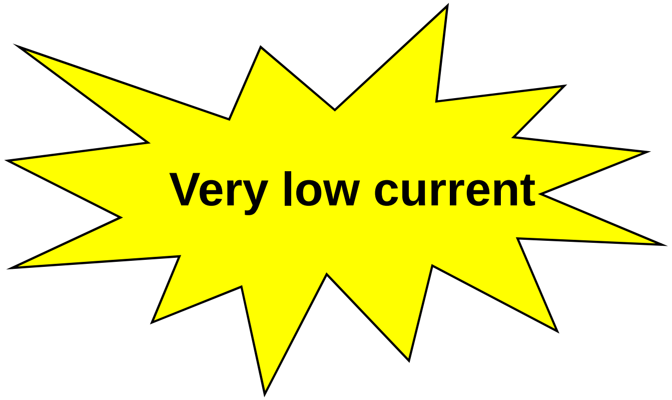
30mA



LVI – Cap 5 : Indirect Contacts

Fault current in IT (first fault)





$I_k = U_r / Z$

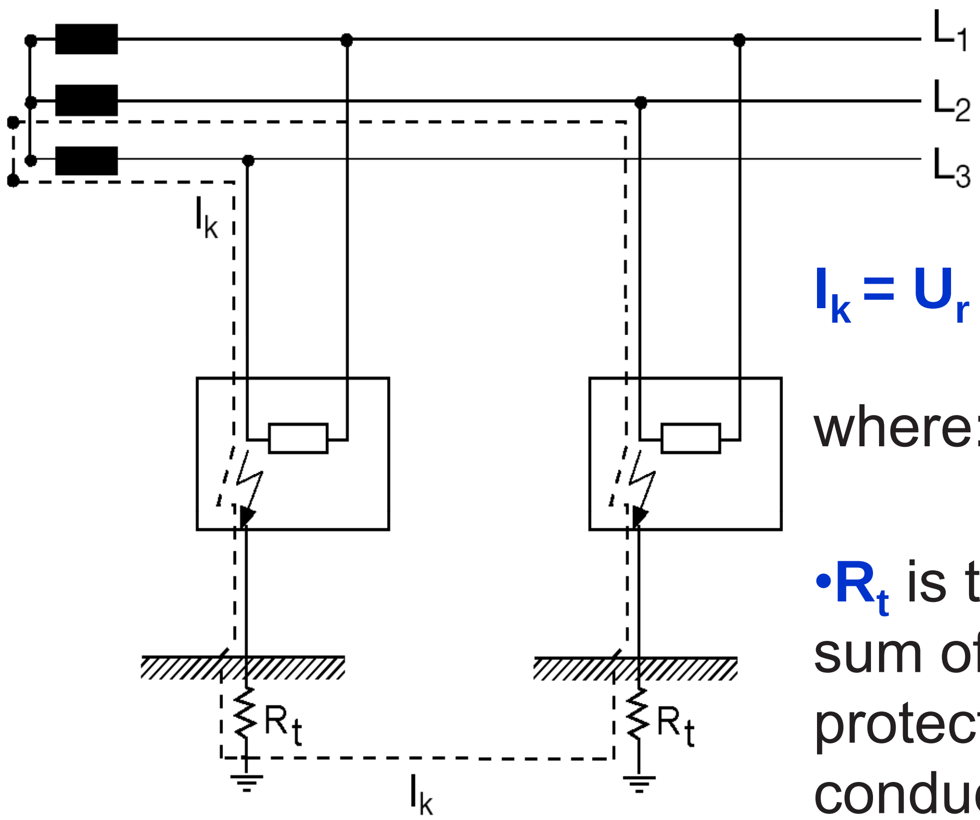
where:

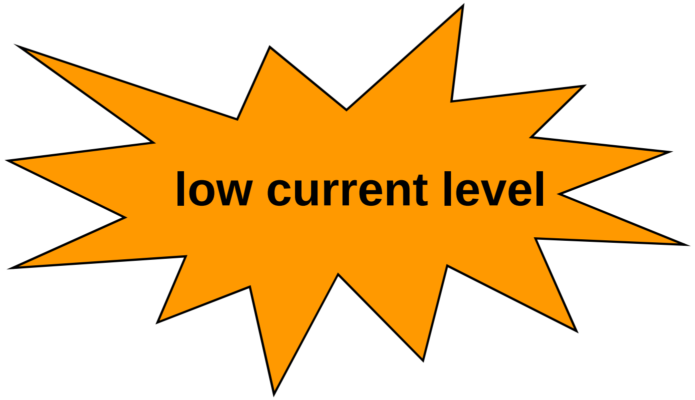
- **Z** is the impedance of the fault loop comprising the source, the live conductor up to the point of the fault and the line capacitance;
- U_r is the rated voltage between phases

NB:usually, I_k is measured and not calculated.

