Earthing systems in LV

Your body is conducting electricity…

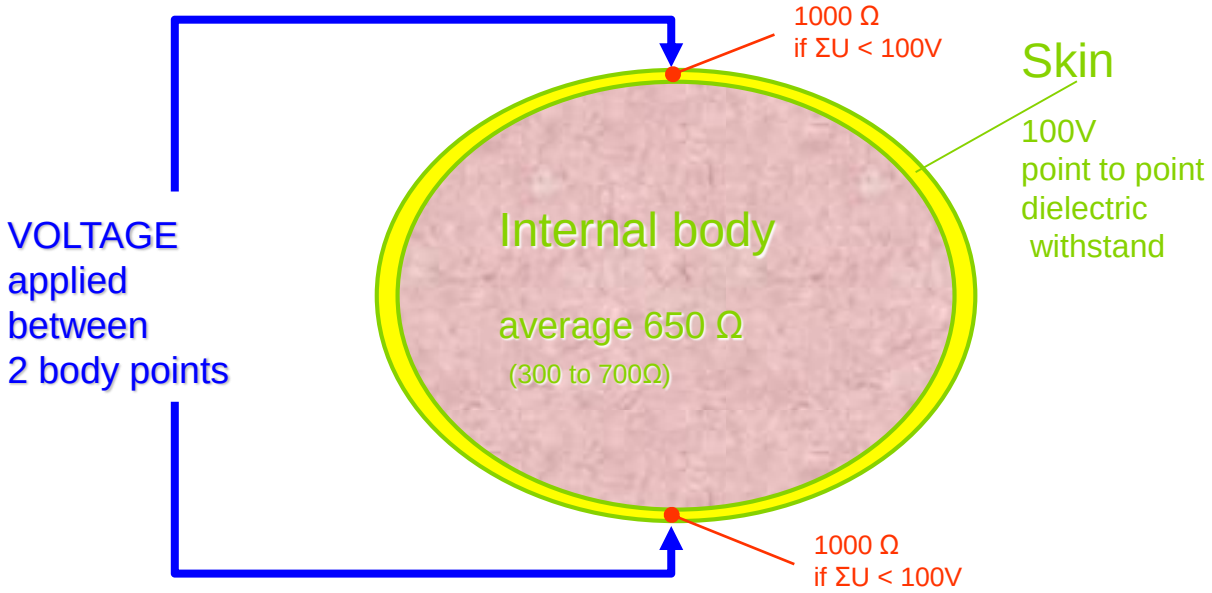
- Below 50 Volts skin impedance remains effective (approx 2000Ω)
  - Total impedance approximately 2500 Ω, so, the current is

    50V / 2500Ω = 20 mA = safe

  The cutaneous resistance varies:

  - it increases with the thickness of the keratinous layer
  - it decreases with the contact surface, pressure, hydration, duration and voltage

- Above 100Volts skin becomes fully conductive (flashed dielectric)
  - Remaining impedance: internal body only =650Ω 100V / 650Ω = 150 mA ➔ Trip

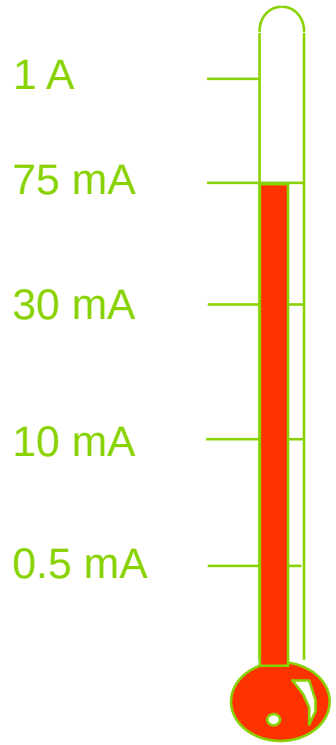


SAFE MAXIMUM CONTACT VOLTAGE is 50Volts

Body behaviour according to current level crossing over

> For average size person, and AC 50 Hz current

Current flowing trough body



1 A — Cardiac arrest

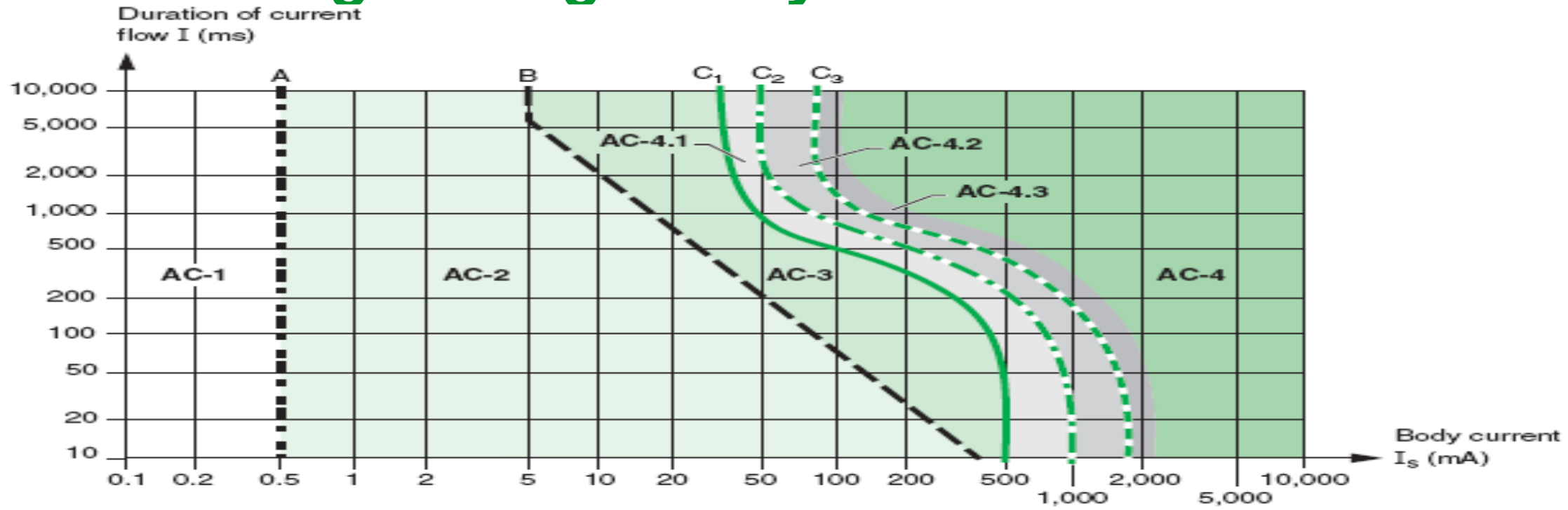
75 mA — Irreversible cardiac fibrillation threshold

30 mA — Respiratory paralysis threshold

10 mA — Non-release threshold, muscle contraction

0.5 mA — Perception threshold, very weak sensation

During how long can we safely withstand current flowing through body ?

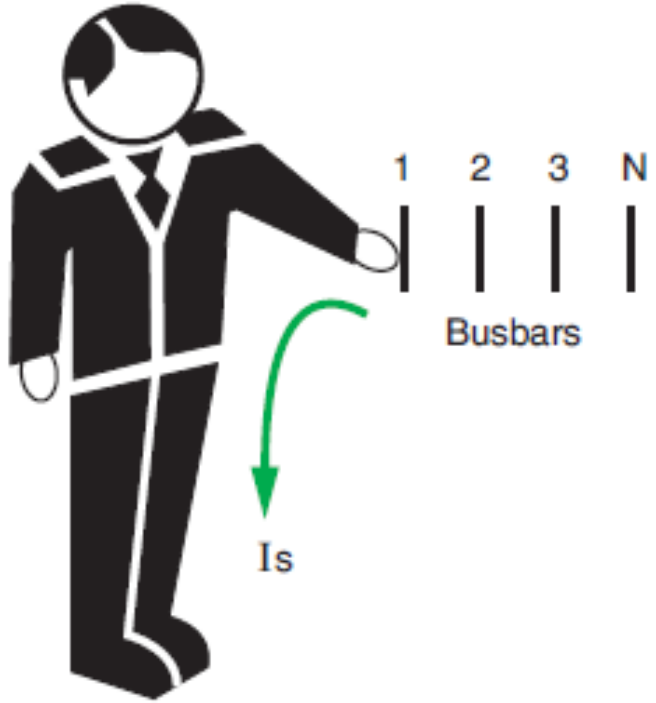


AC-1 zone: Imperceptible
AC-2 zone: Perceptible
AC-3 zone : Reversible effects: muscular contraction
AC-4 zone: Possibility of irreversible effects
AC-4-1 zone: Up to 5%probability of heart fibrillation
AC-4-2 zone: Up to 50% probability of heart fibrillation
AC-4-3 zone: More than 50% probability of heart fibrillation

A curve: Threshold of perception of current
B curve: Threshold of muscular reactions
C_1 curve: Threshold of 0% probability of ventricular fibrillation
C_2 curve: Threshold of 5% probability of ventricular fibrillation
C_3 curve: Threshold of 50% probability of ventricular fibrillation

Zones time/current of effects of AC current on human body when passing from left hand to feet

