FACULTY OF ELECTRICAL ENGINEERING AND COMMUNICATION

NEXT GENERATION VUT:
Increasing the quality and relevance of education at BUT
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MINISTRY OF EDUCATION, YOUTH AND SPORTS

Safety in Electrical Engineering

Presentation for self-study

version 2025

Assoc. Prof. M. Steinbauer, Ph.D., 2026

Instructions

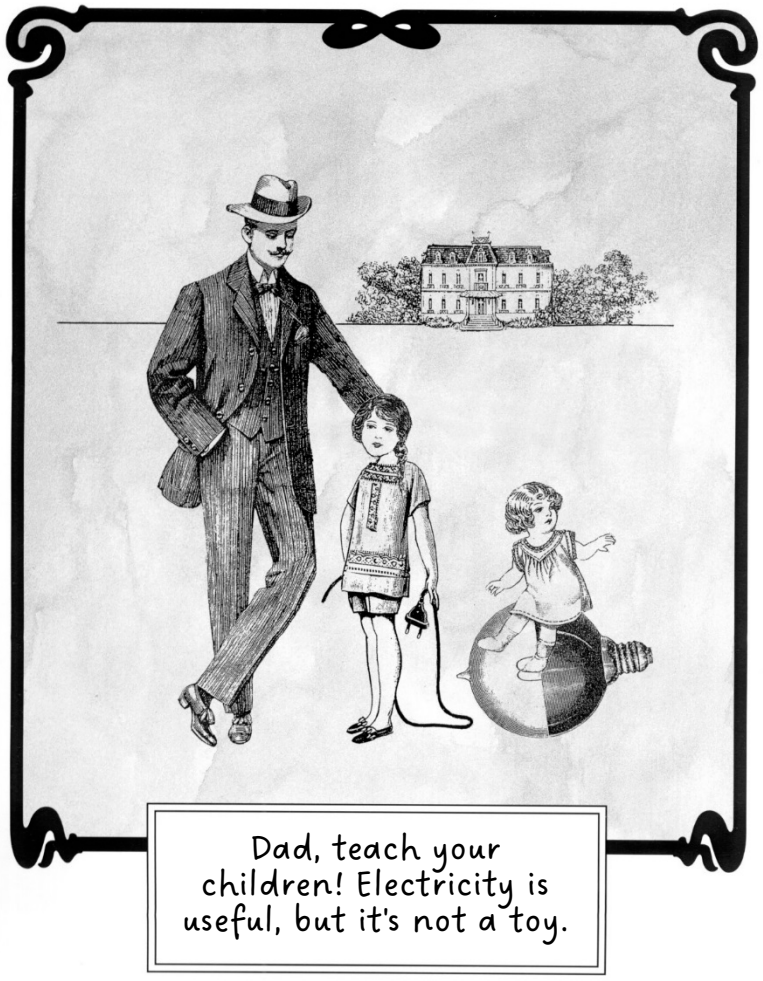
- Read through and study this material. Each chapter contains answers to questions that are then used in ongoing testing through quizzes.
- You must go through all the slides in order; you cannot skip any.
- Some slides have more detailed notes – view them by clicking on the "Notes" button in the upper right corner.
- The presentation contains 6 milestones – quizzes that you must complete in order to advance to the next chapter; if you fail the quiz, you will return to the beginning of the previous chapter.
- You have a maximum of 3 hours to complete the entire quiz.
- Successful completion (passing all quizzes) is considered mandatory training and is a prerequisite for obtaining qualification „instructed person“ to work in FEEC laboratories.

Qualifications for working in FEEC laboratories

- The instruction is mandatory for all students entering study programs at FEEC BUT Brno.
- Qualification within the meaning of Government Regulation No. 194/2022 Coll. is a prerequisite for participation in laboratory classes at FEEC.
- To obtain the qualification, it is necessary to:
  - complete **training – self-study (this presentation)**
  - successfully pass an **online test**
- Qualifications obtained outside FEEC are not accepted
- Detailed information and study materials are available at page Safety in electrical engineering

Contents of instruction

1. Introduction
2. Electrical equipment (EE)
   - EE classification
   - Marking of wires and terminals
   - Sockets and power cords
3. Electrical equipment safety
   - Working on electrical equipment
   - Electrical engineering qualifications
   - Safety assurance
   - Testing rooms and laboratories
4. Electric shock
   - Mechanism of injury
   - Effects of electric current on the human body
5. Protection against electric shock
   - Accident occurrence
   - External influences
   - Insulation and protection classes
   - Means of protection
   - Implementation of protective measures
6. First aid
   - Resuscitation procedure
   - Calling for medical assistance



PART 1

INTRODUCTION

Definition

The safety of electrical equipment (EE)

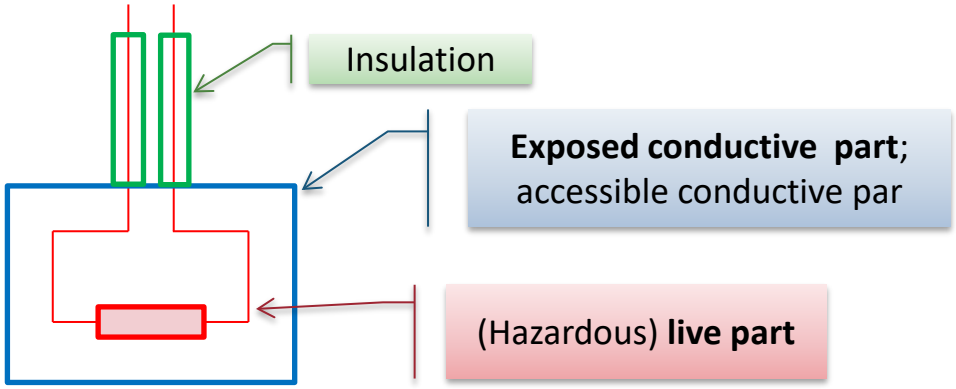
is the ability of electrical equipment

- **not to endanger person, livestock, property**, or the surrounding environment under specified operating conditions through electric current, voltage, or phenomena caused by the effects of electricity, and
- **to protect against non-electrical hazards** that such equipment may cause.

Basic terms (ČSN 33 0010 ED.2)

- **Electrical equipment (EE)** – equipment, regardless of voltage, intended for the generation, transmission, distribution, and use of electrical energy.
  - Live part of EE – part of electrical equipment designed to conduct electric current or conductive part designed to be live during normal operation.
  - hazardous live part of EE – a live part that may cause electric shock under certain conditions.
  - Exposed conductive part of EE – a conductive part of equipment that is not live during normal operation but may become live in the event of a failure of the basic insulation.
- **Electrical circuit** - a system of conductors and their components through which an electric current can flow.
- **Electrical object** – a structural part, assembly, or unit that is connected to an electrical circuit.
- **Electrical installation** – an assembly of interconnected electrical objects with coordinated characteristics, serving to perform one or more specific tasks.
- **Electrical appliance** – used to convert electrical energy into another type of energy, e.g., light, heat, mechanical energy.

BASIC TERMS (ČSN 33 0010 ED. 2)

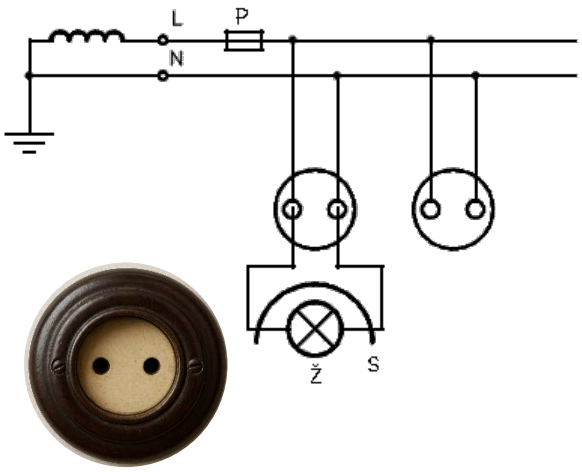


- **Electrical equipment (EE) consist of:**
  - Live part - part of electrical equipment designed to conduct electrical current or conductive part designed to be live during normal operation.
  - Hazardous live part – a live part that, under certain conditions, may cause an electric shock.
  - Exposed conductive part – is the conductive part of the device that is not live during normal operation but may become live in the event of a failure of the basic insulation.

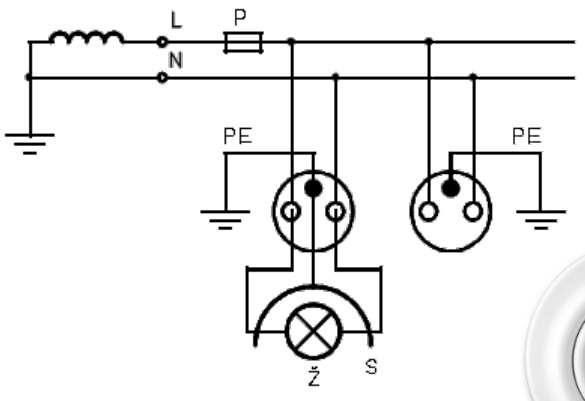
History of protection against hazardous touch

- The original DC networks at the end of the 19th century (with an operating voltage of around 100 V) did not include protection against contact, as DC current at this voltage is essentially not hazardous.
- After the change to AC current, problems with electric shock began to appear. Therefore, the original two-wire distribution was supplemented with a PE conductor (protection by earthing, now classified as a TT system), and later a PEN conductor (protection by neutralization, now classified as a TN system) was used.