LVI – Cap 5 : Indirect Contacts

Fault current in IT (second fault, IT ->TT)





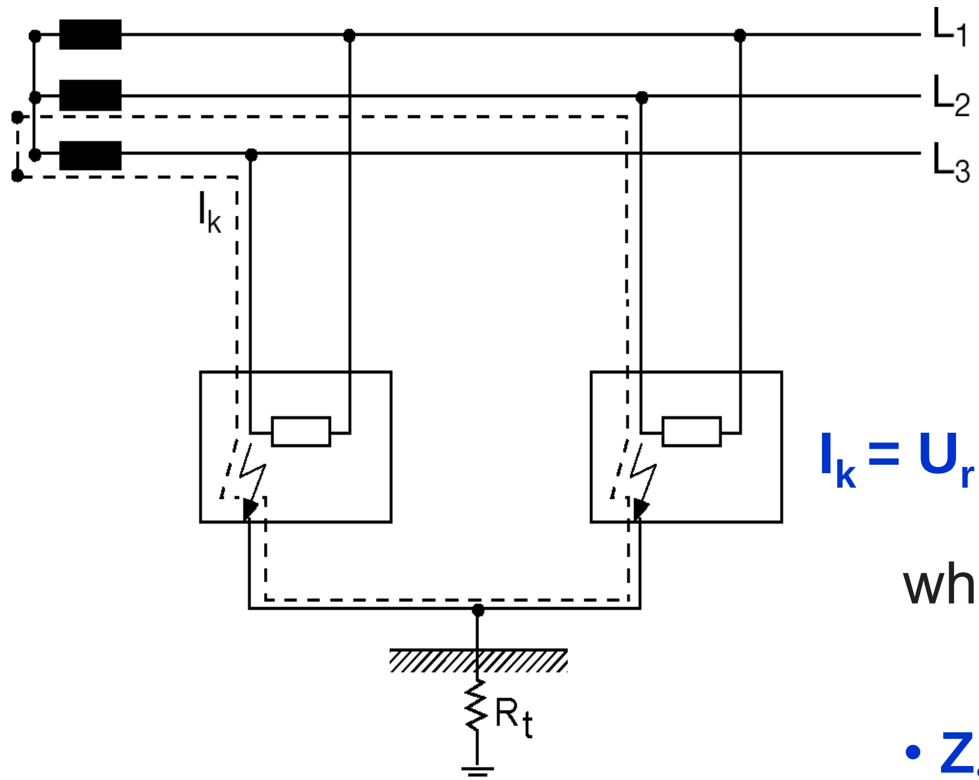
$I_k = U_r / R_t$

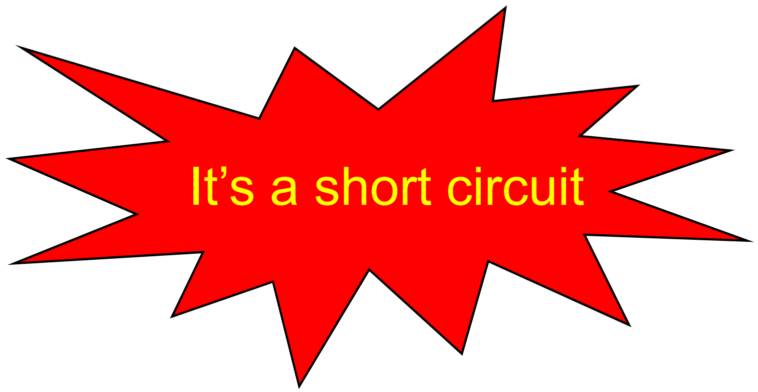
where:

•R_t is the total resistance, equal to the sum of the earth electrode (RA) and the protective conductor for the exposed conductive parts [Ω];

•U_r is the rated voltage between phases

Fault current in IT (second fault, IT ->TN)





$$I_k = U_r / 2Z_s$$

where:

- Z_s is the impedance of the fault loop comprising the phase conductor and the PE conductor;

- U_r is the rated voltage between phases

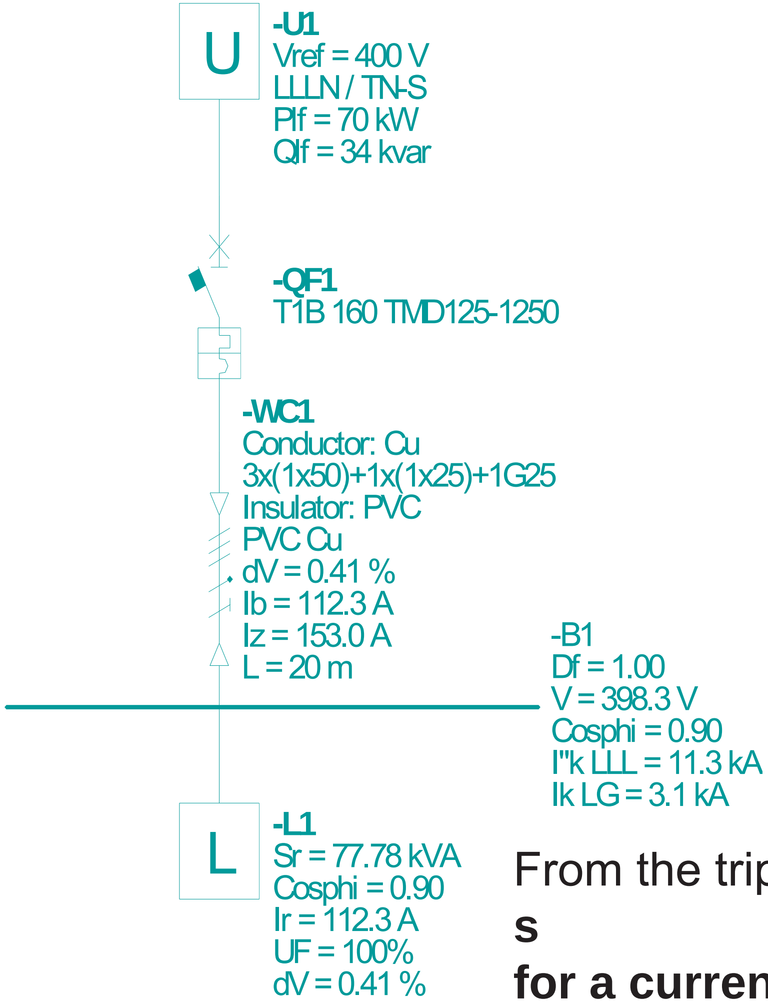
Table 41B – Maximum disconnecting time in IT systems (second fault)