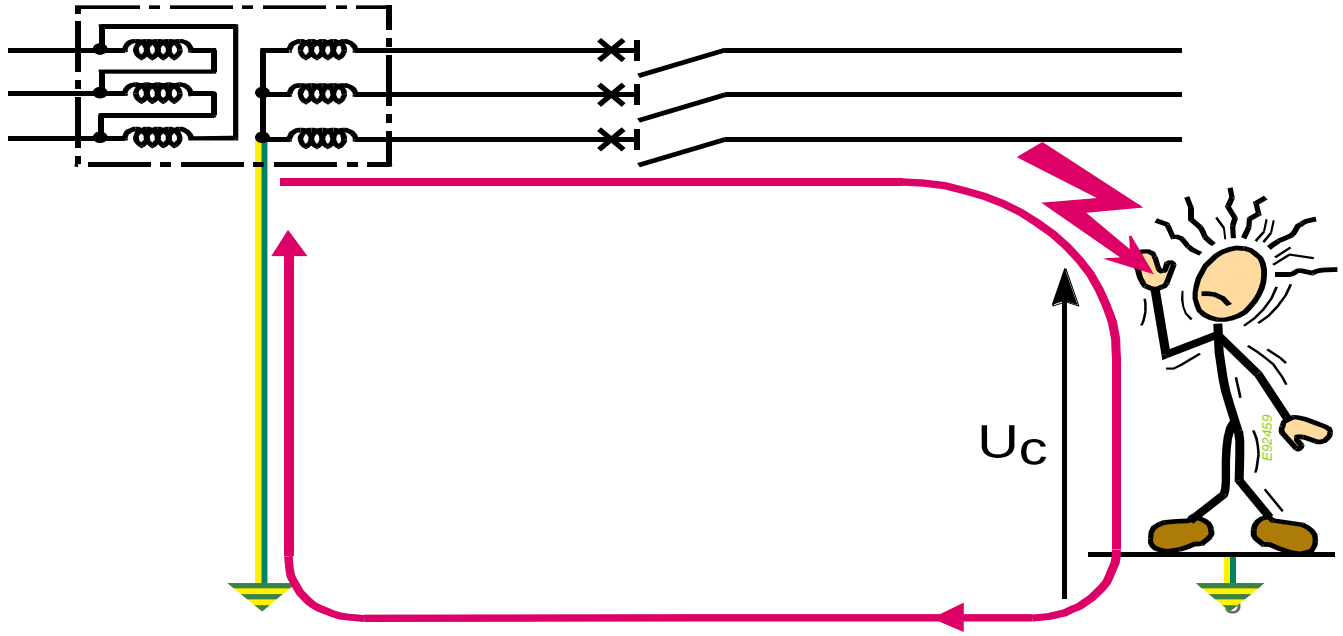
Direct Contact



Is: Touch current

A direct contact refers to a person coming into contact with a conductor which is live in normal circumstances

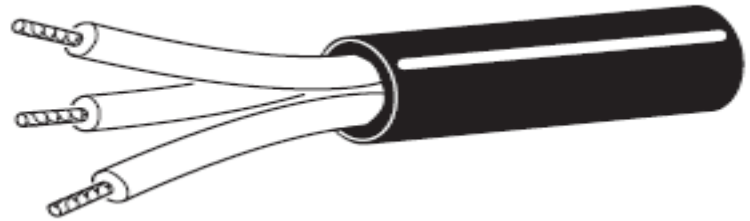
IEC 61140 standard has renamed "**protection against direct contact**" with the term "**basic protection**". The former name is at least kept for information.



Protection against direct contact

- **Protection by the insulation of live parts**

This protection consists of an insulation which complies with the relevant standards**. Paints, lacquers and varnishes do not provide an adequate protection**



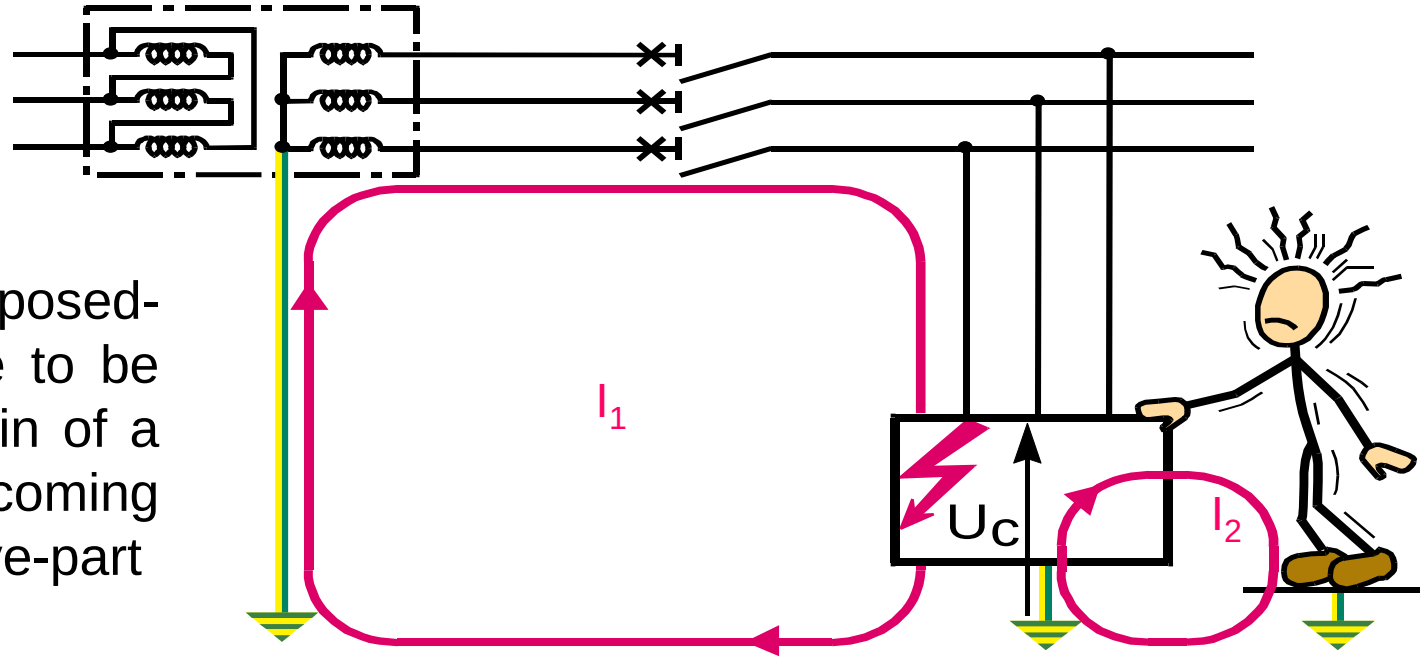
- **Protection by means of barriers or enclosures**

This measure is in widespread use, since many components and materials are installed in cabinets, assemblies, control panels and distribution boards

Indirect Contact

An indirect contact refers to a 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).

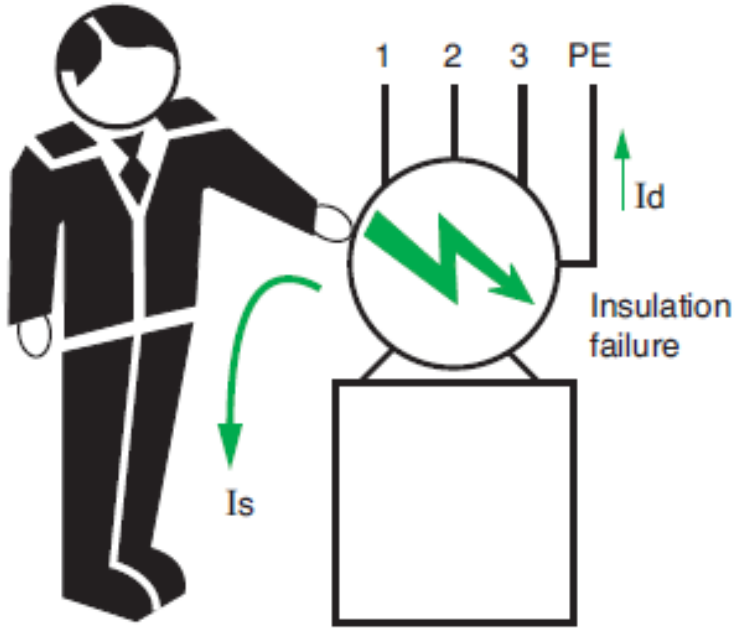
The **fault current I_1** raises the exposed-conductive-part to a **voltage Uc** liable to be hazardous which could be at the origin of a **touch current I_2** through a person coming into contact with this exposed-conductive-part



Indirect Contact

IEC 61140 standard has renamed “**protection against indirect contact**” with the term “**fault protection**”.

The former name is at least kept for information.



Id: Insulation fault current

Protection against indirect contact hazards can be achieved by automatic disconnection of the supply if the exposed-conductive-parts of equipment are properly **earthed**

LV earthing systems

Earth:
the conductive mass of the Earth, whose electric potential at any point is conventionally taken as zero.

Earth electrode:
a conductor or group of conductors in close contact with, and providing an electrical connection with Earth.

Exposed-conductive-part:
a conductive part of equipment which can be touched and which is not a live part, but which may become live under fault conditions.