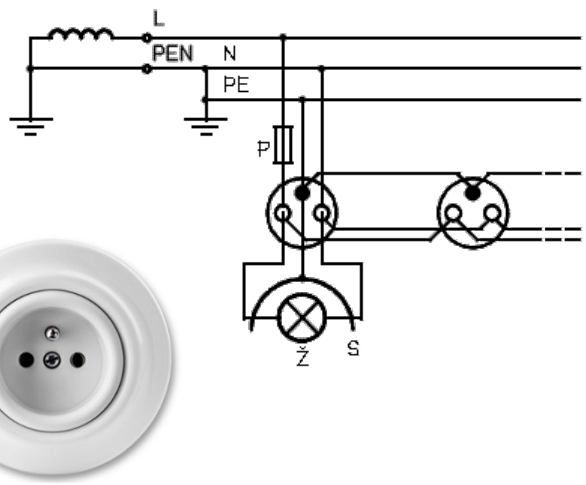
Without protective earthing



Protection by earthing, now TT network



Protection by neutralization, now TN network

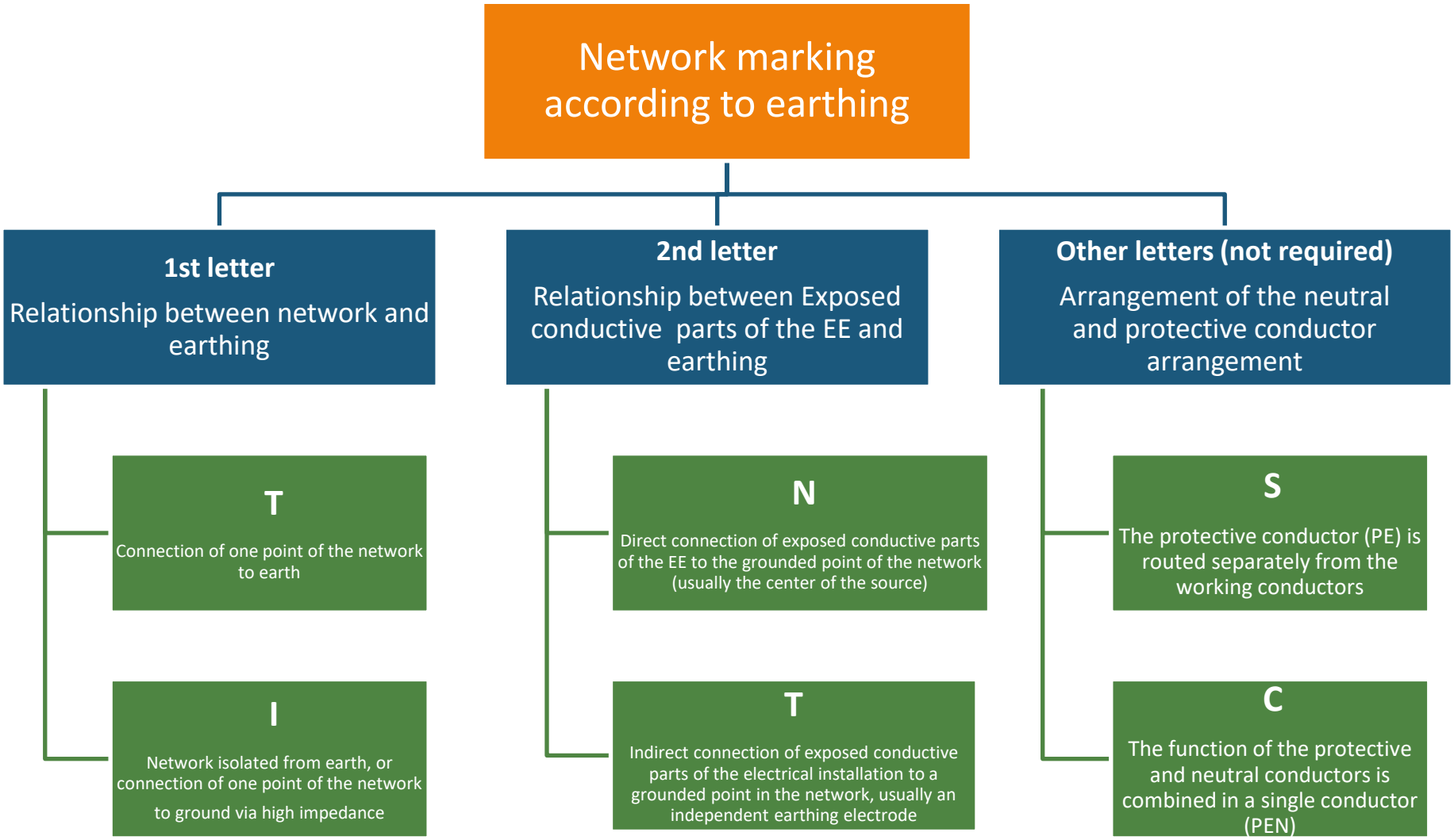


Marking of conductors and terminals of EE with letters and numbers (ČSN EN 60445 ed. 4)

Name	Marking	
	Conductor	Terminal
Alternating current system (AC)		
Phase (line conductor) ~	**L**	**U**
Phase 1	**L1**	**U**
Phase 2	**L2**	**V**
Phase 3	**L3**	**W**
Neutral conductor	**N**	**N**
Direct current system (DC)		
Positive pole +	L+	+ , C
Negative pole	L-	- , D
Center (middle) conductor	M	M

Name	Marking	
	Conductor	Terminal
Special types of conductors and terminals		
Protective earthing	**PE**	**PE**
Combined neutral and protective earthing conductor - AC	**PEN**	**PEN**
Combined neutral and protective earthing conductor - DC	PEM	PEM
Protective bonding conductor	PB	PB
Functional earthing conductor	FE	FE
Functional bonding conductor	FB	FB
Main earthing terminal (busbar)	MET	MET

Types of AC distribution networks (according to earthing)



Types of AC distribution networks (ČSN 33 2000-1 ed. 2)

TT

- Oldest type
- Formerly known as „*protection by earthing*"

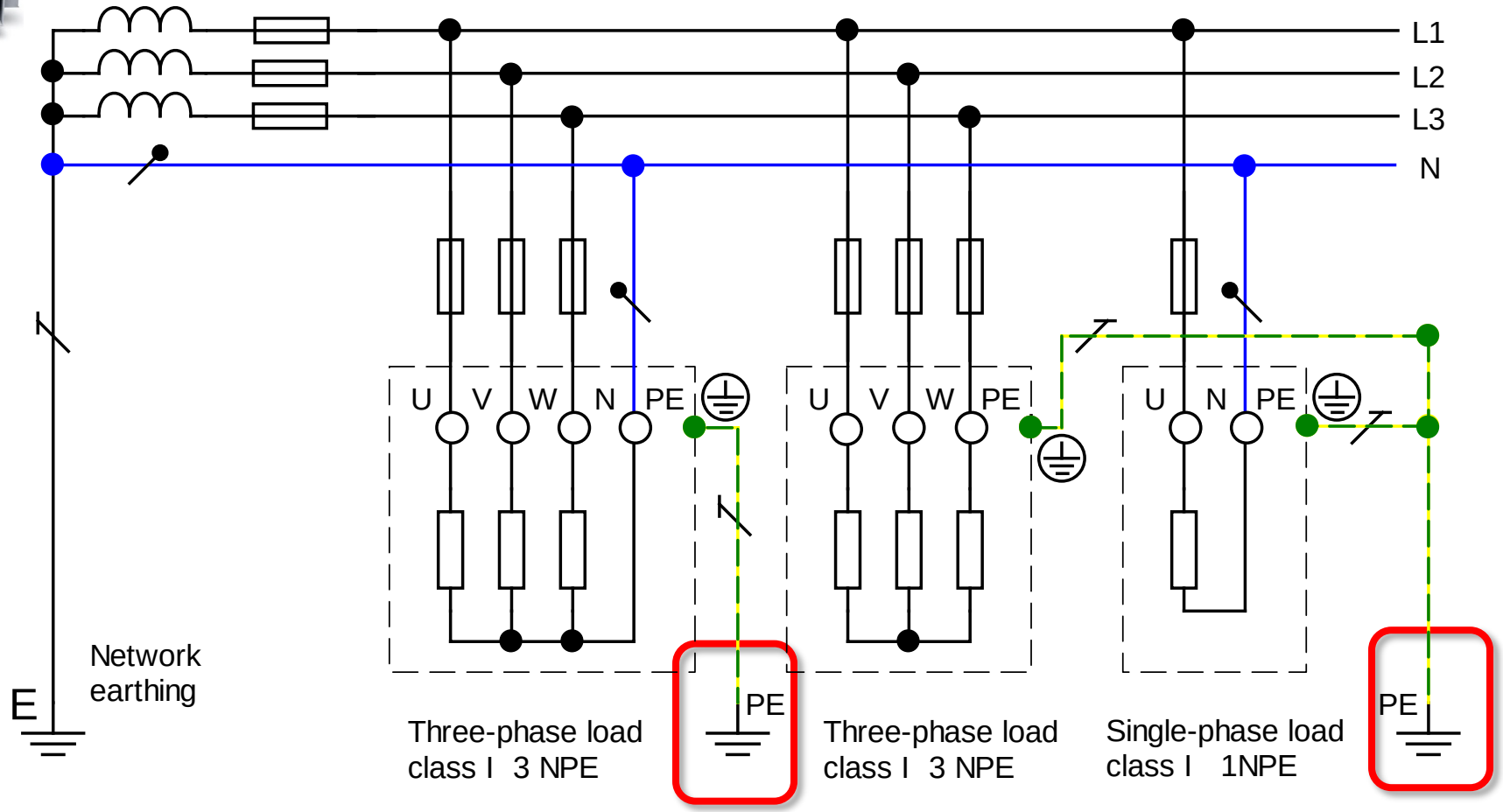
TN

- Formerly known as "*protection by neutralization*"
- Variants are
  - TN-S
  - TN-C
  - TN-C-S