Installation nominal voltage U_o/U V	Disconnecting time s	
	Neutral not distributed	Neutral distributed
120-240	0,8	5
230/400	0,4	0,8
400/690	0,2	0,4
580/1 000	0,1	0,2

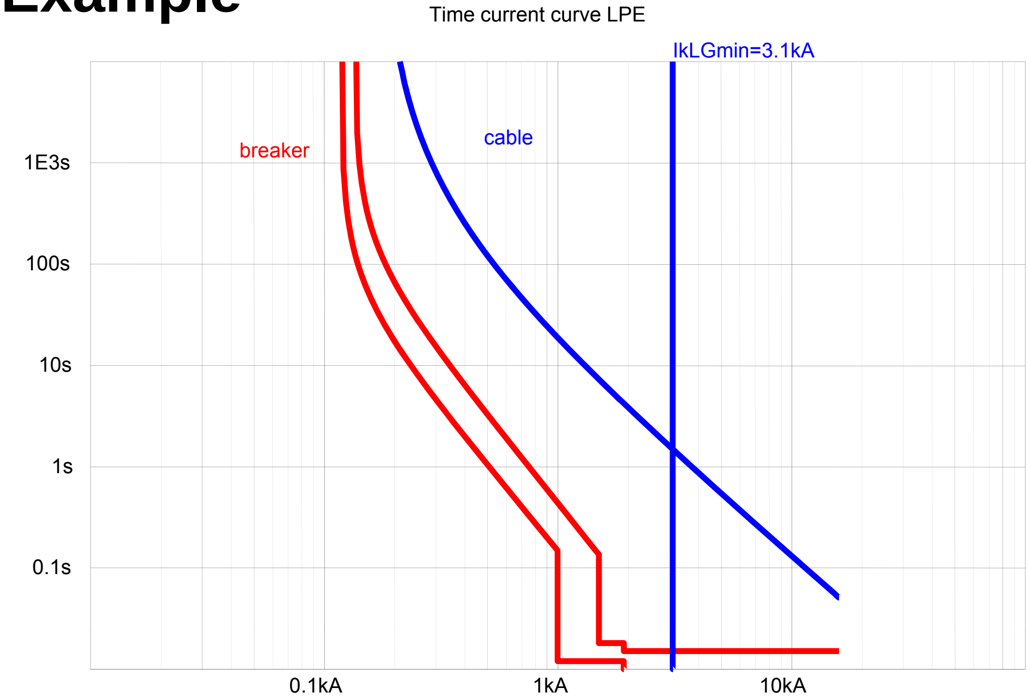
NOTE 1 For voltages which are within the tolerance band stated in IEC 60038, the disconnecting time appropriate to the nominal voltage applies.

NOTE 2 For intermediate values of voltage, the next higher value in the table is to be used.