LV earthing systems

Extraneous-conductive-part:

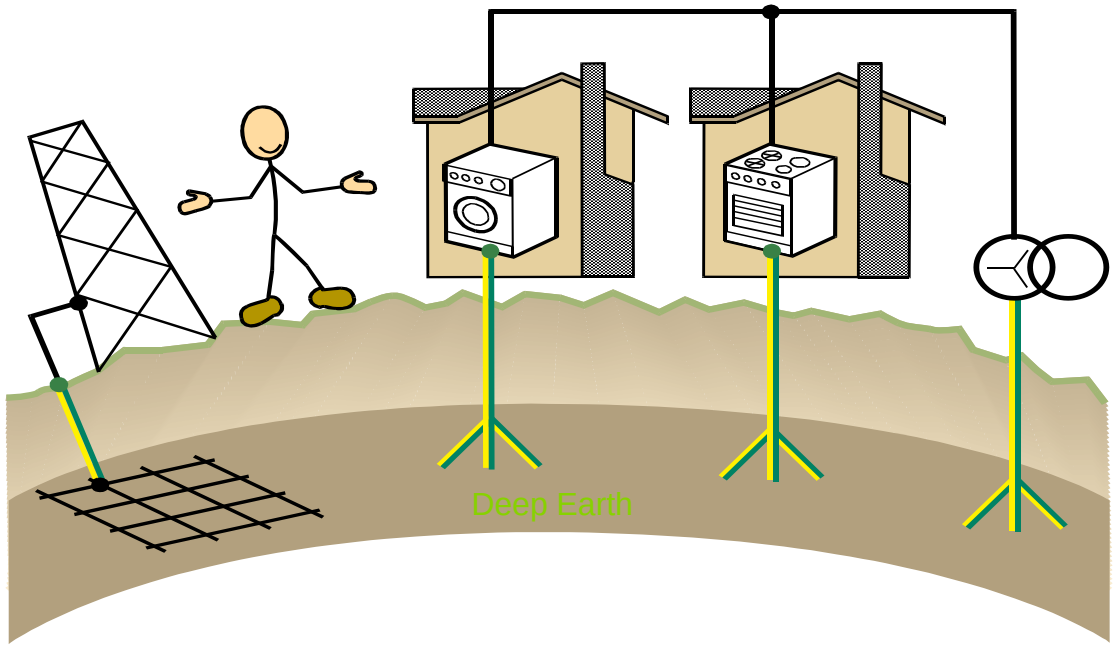
a conductive part liable to introduce a potential, generally earth potential, and not forming part of the electrical installation. (such as steel-framed structure work of buildings, metal conduits and pipe work for water.)

Protective conductor (PE):

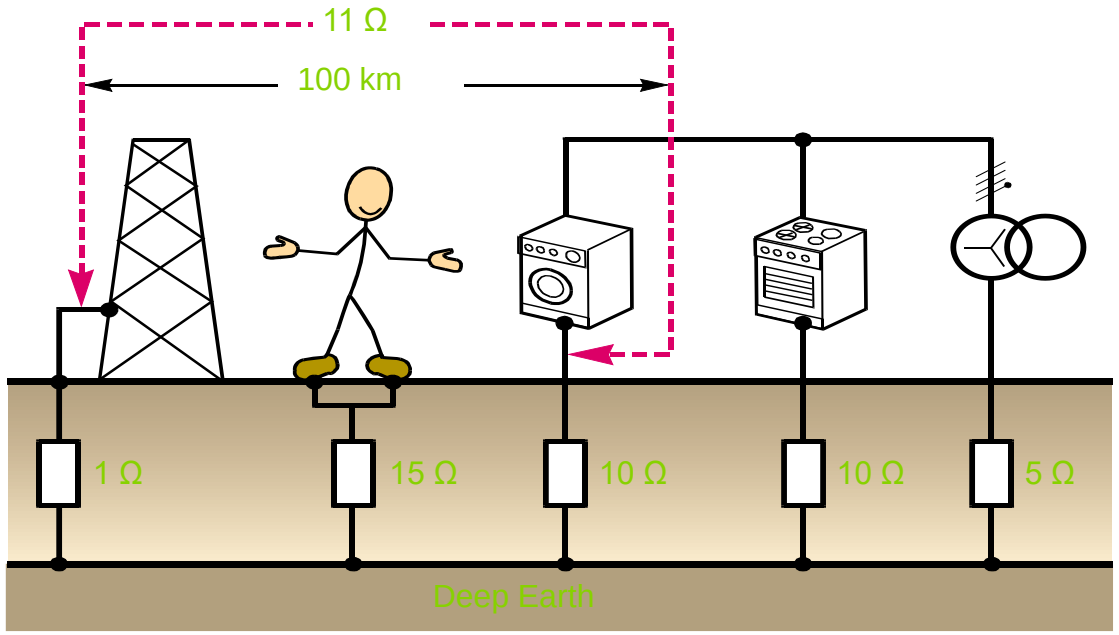
a conductor used for some measures of protection against electric shock and intended for connecting together any of the following parts:
exposed-conductive-parts, extraneous-conductive-parts, the main earthing terminal, earth electrode (s), the earthed point of the source or an artificial neutral;

Understanding Deep Earth behavior

❑ Deep Earth is perfectly conducting,
it would act as an equipotential bonding if it could be reached with no impedance



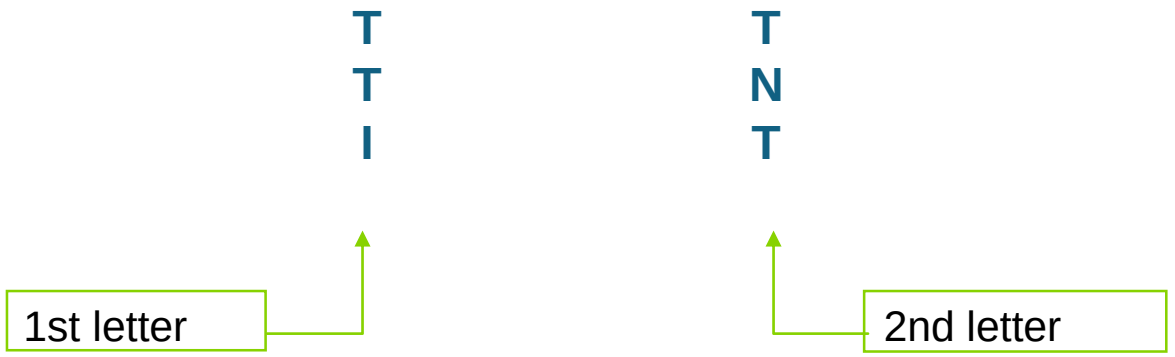
❑ But it cannot be reached without few ohms in series, these Ohms are fortunately limiting fault current



LV earthing systems

Identification of standardized LV earthing systems

- **System**



situation of supply neutral / earth:

T = direct connection to earth.

I = isolated (unearthed) or (impedance-earthed)

situation of installation frames / earth :

T = frames directly earthed

N = frames connected to the supply neutral point which is earthed

TN system complementary letters:

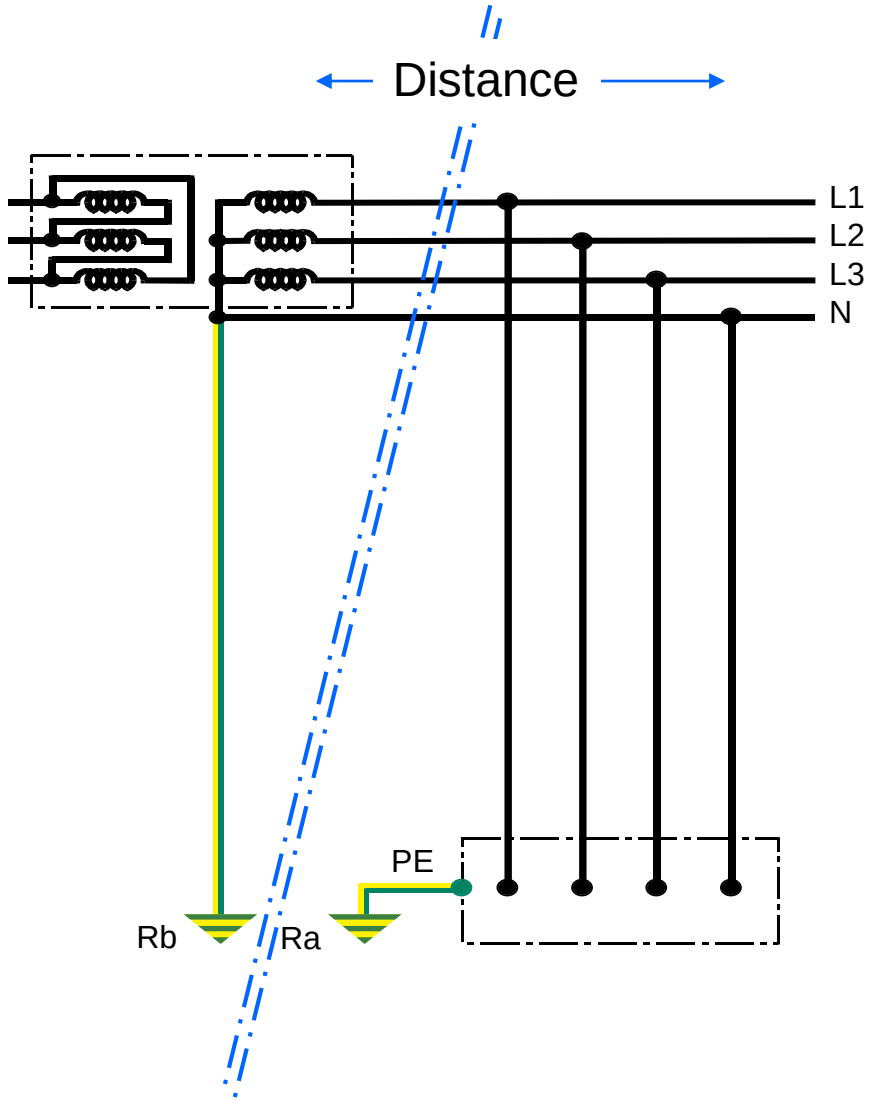
C = (PE) protective conductor connected to (N) = (PEN)

S = (PE) protective conductor is separate from (N)

C-S = Part of the system uses a combined (PEN) conductor, while at some point splits up into separate (PE) and (N).