IT

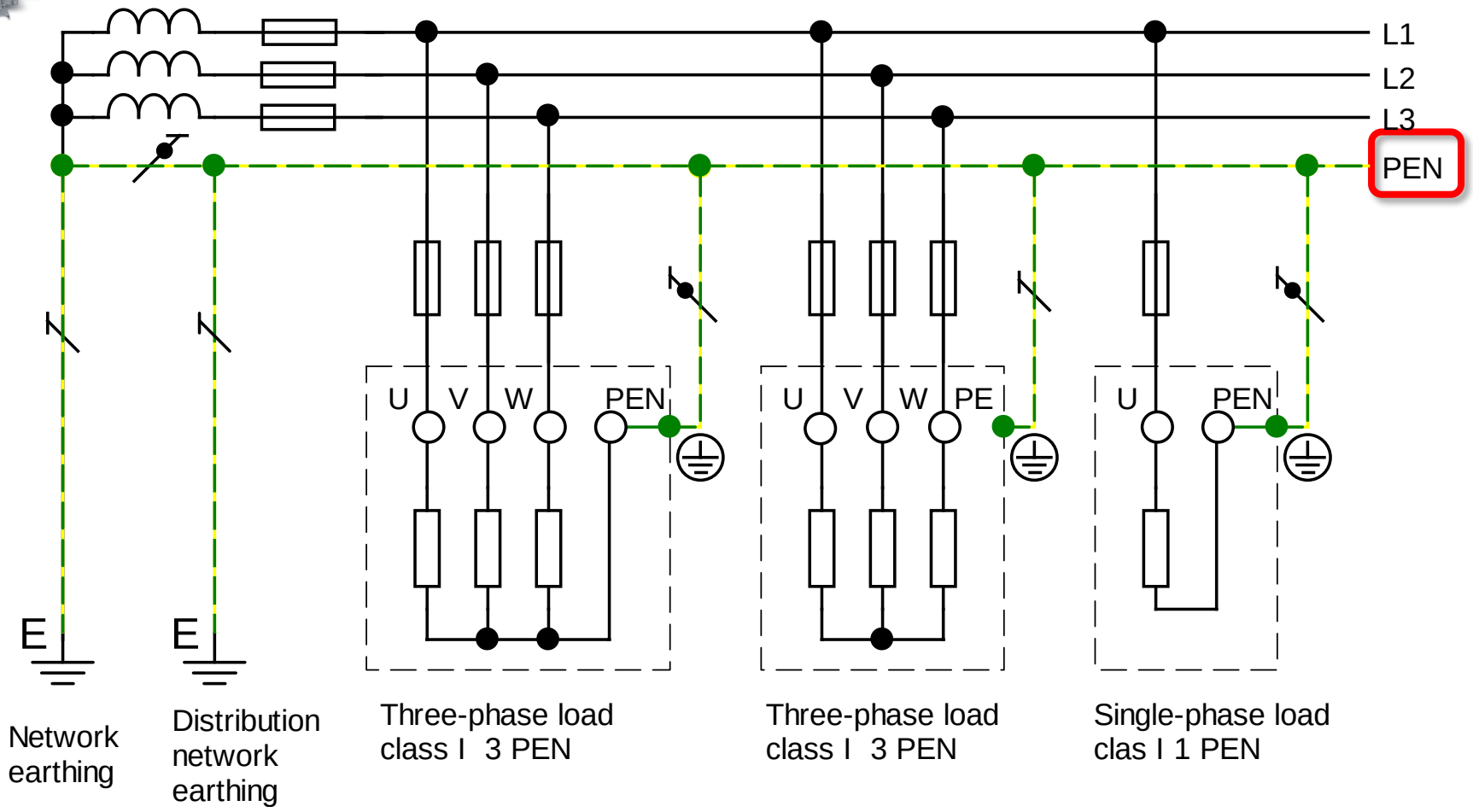
- Isolated system
- For special purposes where, for example, there is a requirement for uninterruptible power supply or higher safety
- Examples: some laboratories, some healthcare facilities, special production lines

TT NETWORK



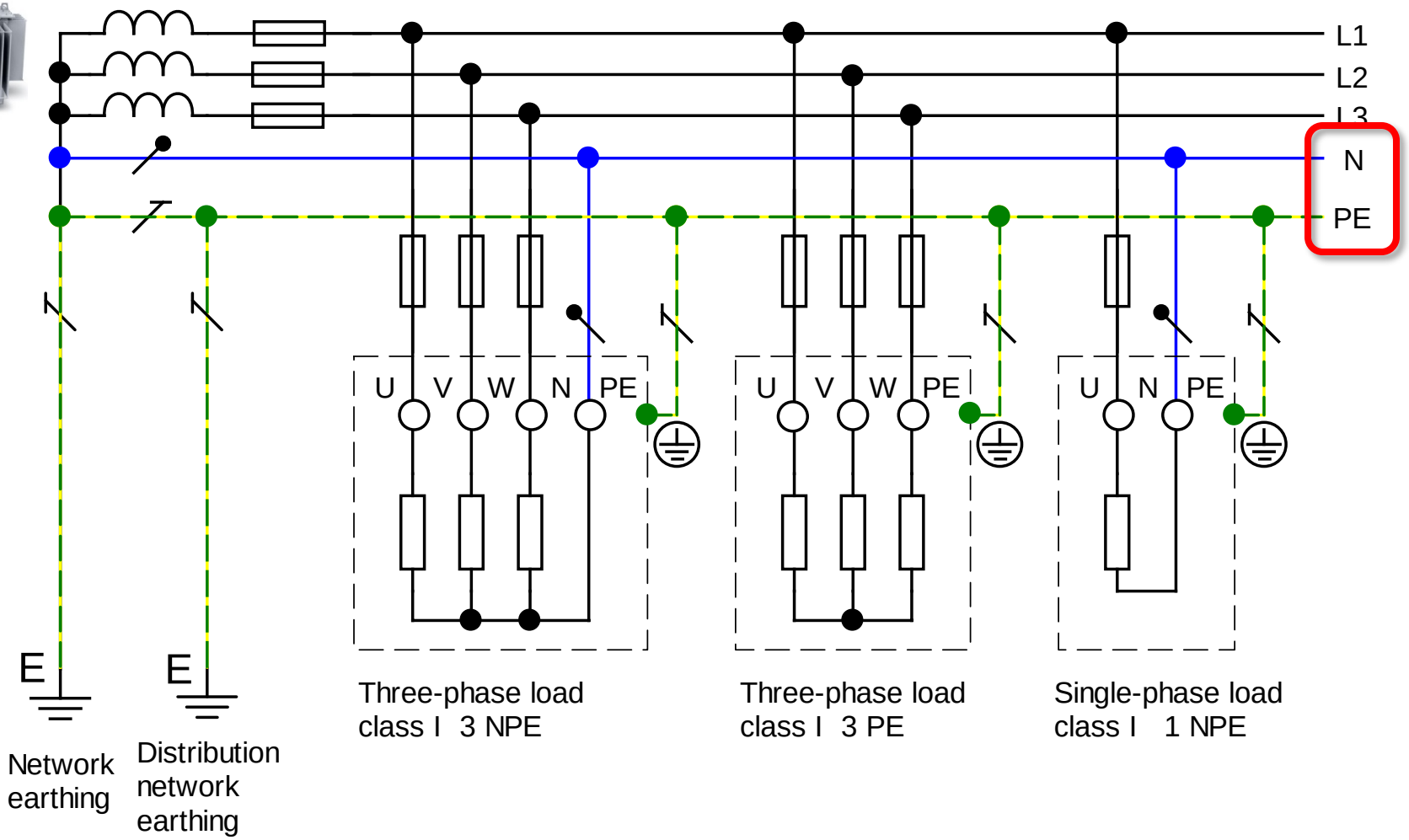
- Additional earthing of the PE conductor in the electrical installation can be performed.

TN-C NETWORK



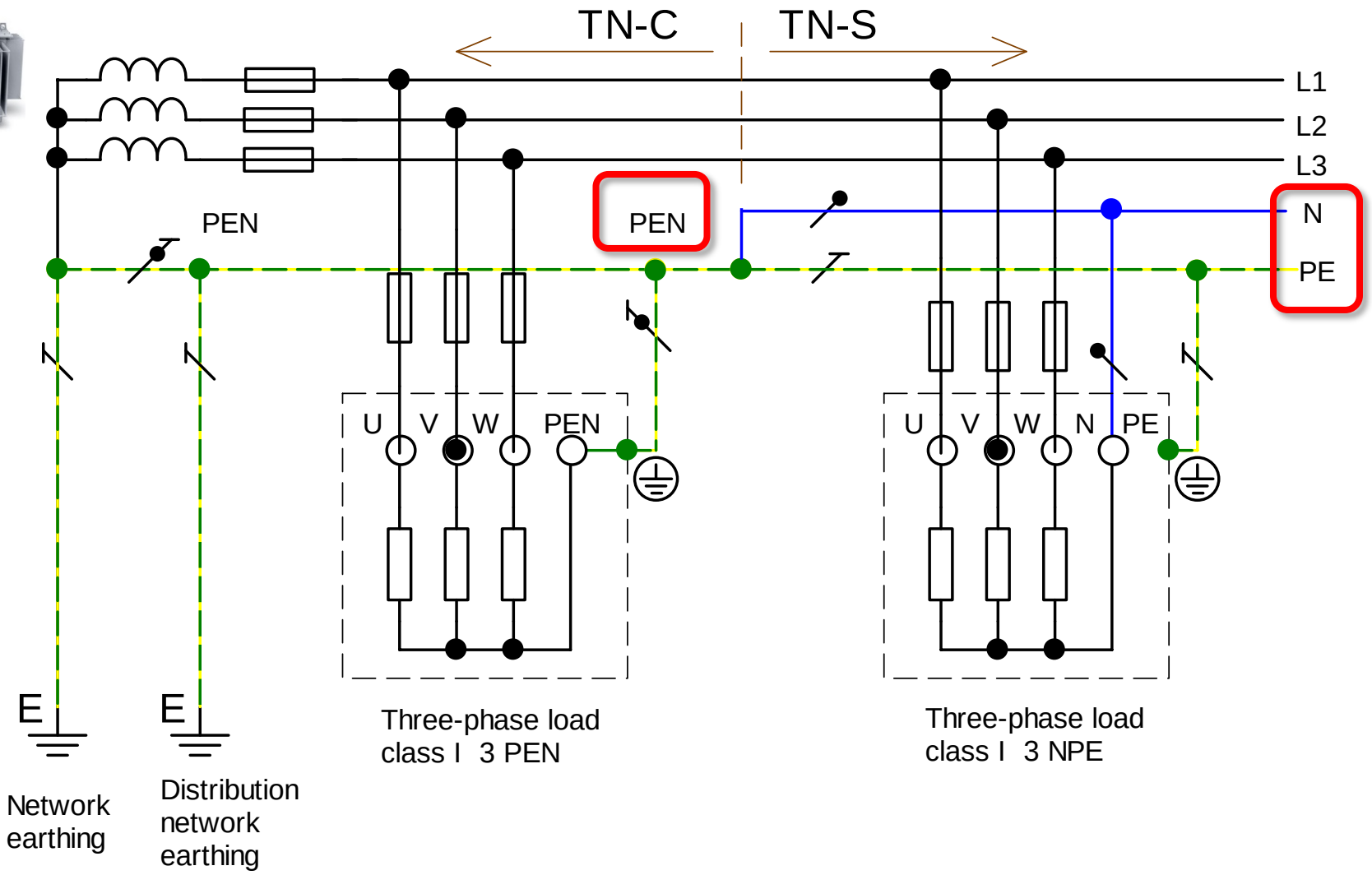
- Additional earthing of the PEN conductor should be provided in the electrical installation.