LVI – Cap 7 : Protections and CBs selection

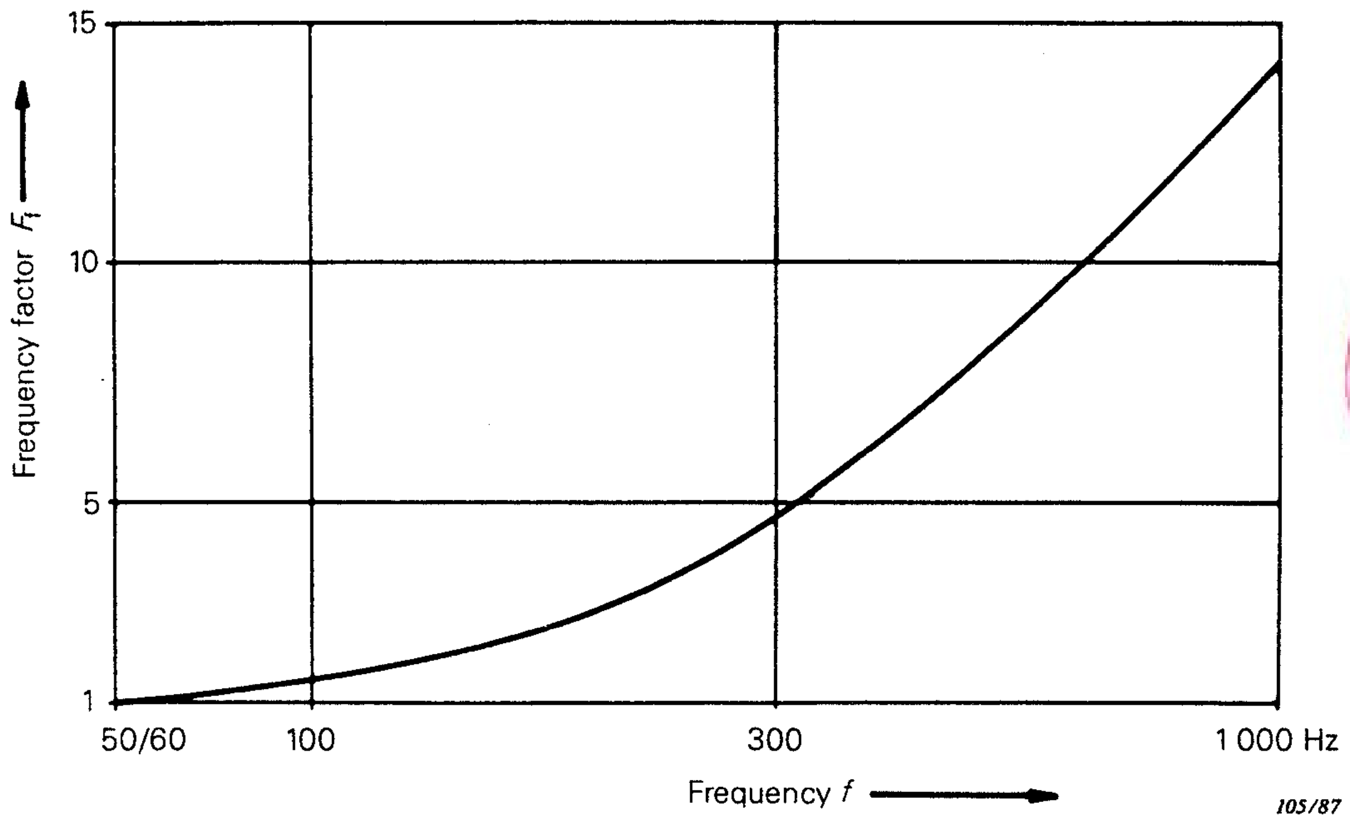


Example



From the tripping curve, it is clear that **the circuit-breaker trips in 0.4 s for a current value lower than 950 A.** As a consequence, **the protection against indirect contact is provided by