1. TT scheme

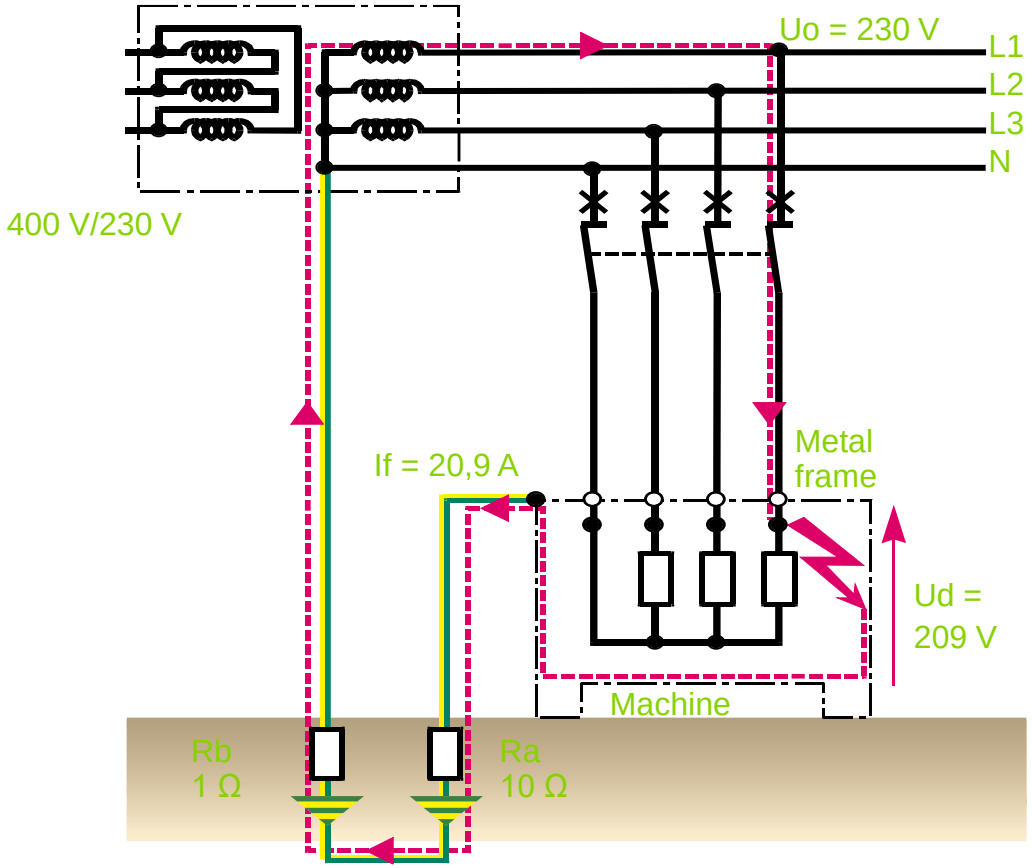
Definition



- Neutral of transformer is earthed separately (generaly away) from LV loads frames,
  earthed all together but locally

1. TT scheme

Example of Earth leakage



Fault current value:

If = Uo / (Rb + Ra)

= 230 / (10 + 1)

= 20,9 A

Ud = Ra x If

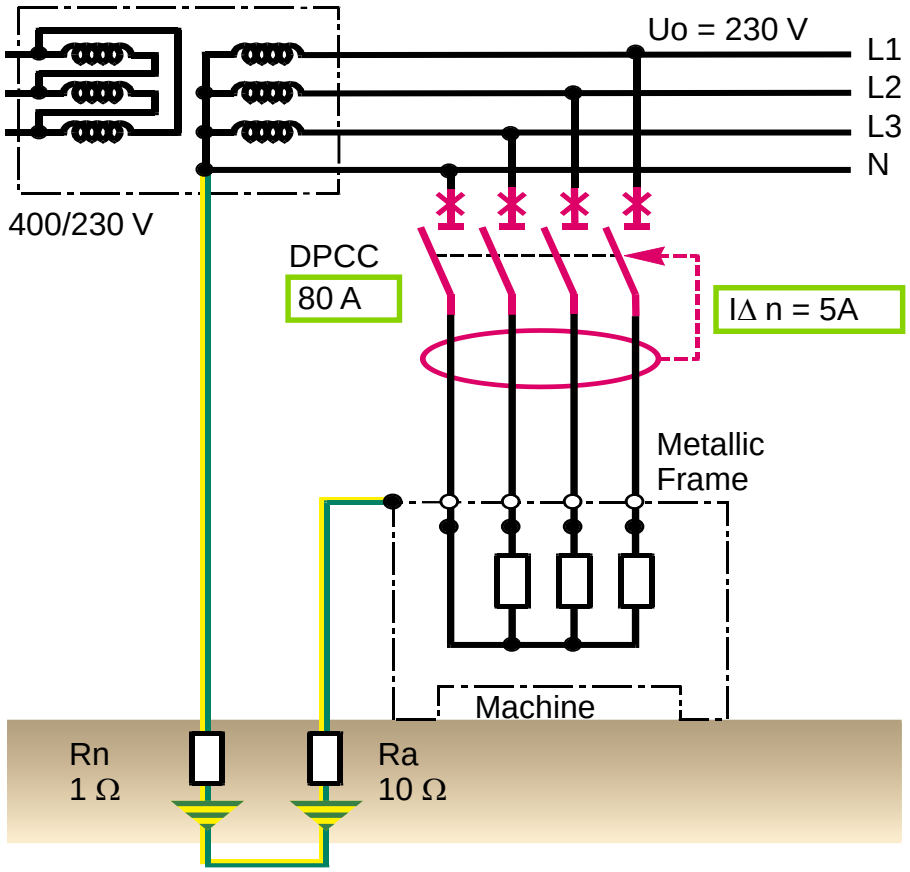
= 10 x 20,9

= 209 V > UL = 50 V

- Contact voltage is dangerous
- Feeding circuit breaker will not detect this small extra current

1. TT scheme

Protection against fault current



Solution

- The 80A Circuit breaker will not detect this 20,9 A fault
- A Residual Current Device will be installed
- Tripping treshold adjustment

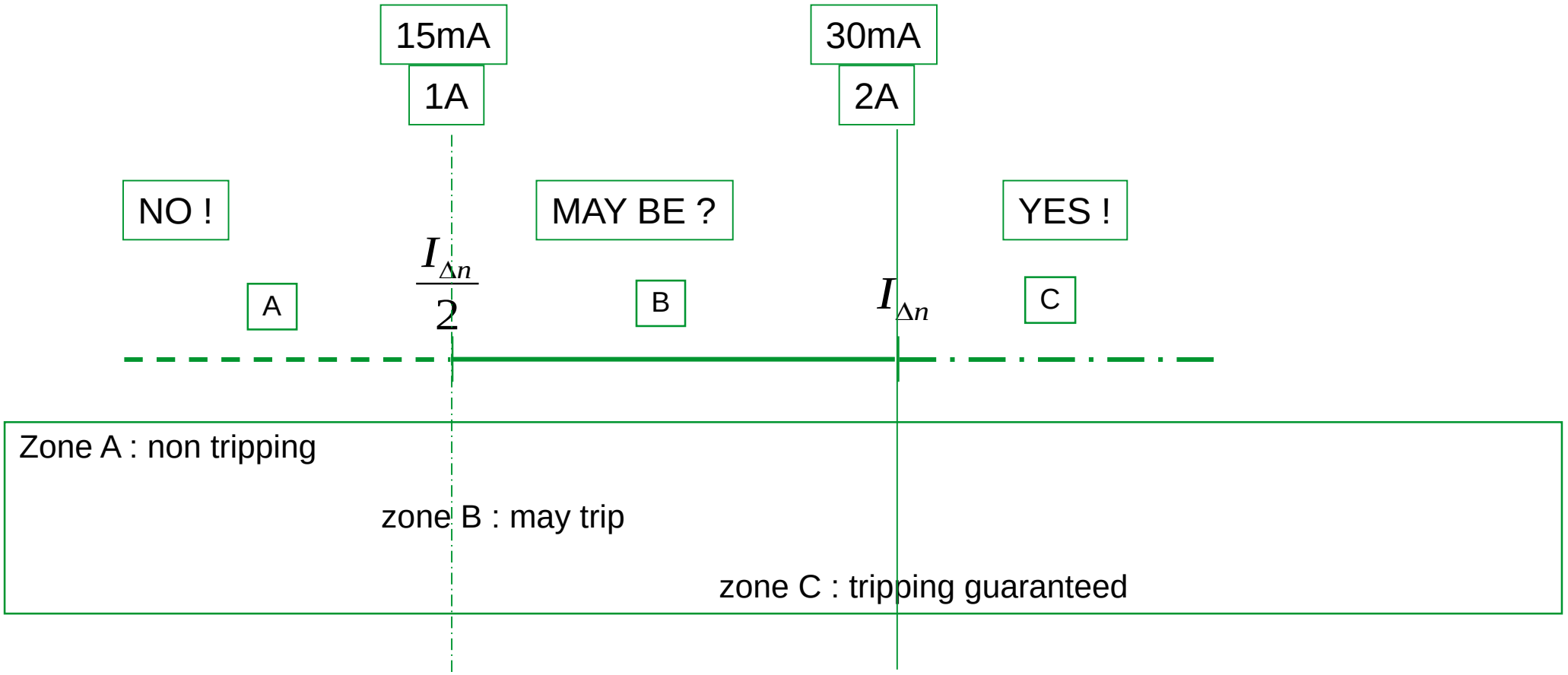
U_C max < UL

Ra x I Δn < U_L

(I Δn is the adjusted tripping threshold of the RCD)