TN-S NETWORK



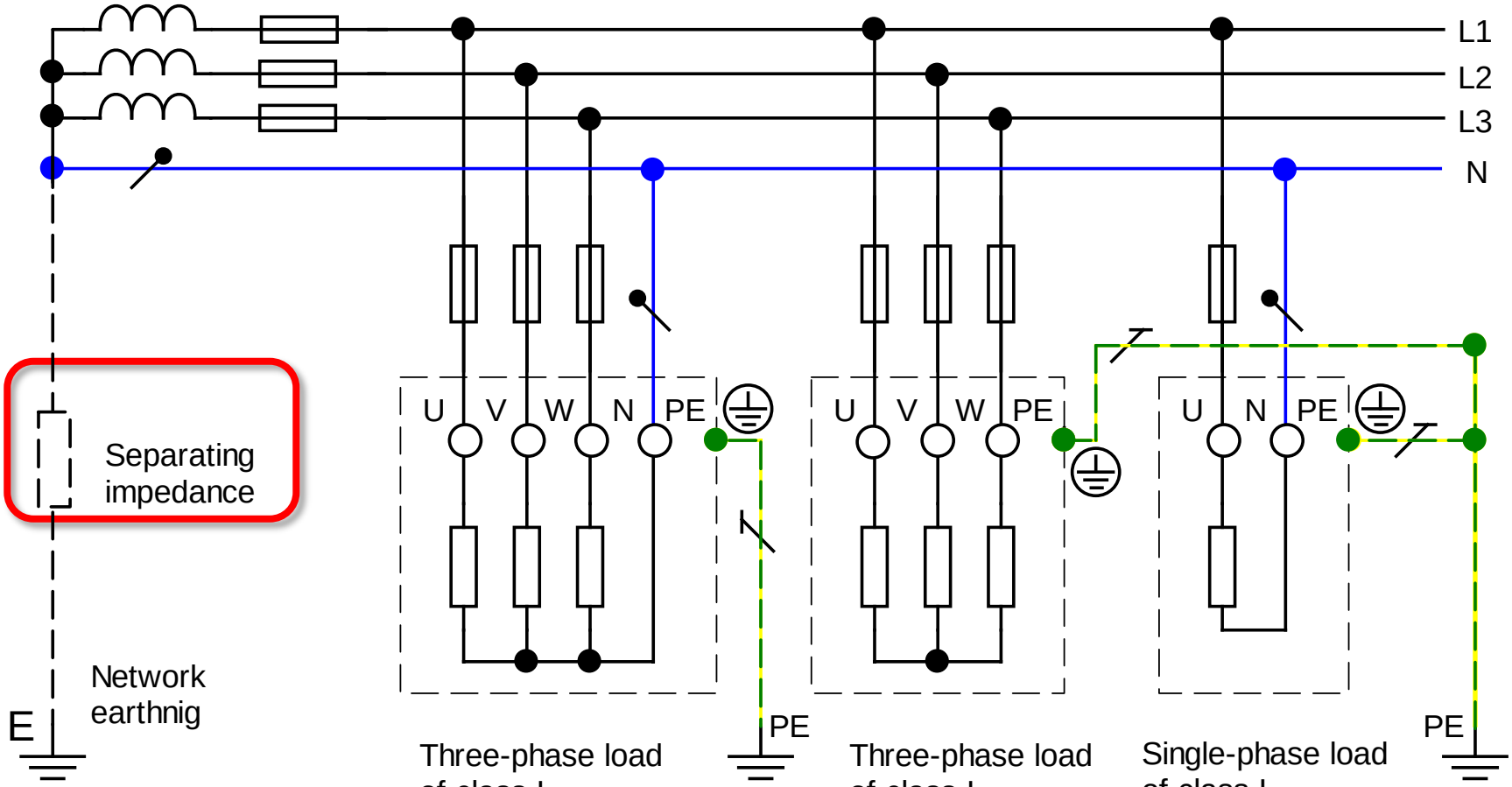
- Additional earthing of the PE conductor should be provided in the electrical installation.
- A network without a neutral conductor, only with PE, is still a TN-S network.

TN-C-S NETWORK



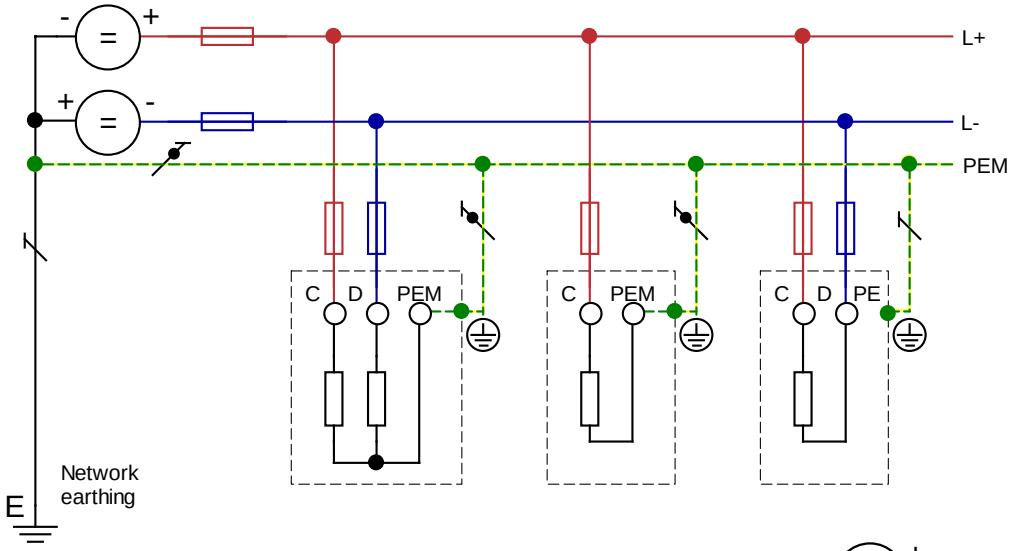
- Additional earthing of PEN or PE conductor should be provided in the electrical installation.

IT NETWORK

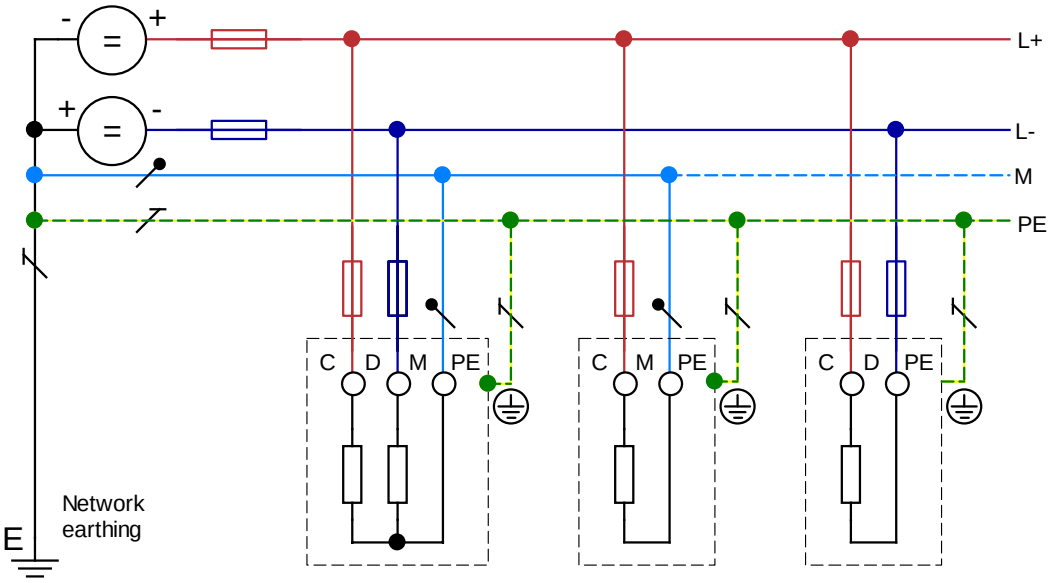

L1
L2
L3
N
Separating impedance
Network earthnig
E
U V W N PE
PE
Three-phase load of class I
U V W PE
Three-phase load of class I
U N PE
PE
Single-phase load of class I