the same circuit-breaker which protects the cable against short-circuit and overload,** without the necessity of using an additional residual current device.

Variation of ventricular fibrillation (479-1)



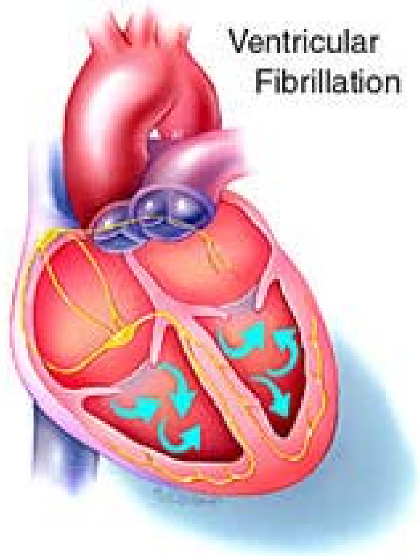
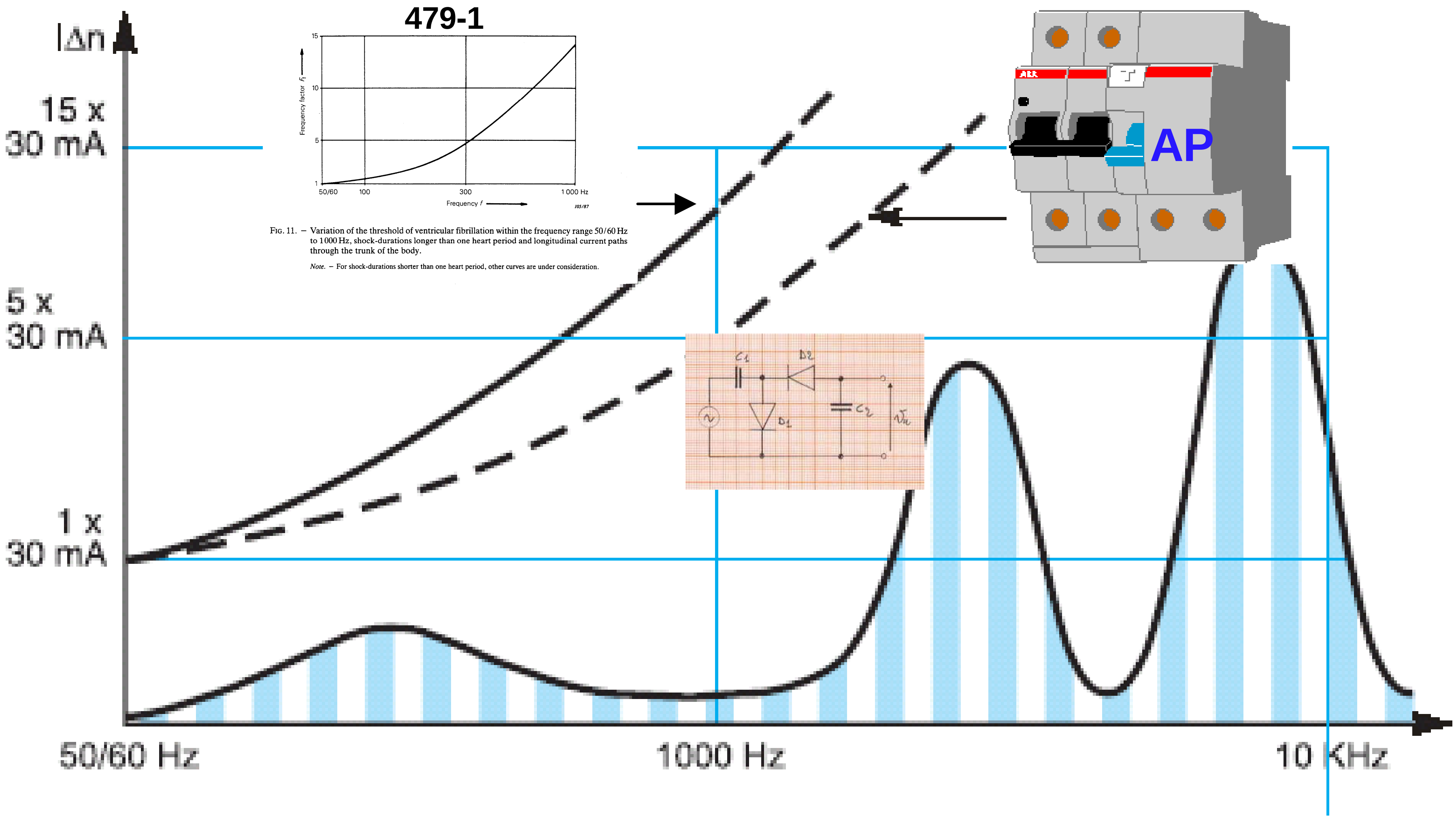