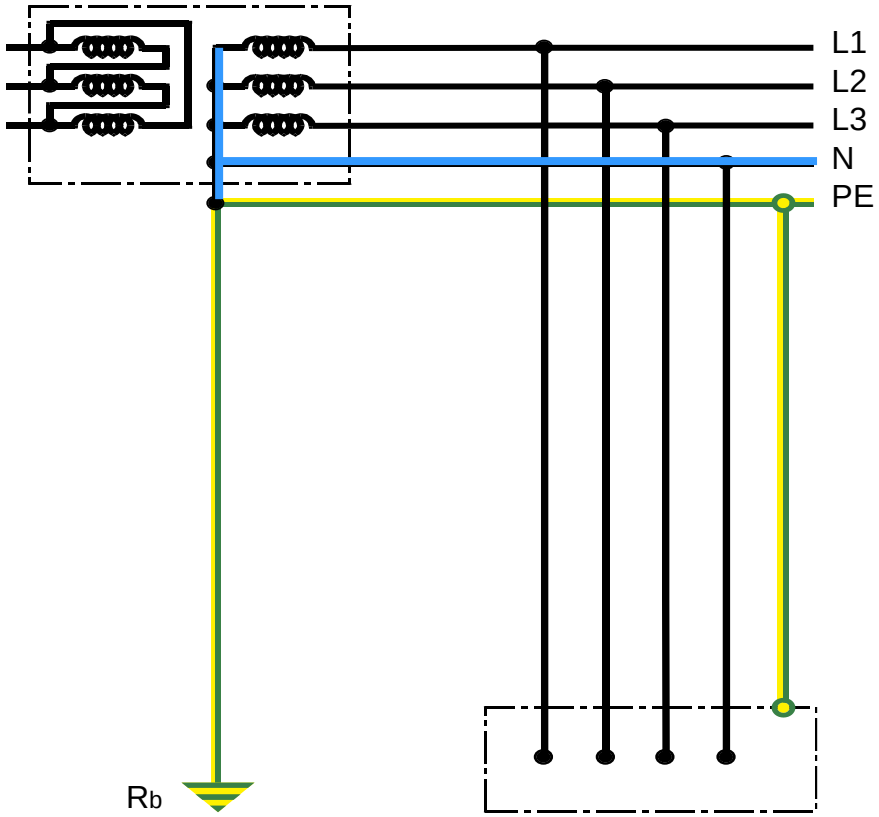
$$I\,\Delta n = U_L / Ra$$
$$= 50 / 10$$
$$= 5\ A$$

RCD's can trip with 50% Δcurrent only



2. TN scheme

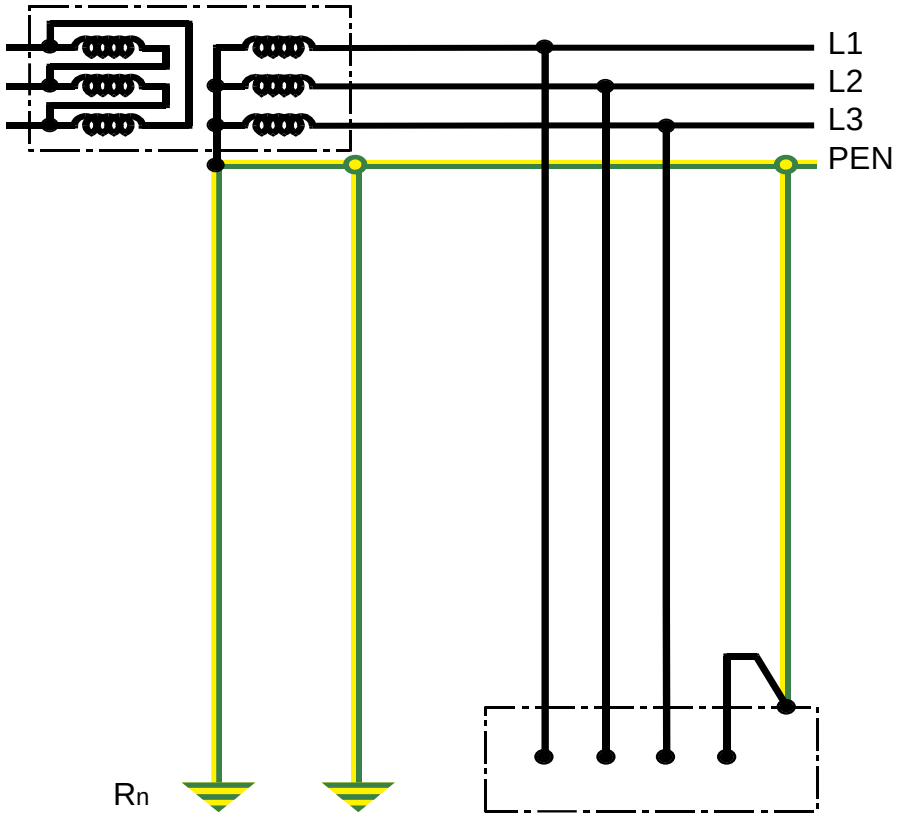
Definition



- Neutral of transformer is directly earthed
- Frames in the installation are connected via the protection PE conductor, to the same earth electrode

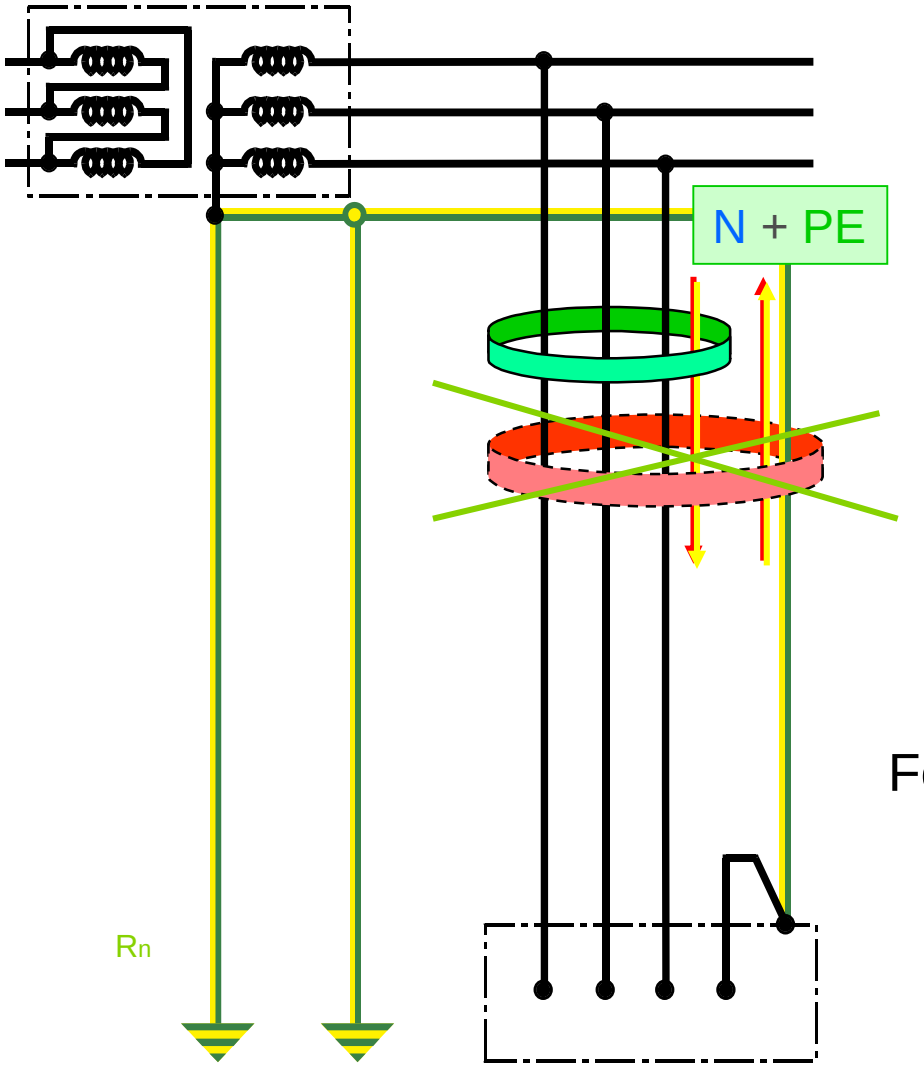
2.a TN-C scheme

Definition



- Neutral and Protection Earthing wire are physically grouped in same single PEN wire carrying both functions
- PEN can never be switched. So neutral cannot be switched !! CB's are strictly 3pole only (cost saving)
- Mixed clean neutral function, and polluted protection function, are often source of problem
- being unique PE+N=PEN wire has even more essential continuity
- RCD's do not work under TN-C

RCD's do not work under TN-C scheme



?