Direct current (DC) networks

All of the above variants also apply to DC networks

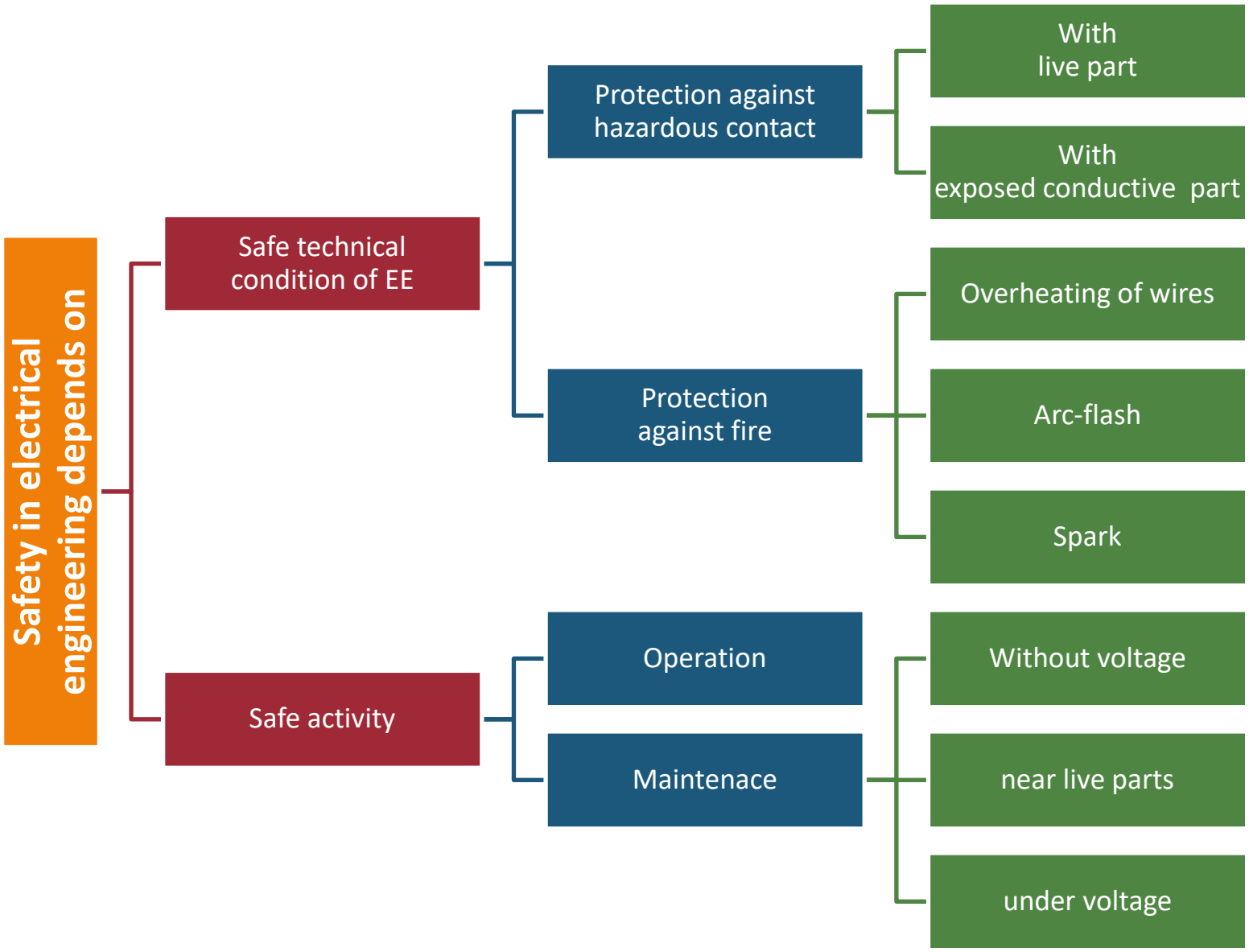


DC TN-C



DC TN-S

THE CONCEPT OF SAFETY IN ELECTRICAL ENGINEERING



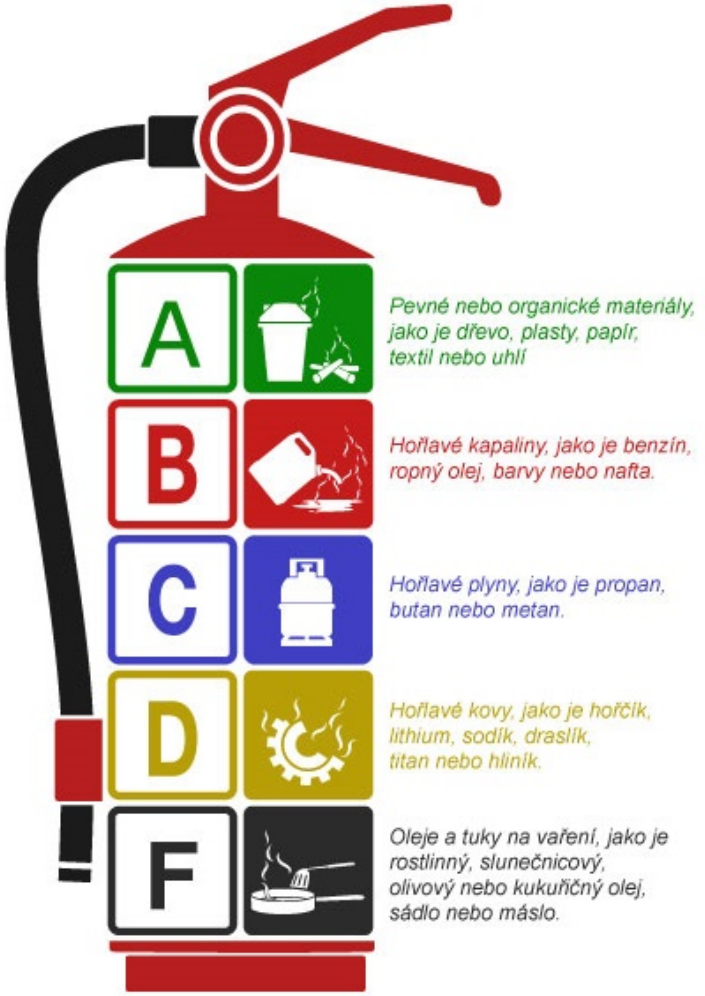
SAFE PRODUCT AND INSTALLATION

- **A product** that has been shown to comply with the requirements of the relevant directive is marked with the **CE conformity mark**. Regular inspections and revisions are carried out
- **Dedicated technical facility** – exist increased risk to life, health, and safety of individuals.
  These are pressure equipment, lifting, **electrical**, and gas equipment that pose a serious risk to to the life, health, and safety of individuals.
- **Installation** – consists of products but is not a product. However, it is part of the building – it meets the requirements of the Building Act.
  It is necessary to create documentation and perform a review for each one.

	Former approval mark for electrical products
	Newer approval mark
	Czech conformity mark (CCZ)
	Conformity mark used in the EU (CE)

FIRE EXTINGUISHING EQUIPMENT

- For initial intervention – **portable fire extinguishers (PFE)**,
  weighing up to 10 kg and with an operating time of up to 60 seconds.
- They are located near the likely source of a fire and in escape routes.
- The location of PFE must be **marked and illuminated by** emergency lights.
- PFE must be inspected at least once a year or after use.



FIRE EXTINGUISHING EQUIPMENT

- **Fire alarm guidelines and evacuation plans** are posted for FEEC buildings.
- The person who notices the fire shall, if possible, extinguish it using **portable fire extinguishers** located in the escape routes and immediately report the fire to the fire reporting office at the **reception desk:**
  - for buildings T8 and T10 – dial **6110**
  - for buildings T12 and T14 – dial **6112**
- When calling from a mobile phone, dial **541 14** before this number
- The person reporting the fire should briefly describe the situation, state the exact location of the fire, and any potential hazards.

Carbon dioxide (CO_2) fire extinguisher

- High-pressure container with compressed carbon dioxide.
- The main extinguishing effect is dilution and suffocation, as CO_2 e reduces the oxygen content in the vicinity of the fire.
- It cannot be used to extinguish loose solids, as the gas stream could stir them up and spread the fire.
- When extinguishing a fire, hold the handle, never the hose or nozzle, as there is a risk of severe frostbite.

Powder fire extinguisher

- The extinguishing agent is sodium bicarbonate or ammonium phosphate and ammonium sulfate.
- The powder forms a glaze on smouldering surfaces, preventing access to air, and its decomposition produces ammonia, which has an anti-catalytic effect.
- It cannot be used to extinguish loose solids, which could be stirred up by the flow of powder and expulsion gas, spreading the fire.
- The extinguished equipment and its surroundings are often destroyed by the powder.
- **EE with a voltage of up to 1,000 V from a minimum distance of 1 m!**

EXTINGUISHING FIRES IN ELECTRICAL EQUIPMENT

Clean agent fire extinguisher

- These are the most expensive of all and have replaced halon devices, which are no longer manufactured.
- They use agents based on tetradecafluorohexane, hexafluoropropane, or other fluorinated hydrocarbons.
- The electrically non-conductive extinguishing agent is non-corrosive and frost-resistant, effectively cooling flames and preventing oxygen access.
- They are highly effective and can be used to extinguish all materials except solid glowing substances.
- They are suitable for extinguishing electronic equipment, computer and recording technology, data carriers, archives, and telephone exchanges.
- It is not recommended to use them in enclosed spaces without ventilation, as the active substance decomposes into components that are harmful to health when heated.

THEY MUST NOT BE USED TO EXTINGUISH ELECTRICAL FIRES!

Foam fire extinguishers

- A mixture of Pyrocool foam concentrate and water. The extinguishing foam contains water, and therefore, also eliminates smouldering.
- They are suitable for extinguishing solid combustible materials and liquids that do not mix with water.
- They are not suitable for extinguishing liquids that mix with water, hot gases, and combustible metals.
- **They must not be used to extinguish electrical equipment under current and in their vicinity.**

Water fire extinguishers

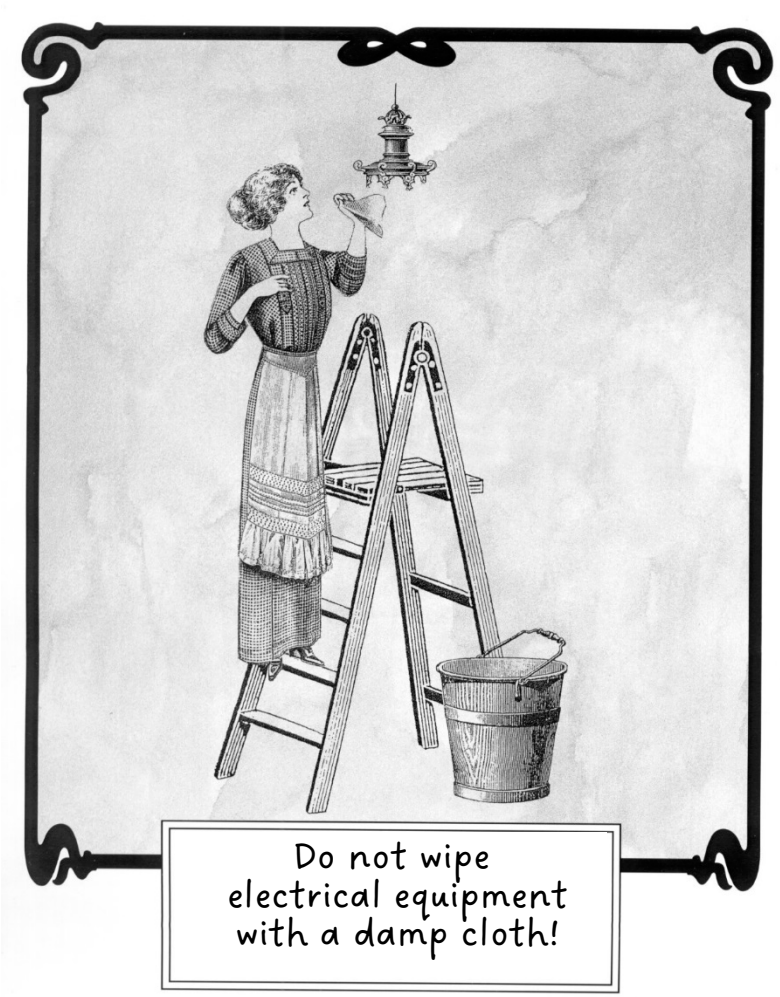
- They are completely sufficient for extinguishing most common materials. The extinguishers are frost-resistant.
- **They must not be used to extinguish electrical fires under current or in their vicinity.**
- They are suitable for extinguishing solid combustible (organic) materials (paper, wood, textiles, coal, rubber) – water extinguishes directly at the source and also eliminates smouldering.
- They are unsuitable for extinguishing liquids that do not mix with water (e.g., gasoline, diesel fuel, mineral oils).