FIG. 11. – Variation of the threshold of ventricular fibrillation within the frequency range 50/60 Hz to 1000 Hz, shock-durations longer than one heart period and longitudinal current paths through the trunk of the body.

Note. – For shock-durations shorter than one heart period, other curves are under consideration.

A good compromise

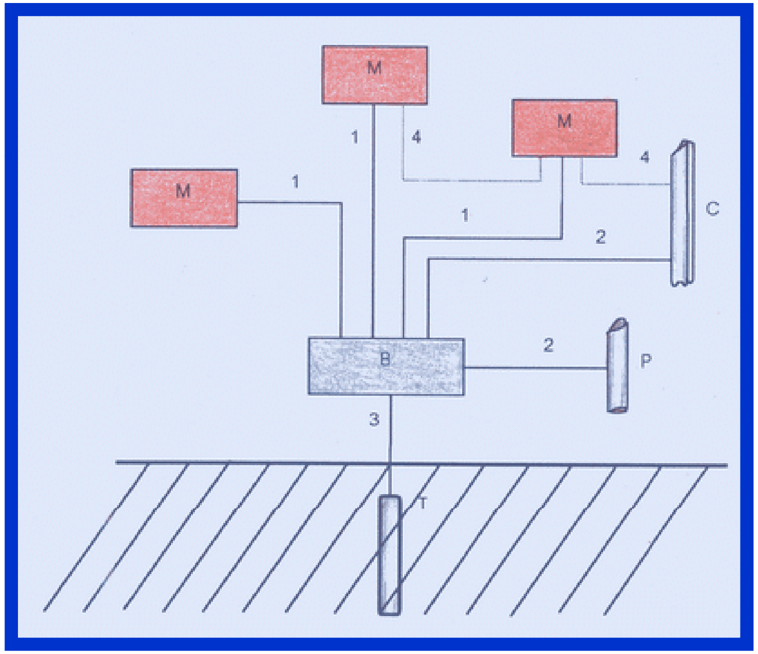


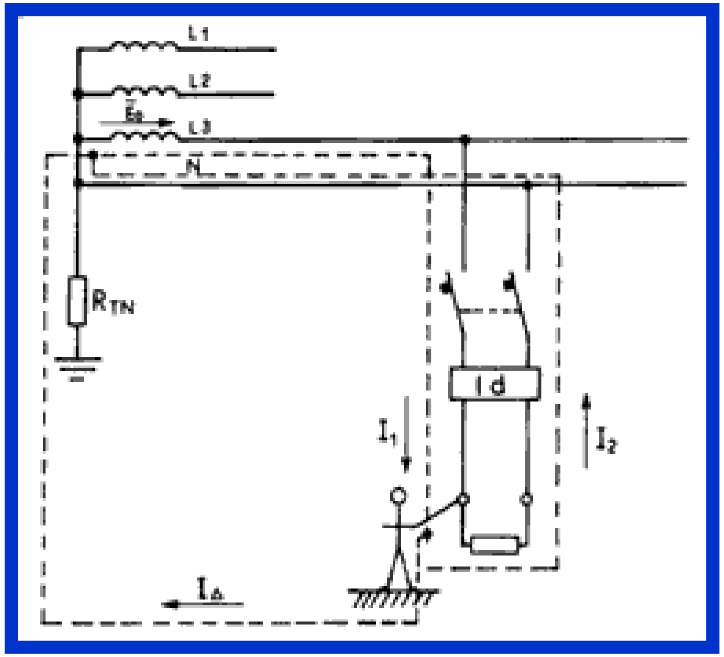
Indirect Contact Protection

The protection against indirect contact by the automatic disconnection of supply

needs

an appropriate Earthing Systems connected to all <u>exposed conductive parts</u>





Earthing Systems: TN SYSTEM

Power system:
One point directly earthed (normally N point)

Electrical installations:
Exposed conductive parts connected to that point by protective conductors (PE or PEN)

TN-S system: neutral and protective functions realised by separate conductors (N and PE)
TN-C system: neutral and protective functions combined in a single conductor (PEN)
TN-C-S system: neutral and protective functions combined in a single conductor in a part of the system

Earthing Systems : TN SYSTEM

TN-S, TN-C and TN-C-S systems

- Typical applications:
  industrial, utilities or building installations fed from the M.V. network;
- Medium/high TN-S values of short-circuit currents to earth
- Protection against earth-faults:
  overcurrent protective devices
  residual current protective device or ground-fault releases (G function) ***only*** in TN-S system

- TN-C systems: PEN-conductor ***can't*** be interrupted

Disconnecting time in TN systems

Table 41A – Maximum disconnecting times for TN systems

U_o * V	Disconnecting time s
120	0,8
230	0,4
277	0,4
400	0,2
>400	0,1

* Values based on IEC 60038.

Earthing Systems: TT SYSTEM

Power system:
One point directly earthed (normally N point)

Electrical installations:
Exposed conductive parts connected to earth electrodes electrically independent of the earth electrodes of the power system.

Earthing Systems: TT SYSTEM

- Typical applications:
  domestic and small industrial installations fed by the utilities directly from the low-voltage network

- Small values of short-circuit currents to earth:
  typically 10 to 100 A

- Protection against earth-faults:
  residual current protective device
  overcurrent protective devices

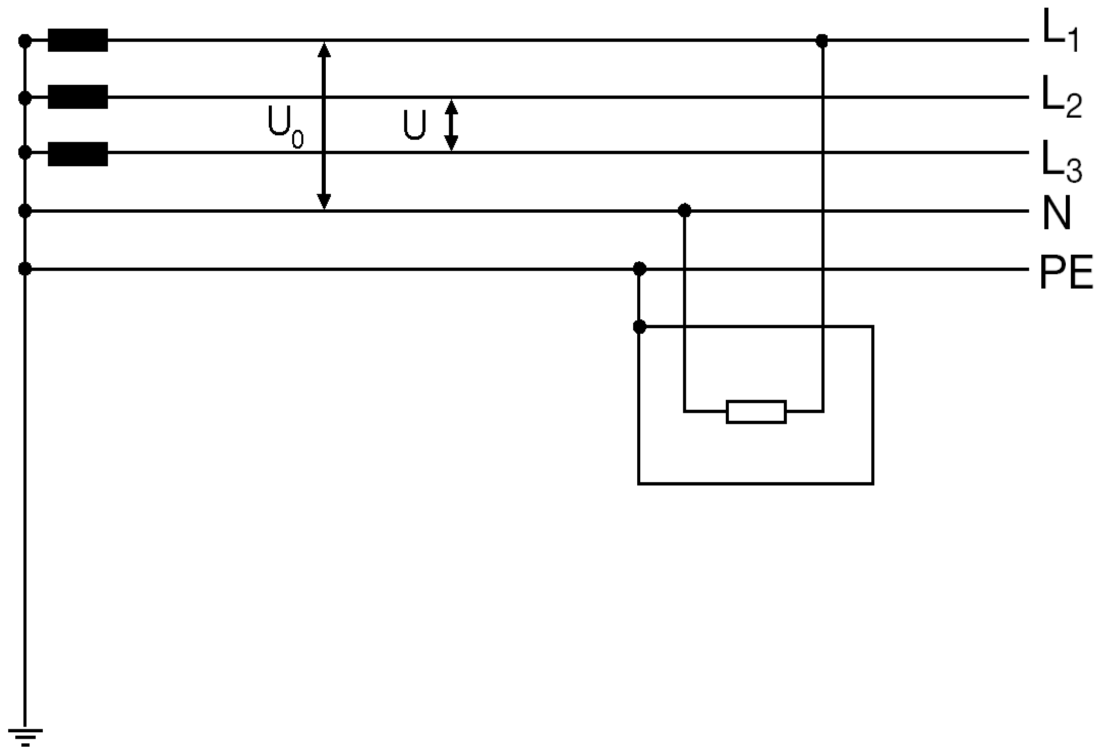
Earthing Systems: Neutral conductor

The neutral conductor is connected to the neutral point of the system and it contributes to power transmission