For detection of earth faults
return (PEN) must not travel inside toroïd

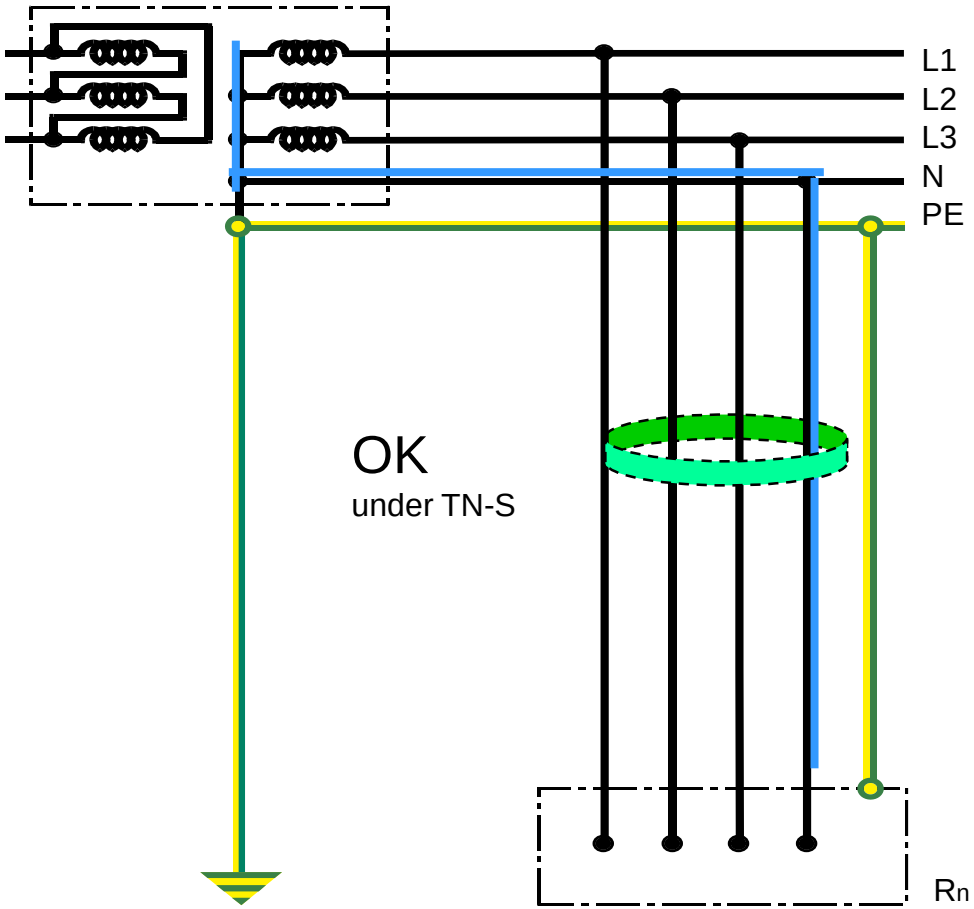
⇕

Impossible !! ⇒ no fire prevention !!

For no tripping on single phase or unbalanced daily loads
neutral (PEN) must travel inside toroïd

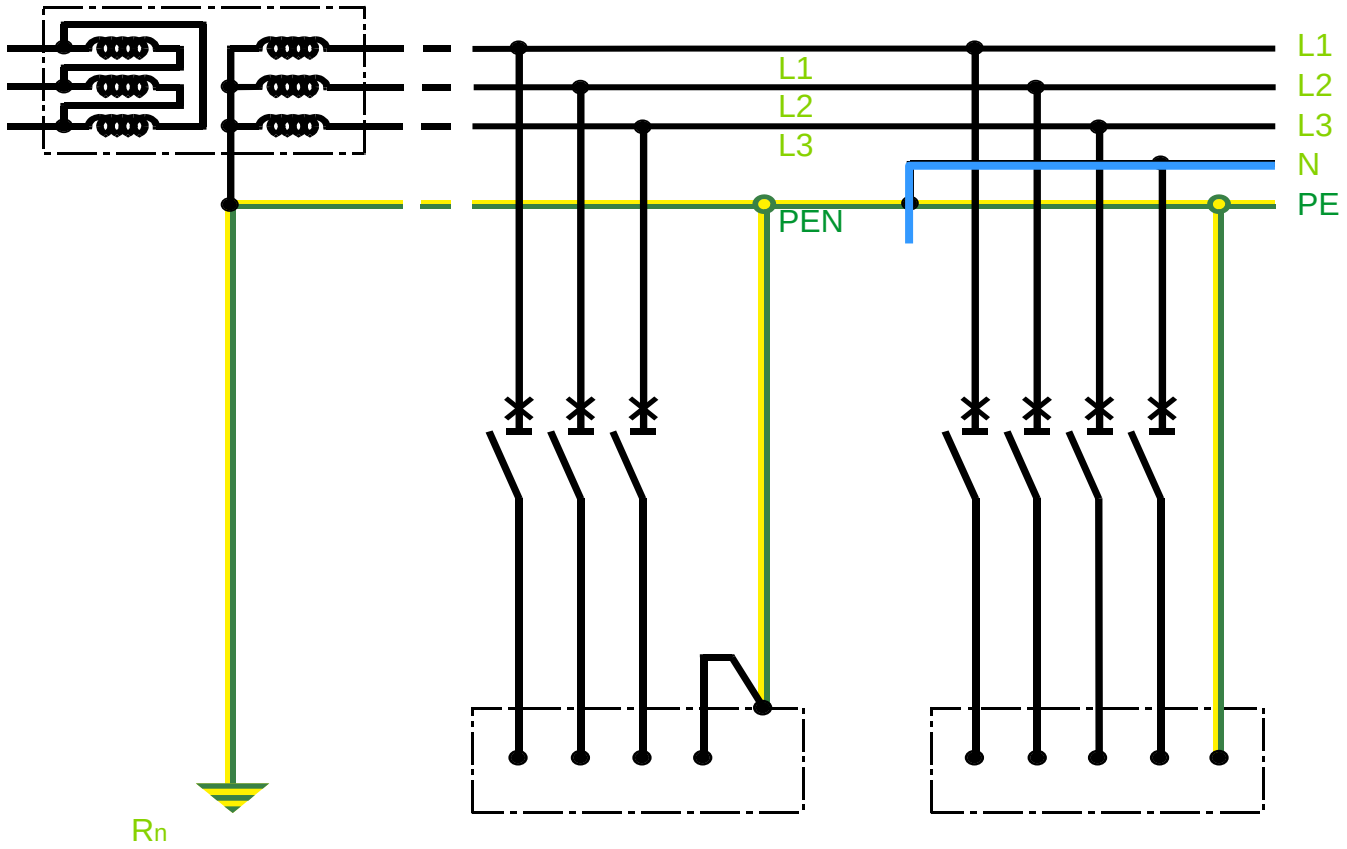
2.b TN-S scheme

Definition



- PE earthing protection wire and active neutral wire are both distributed separately
- They come from the same earth electrode upstream in the installation
- Neutral distributed can be switched (4pole CB's according to countries)
- RCD's can be used