Quiz

Click the **Quiz** button to edit this object

Review questions – Quiz 1 (Introduction)

- Read each question carefully
- You have 30 seconds for each answer
- Press the **Submit** button to submit your answer
- To pass, you must answer at least 85% of the questions correctly



PART 2

ELECTRICAL EQUIPMENT

Classification of electrical equipment according to the risk of injury

- **Power equipment**
  - currents hazardous to persons, animals and property **may be generated** during normal use.

- **Low-power equipment**
  - currents hazardous to persons, animals and property **cannot arise** during normal use.

Types of EE with regard to voltage (AC)

Voltage category	Voltage designation		Nominal voltage *U*		
			earthed system		isolated system
			between conductor and earth	between conductors	between conductors
I	ELV	Extra low, Small	$U \leq$ 50 V	$U \leq$ 50 V	$U \leq$ 50 V
II	LV	Low	50 V < $U \leq$ 600 V	50 V < $U \leq$ 1000 V	50 V < $U \leq$ 1000 V
A	HV	High	0,6 kV < U < 30 kV	1 kV < U < 52 kV	1 kV < U < 52 kV
B		Very high	30 kV $\leq U <$ 171 kV	52 kV $\leq U <$ 300 kV	52 kV $\leq U <$ 300 kV
C		Extra high	-	300 kV $\leq U \leq$ 800 kV	-
D		Ultra high	-	$U >$ 800 kV	-

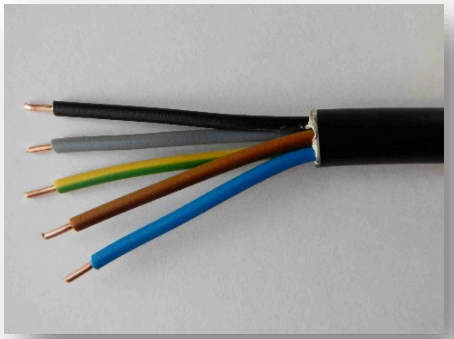
Nominal voltage of AC socket in Europe is **230/400 V**
(three phase system)

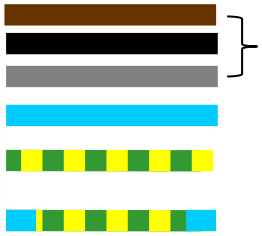
Colour coding of conductors (ČSN 33 0165 ed. 2, ČSN EN 60445 ed.6)

- **Alternating current system**

AC

  - Insulated conductors





Conductor		Identification colour
L	Phase	black, brown, light gray
N	Neutral	light blue
PE	Protective earthing	green/yellow
PEN	PEN conductor	green/yellow + light blue

  - Bare conductors

Conductor		Identification colour
L	Phase	orange
N	Neutral	light blue
PE, PEN	Protective earthing	green/yellow

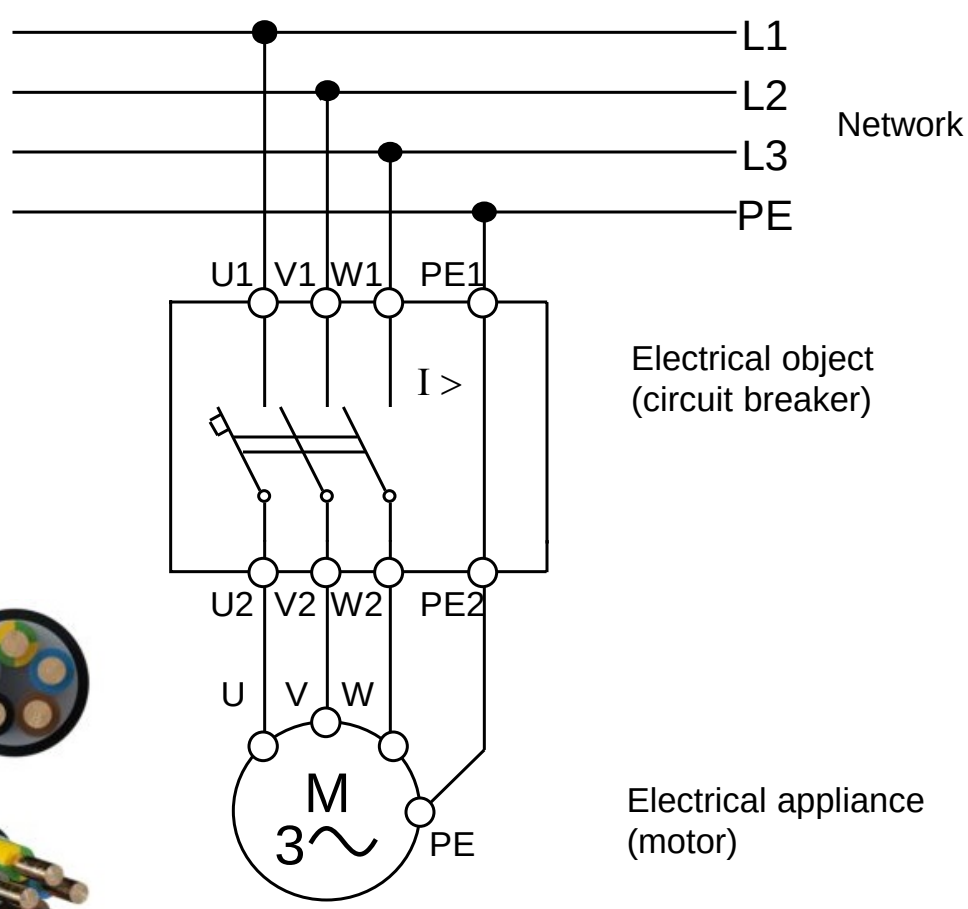
- **Direct current system**

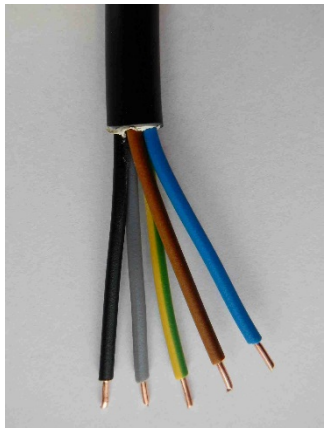
DC

Conductor		Identification colour
L+	Positive	dark red
L-	Negative	dark blue
M	Mid-wire	light blue
PE, PEM	Protective earthing	green/yellow

MARKING WIRES AND TERMINALS – EXAMPLE

- The colours GREEN and YELLOW can only be combined with each other for the protective conductor.
- Single phase wires can be combined as desired (e.g., 3x black).

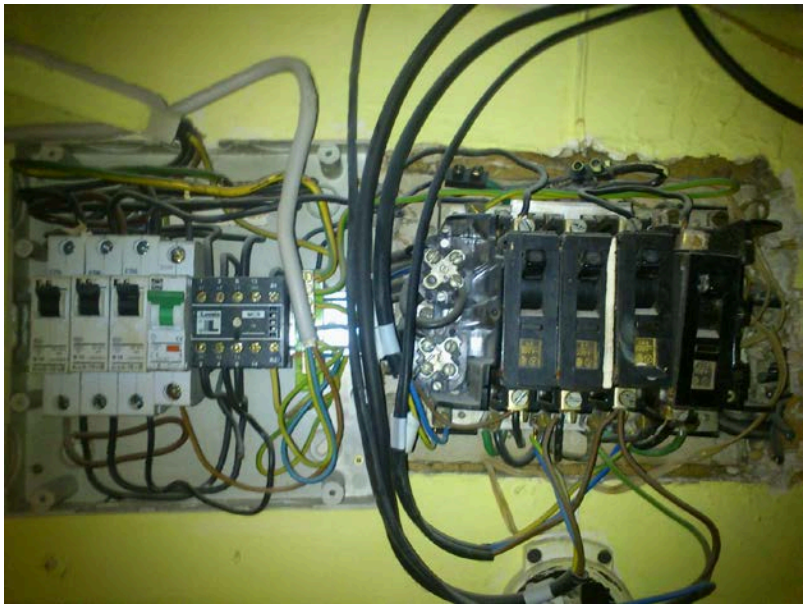




Motto: If a wire can be connected in two ways, the first one will blow your fuses...

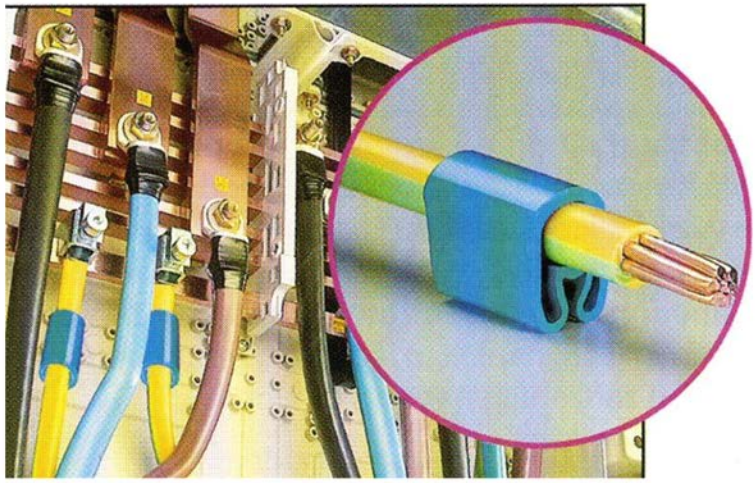
Marking wires and terminals – example

Definitely not like this
Colour coding must be obey...