- It makes available a voltage U_0 different from the phase to phase voltage U
- It makes the single-phase loads functionally independent from each other
- It makes the star voltage system symmetrical enough even in the presence of non-symmetrical loads
- Under specific conditions, the functions of neutral conductor and protective conductor can be combined in a single conductor PEN (TN-C system)

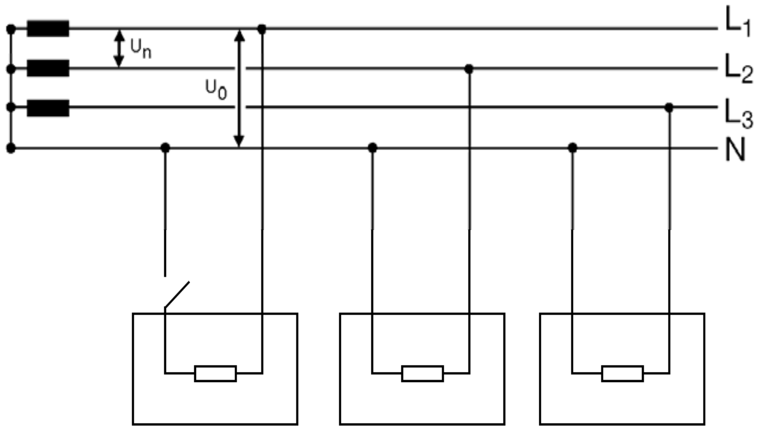
Earthing Systems: Neutral conductor

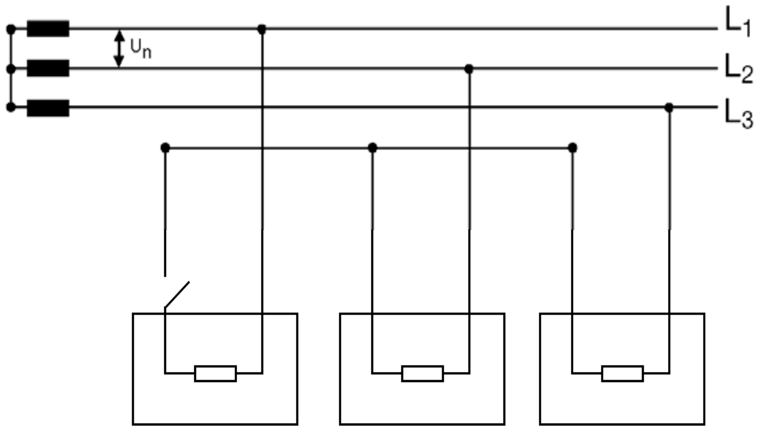
It makes available a voltage U_0 different from the phase to phase voltage U



Earthing Systems: Neutral conductor

It makes the single phase loads functionally independent from each other

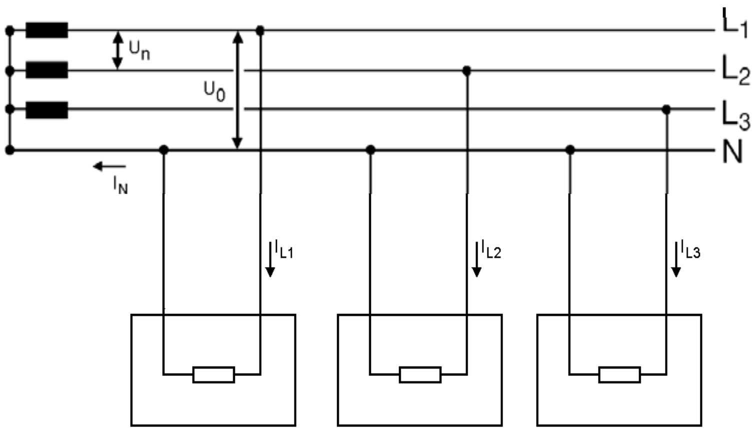


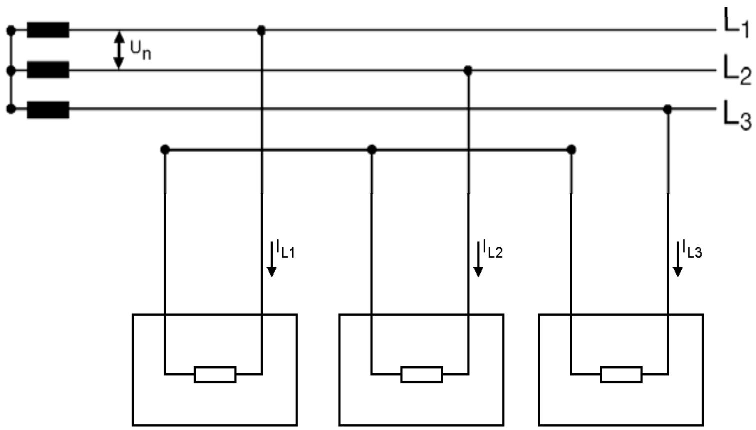


In absence of the neutral conductor, the disconnected load induces the other two loads to work at a voltage equal to Un/2

Earthing Systems: Neutral conductor

It makes the star voltage system symmetrical enough even in the presence of non-symmetrical loads