2.c TN-C-S Scheme

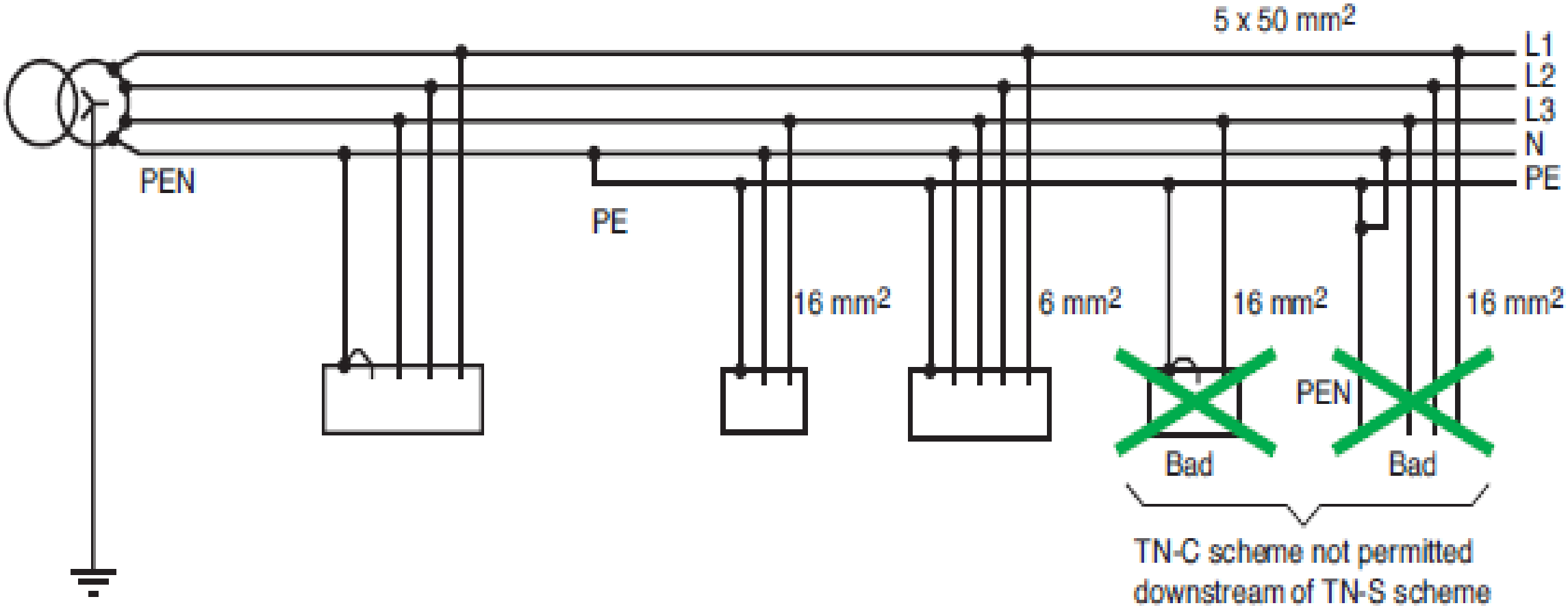


Definition

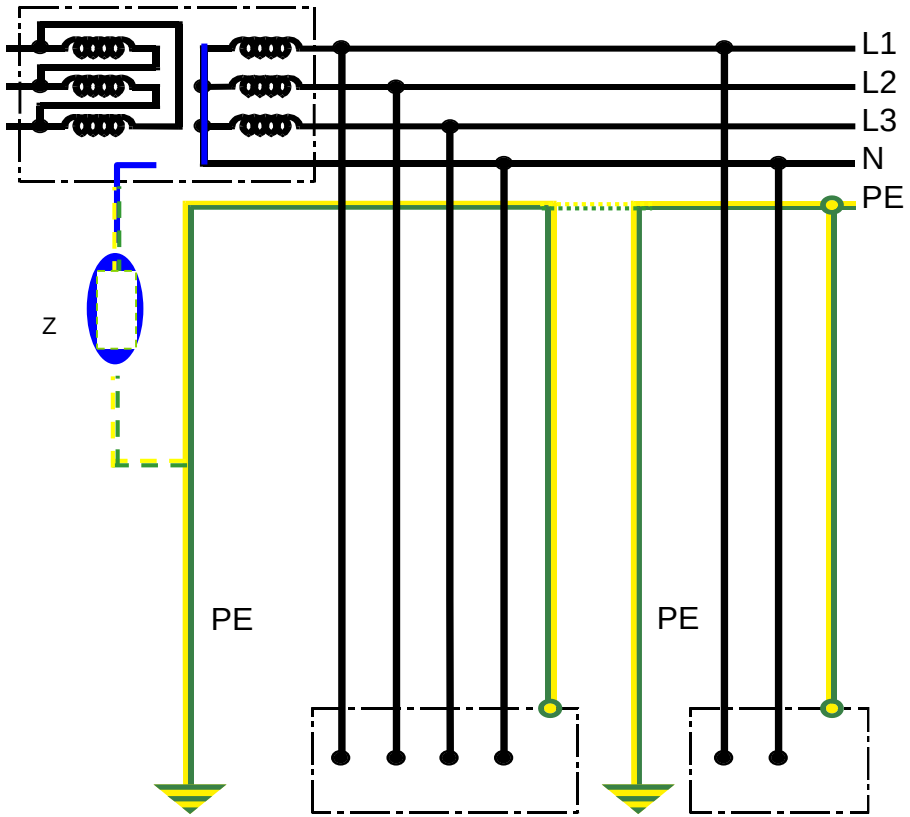
- Very common scheme used in TN distribution
- Top head of LV installation is TN-C (large current ratings, rare appliances direct feeding)
- Lower part of installation, TN-C becomes TN-Sby splitting PEN in PE & N

2.c TN-C-S Scheme

- TN-C not permitted downstream of TN-S ?



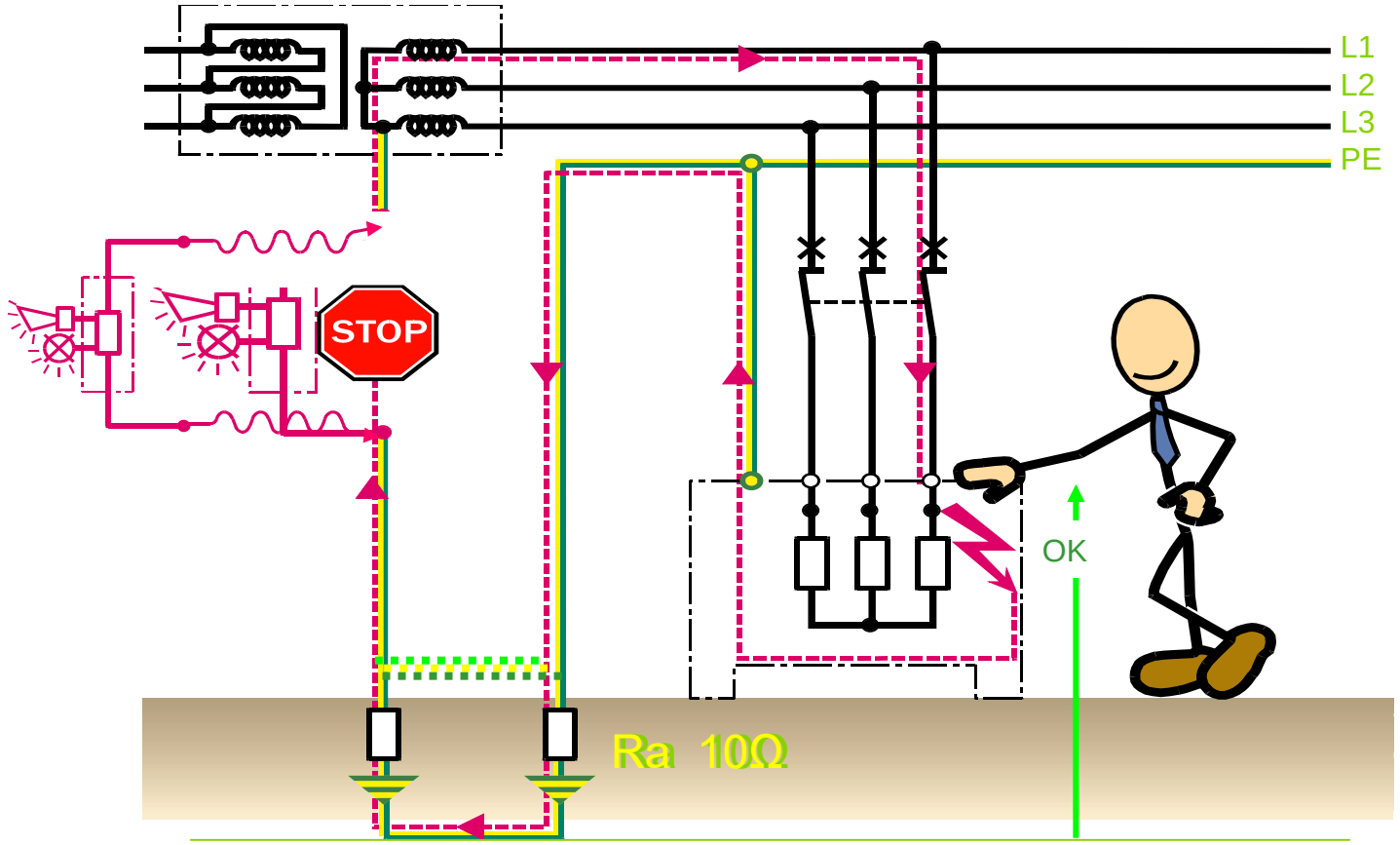
3. IT Scheme



Definition

- Transformer neutral is not earthed or slightly earthed trough high value impedance (1000 Ω or more)
- LV loads frames are bonded to the same central earth electrode via equipotential PE

3. IT scheme
typical 1st fault to earth

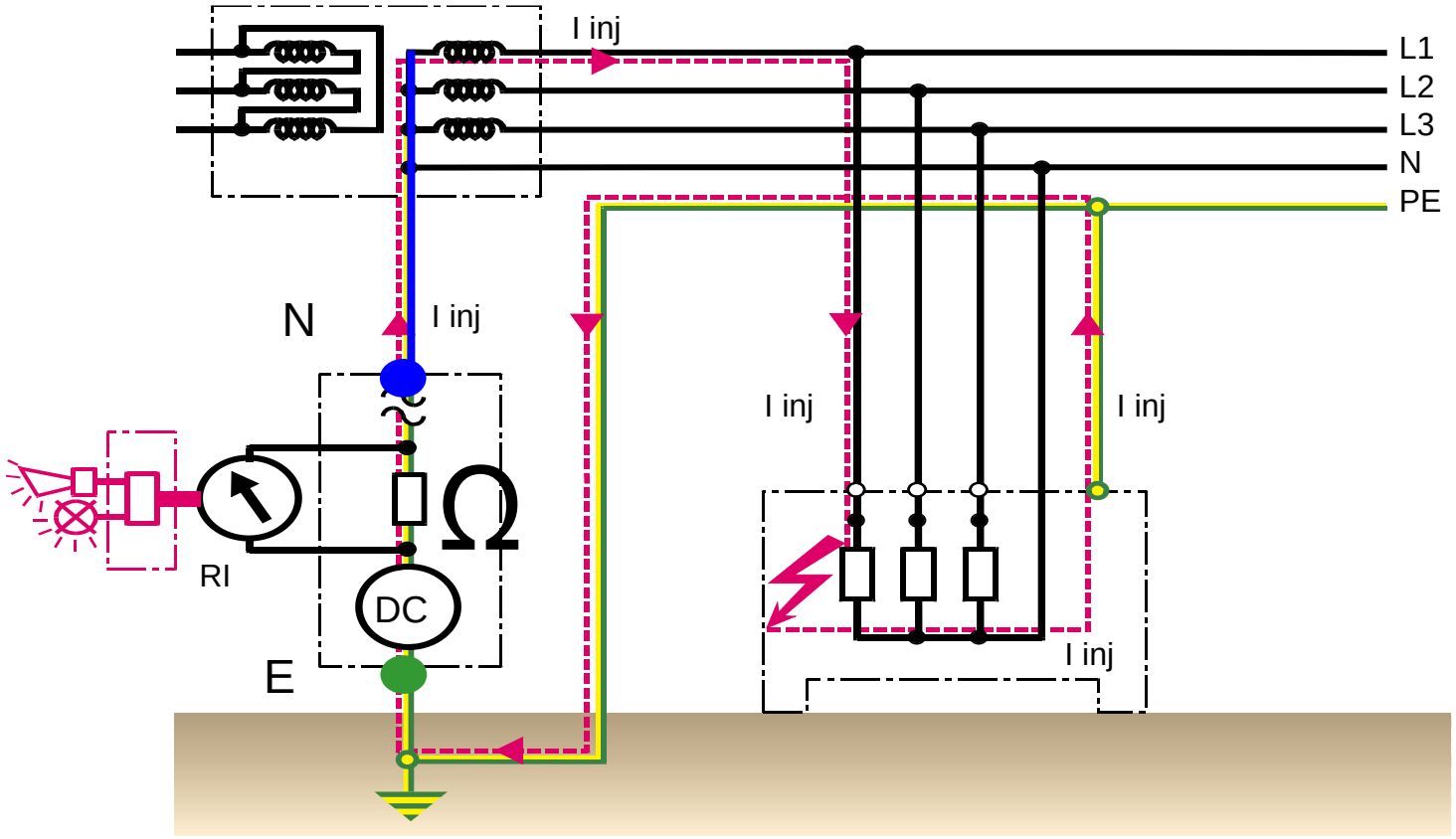


- Earth fault current cannot return to transformer neutral
  electric loop is open