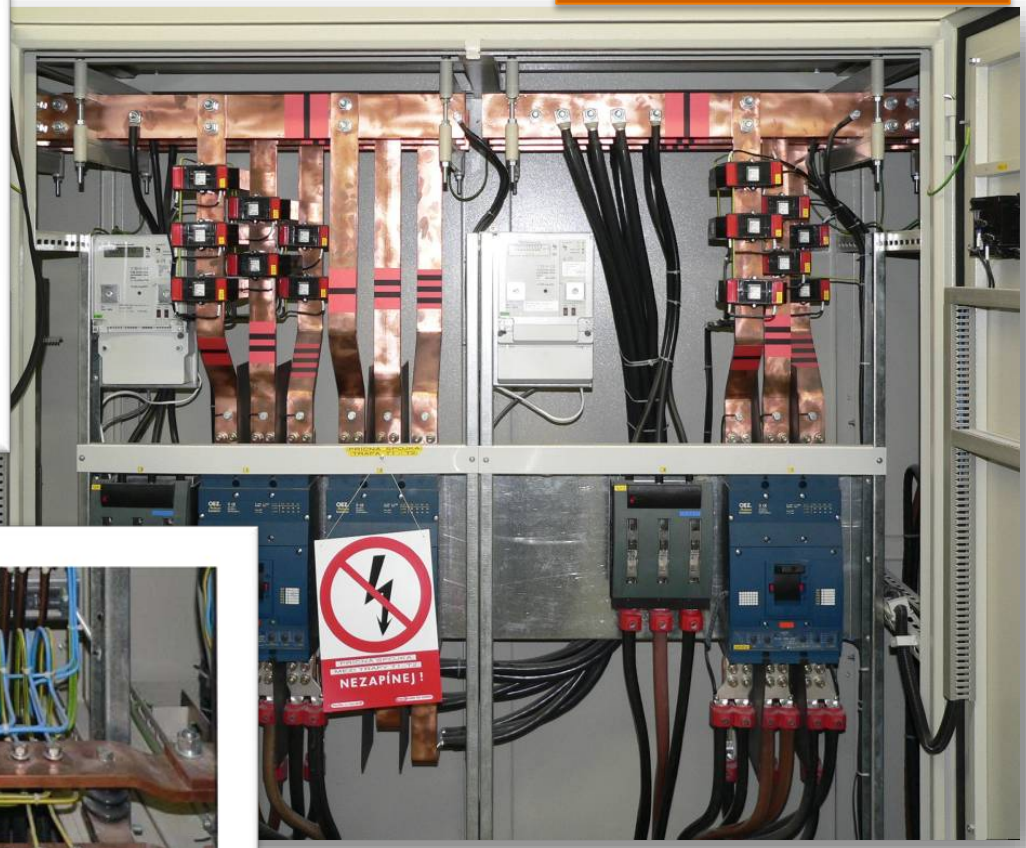
Definitely not like this
Hazardous live parts must not be accessible, and the wiring should be clear...

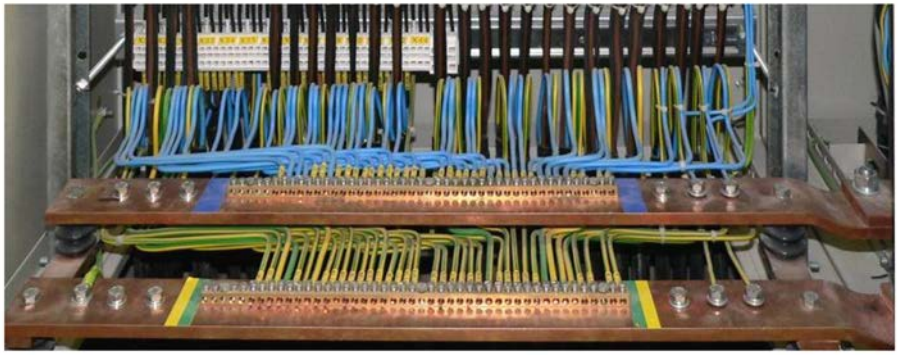
Colour coding of wires



PEN conductor

Bare busbars



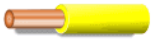
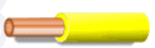


PE and N bridge

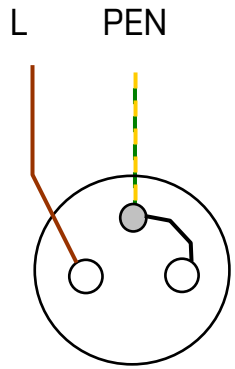
Colour coding of conductors - World

ELECTRICAL WIRING COLOR CODES (NEC & IEC) - 1 & 3 PHASE (AC)

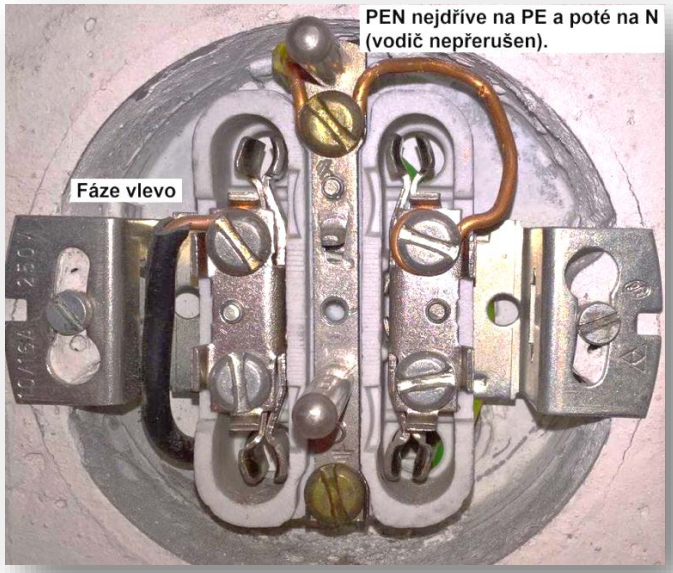
www.electricaltechnology.org

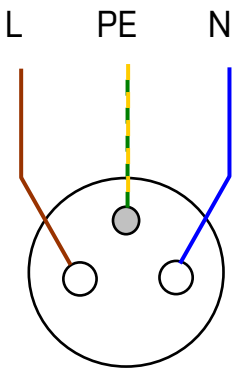
PHASE SUPPLY	WIRE & CABLE	NEC - US / CANADA (120, 208 & 240V)	NEC - US / CANADA (277 & 480 V)	IEC- UK & EU	CHINA & RUSSIA (Old)	AUS & NZ	JAPAN	INDIA, PAK & SA
3-PHASE	LINE 1 "L1"							
	LINE 2 "L2"							
	LINE 3 "L3"							
COMMON	NEUTRAL "N"						* 	
GROUND / EARTH "PG" or "PE"		 Or 						
1-PHASE	LINE "L"							
	NEUTRAL "N"							

Low voltage AC distribution sockets – 230V (single-phase)

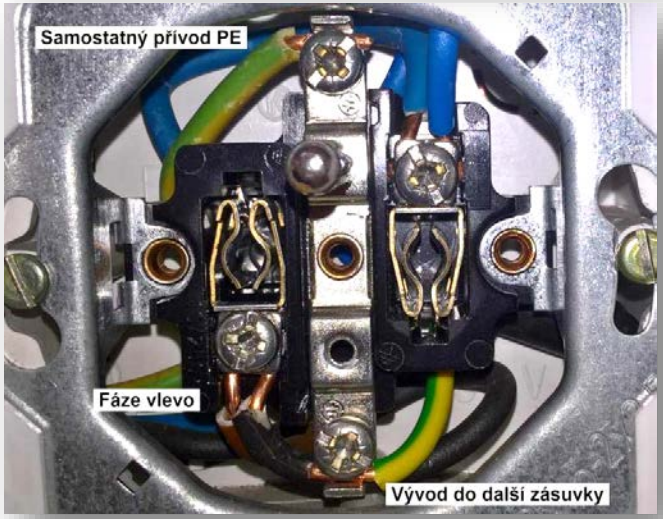


TN-C network

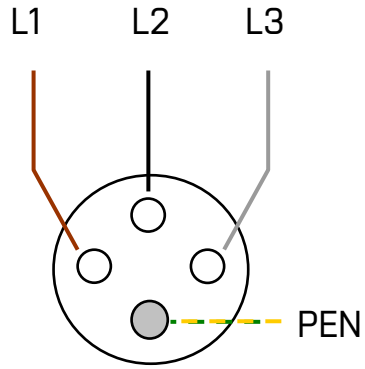




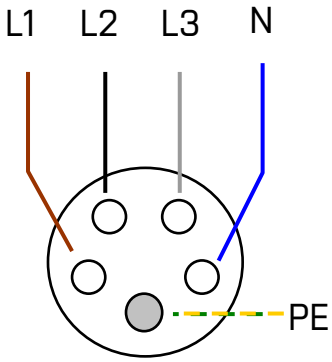
TN-S or TT networks



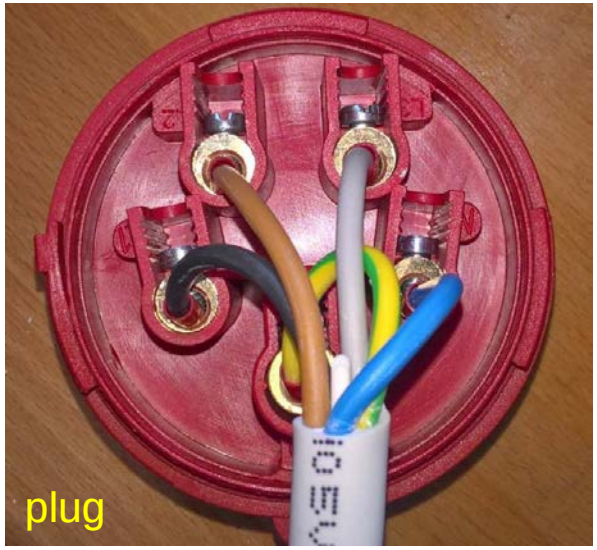
Low voltage AC distribution sockets - 400V (three-phase)



TN-C network



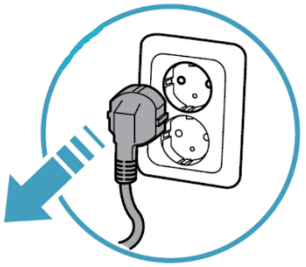
TN-S or TT networks



Types of connections to electrical appliances (ČSN 34 0350 ed. 2)

- Types of connections
  - Fixed connection
  - Flexible connection
  - Detachable connection
    - Fixed to appliance
    - Detachable from appliance
    - Extension cord
    - Two-wire extension cord