In absence of the neutral conductor, the sum of the currents on the loads must be zero and this causes a dissymmetry of voltages

The presence of the neutral conductor and its reduced impedance binds
the value of the star point on the load to the ideal one

Earthing Systems: Neutral conductor

Protection of the neutral conductor:

TT or TN systems:

- If $S_N \geq S$ no breaking devices are needed to protect the neutral

- If $S_N < S$ neutral protected but not disconnected:
  - Detection of neutral currents is needed
  - Opening of the phase contacts is needed
  - Opening of the neutral contact is not needed
  - If $I_{NMax} < I_{Nz}$ detection of neutral currents is not needed too

- In TN-C systems the neutral conductor cannot be disconnected

Earthing Systems: Neutral conductor

Protection of the neutral conductor:

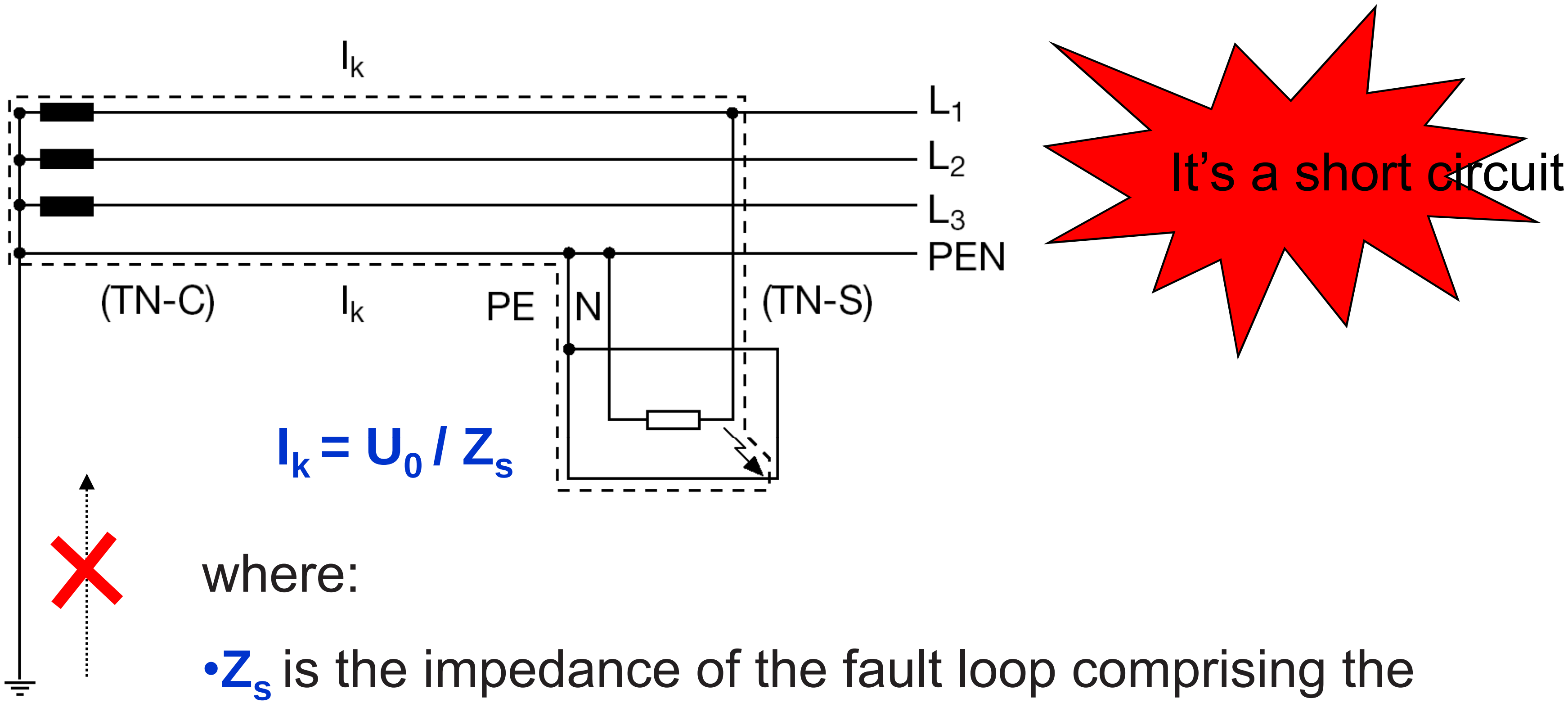
IT systems:

- It is strongly recommended that the neutral should not be distributed
- If it is distributed:
  - Detection of neutral currents is needed
  - Opening of all the contacts (phase and neutral) is needed

- Detection of neutral currents is not necessary :
    - If the neutral is protected against SC by an upstream protective device
    - Or
    - If the circuit is protected by a RCD with $I_{\Delta n} \leq 0.15 \cdot I_{Nz}$

Indirect Contacts in TN-C-S system

Fault current in TN (C-S)



$I_k = U_0 / Z_s$

where:

• Z_s is the impedance of the fault loop comprising the source, the live conductor up to the point of the fault and the protective conductor between the point of the fault and the source [Ω];

• U_0 is the rated voltage between phase and ground

Thank You