- Touch voltage is safe
  Ra x 0 A = 0 volts or so
- No fire risk
- No tripping required
  machine can still run
  with 1st fault on

but this fault must be detected, located, and cured before a second one pops out

3. IT scheme
how to detect faults

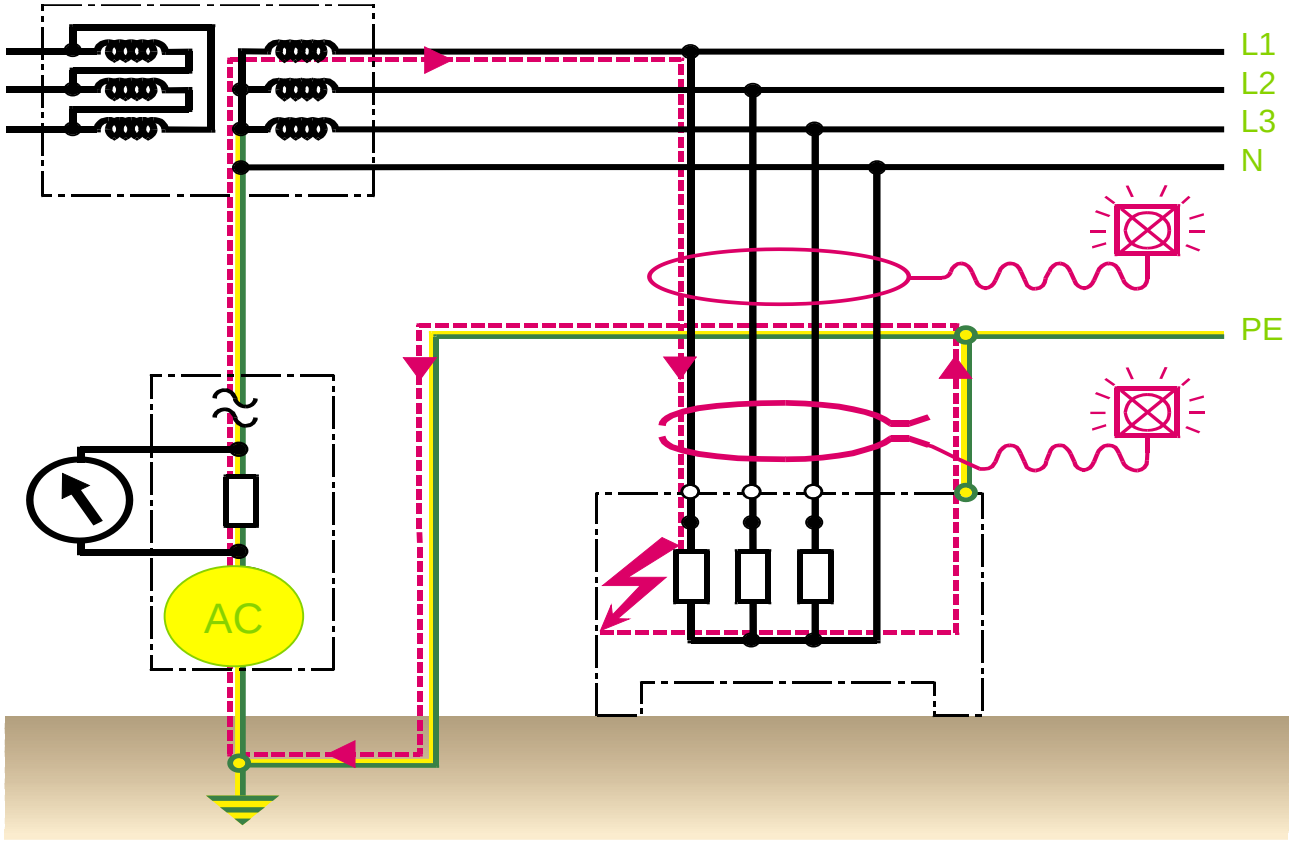


To only detect and warn

- Just works as an Ohm-meter injection of test DC voltage between installation and Earth if current is circulating, installation is not insulated properly
- current value informs about impedance of fault
- From test current detection horn and light warnings are activated

  Investigations must start immediately

3. IT scheme
how to locate faults



To detect, warn, and locate

- Detectable in cables with current clamps
- Portable or fixed current clamps will detect test AC current, in the faulty circuit only

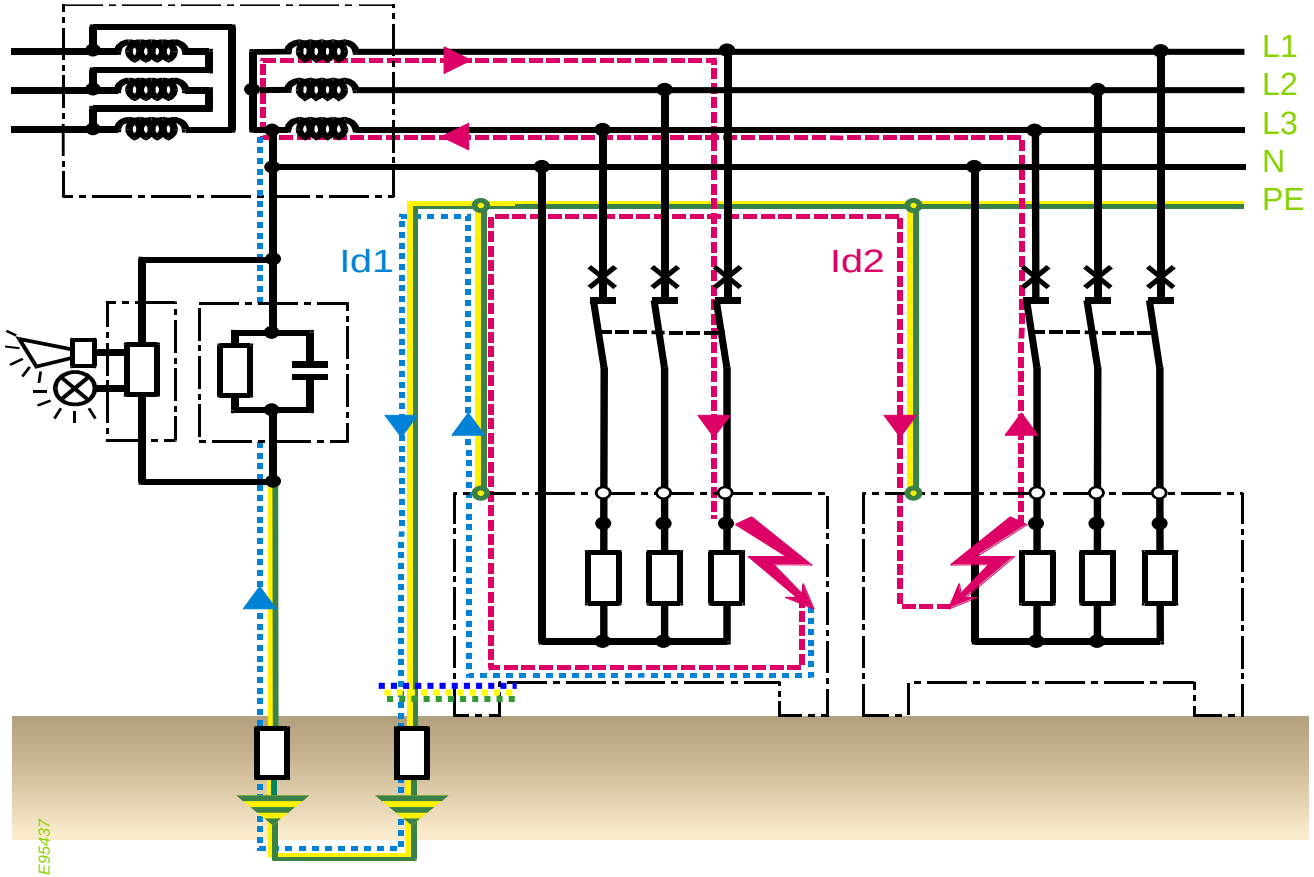
Fixed=quick location
Portable= operator must visit each poor feeder

Fault is generating overvoltage from V to V√3 between earth and healthy phases Fault must be eliminated.

3. IT scheme

risk of 2nd fault

Bonded Loads Earthing scheme



On occurrence of 2nd fault

- Tripping is achieved by feeder CB's
- Same situation as TN-S fault, except 2 CB's involved , breaking short circuit current

– If neutral is distributed it must be protected ⇒ 4Pole 4Trip CB's

– CB‘ s must be capable to break line to line voltage (400V)

- loop impedance must be checked by calculation (each feeder) to secure tripping in case of 2nd fault

Thank you!