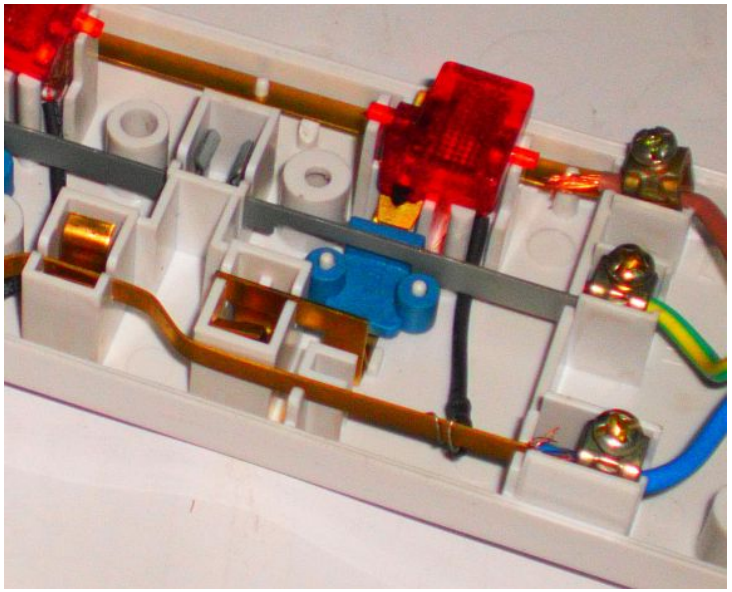
Flexible connection



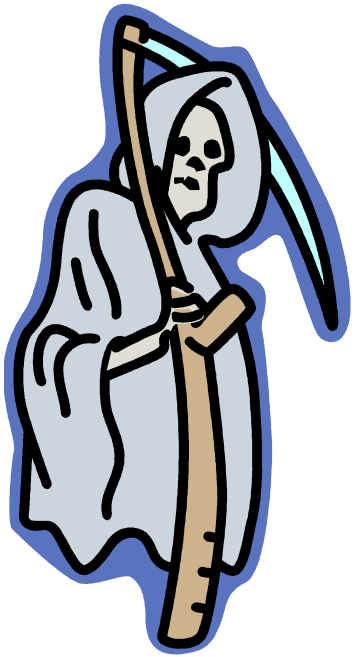
Detachable connection

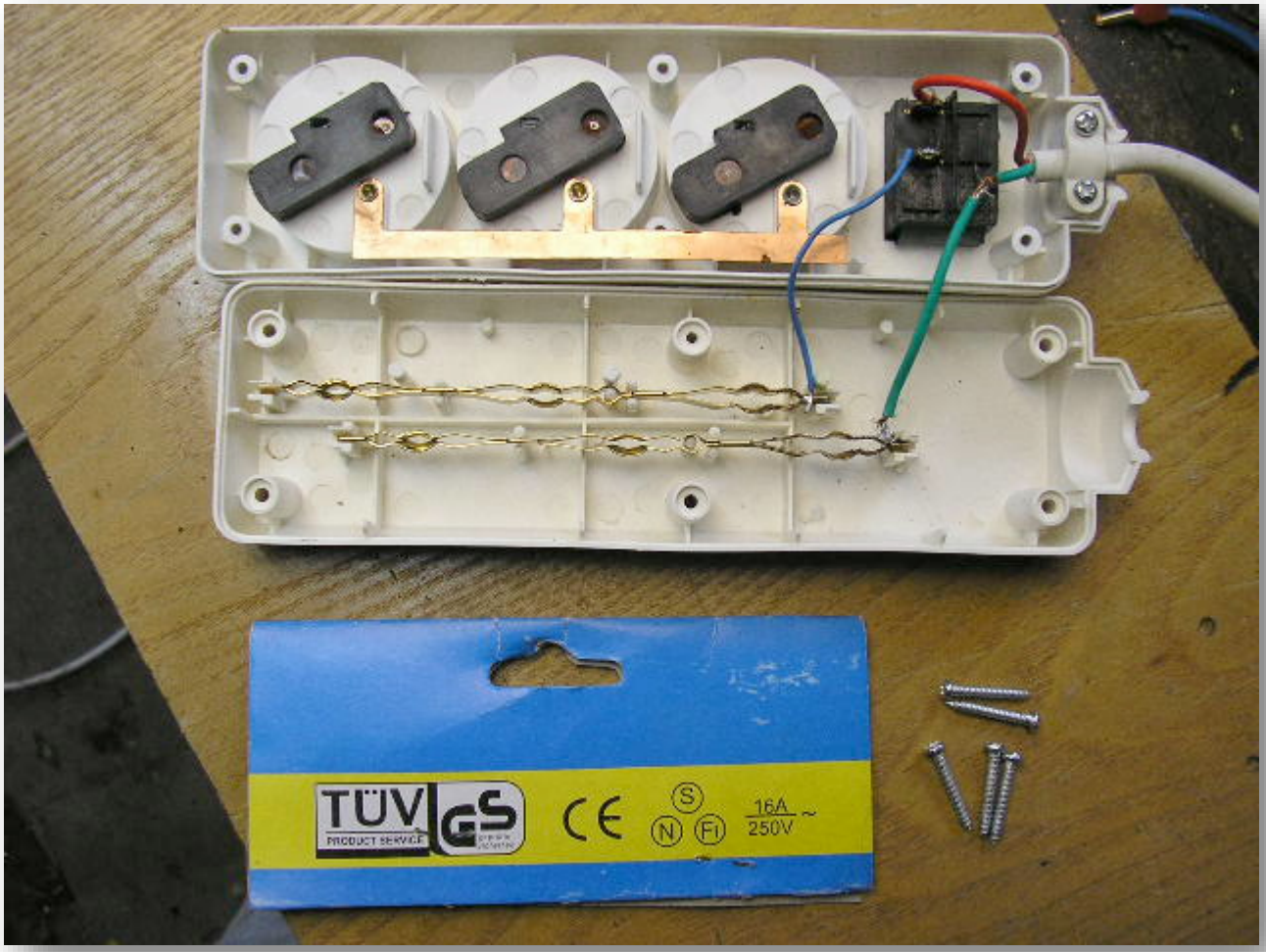
Extension cord

- Plugs and sockets must have the **same rated current and voltage, and the same number of poles**
- Cords must be reliably **relieved of tension** and secured against displacement or tearing of the wires;
- **The protective conductor** must be the last to break when pulled out, which is why it is longer.
- **Under no circumstances** may voltage appear on the pins of unconnected plugs.
- Movable cables with protective conductor (for EE protection class I) **must have a plug and socket with protective contact**
- Movable cables without a protective conductor (for EE protection class II and III) must be **inseparably connected to the plug and either permanently connected at the other end or fitted with a non-interchangeable plug.**



Life-threatening extension cord





For a description, see "Notes" – top right

Quiz

Click the **Quiz** button to edit this object

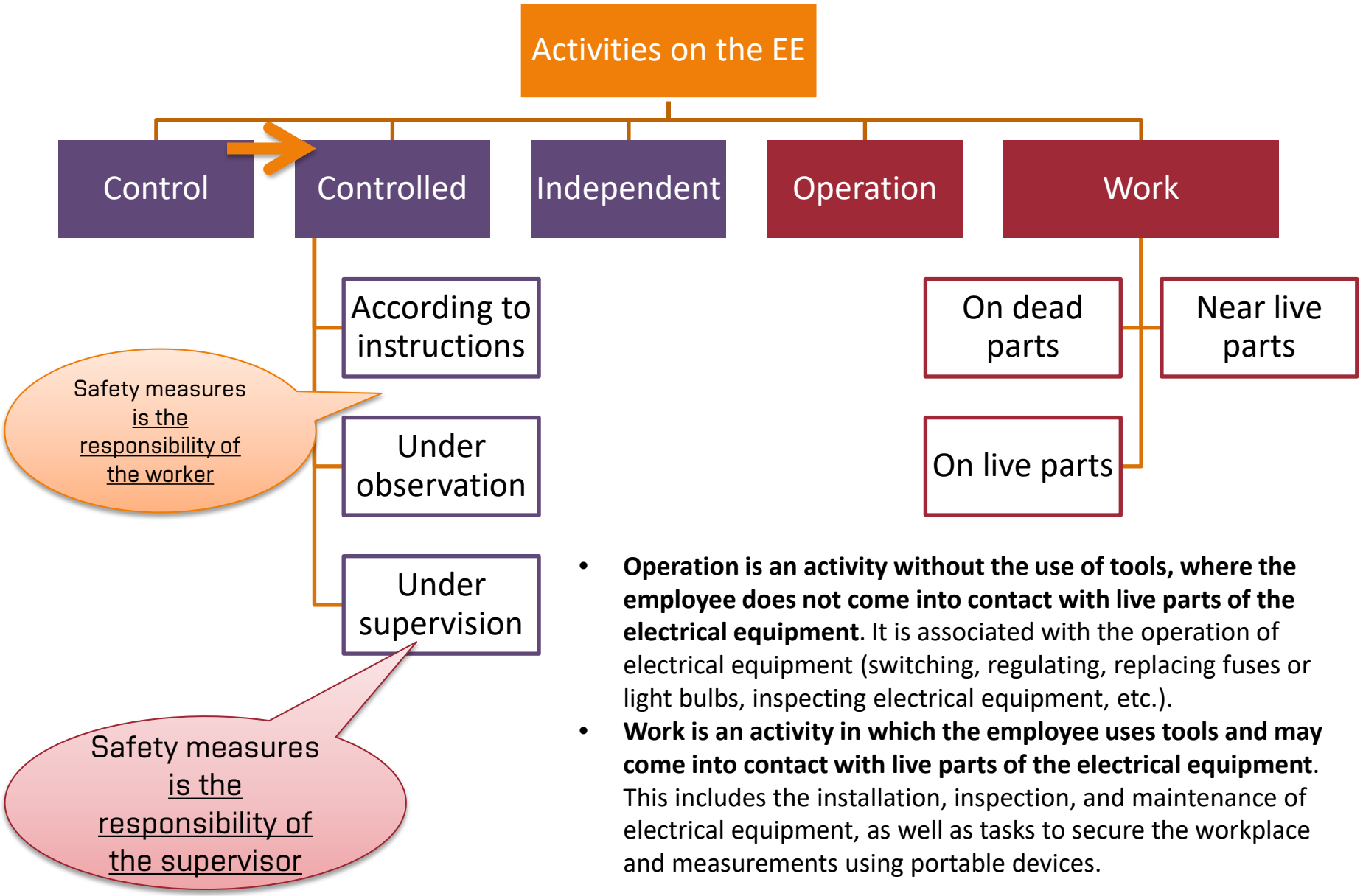
Review questions – Quiz 2 (Electrical equipment)

- Read each question carefully
- You have 30 seconds for each answer
- Press the **Submit** button to submit your answer
- To pass, you must answer at least 85% of the questions correctly

PART 3

SAFETY OF ELECTRICAL EQUIPMENT

Overview of activities on EE (GR 190/2022 Coll. and ČSN EN 50110-1 ed. 3)



- **Operation is an activity without the use of tools, where the employee does not come into contact with live parts of the electrical equipment**. It is associated with the operation of electrical equipment (switching, regulating, replacing fuses or light bulbs, inspecting electrical equipment, etc.).
- **Work is an activity in which the employee uses tools and may come into contact with live parts of the electrical equipment**. This includes the installation, inspection, and maintenance of electrical equipment, as well as tasks to secure the workplace and measurements using portable devices.

Overview of activities on EE (GR 190/2022 Coll. and ČSN EN 50110-1 ed. 3)

Working according to instructions

- The necessary instructions for safe work performance are provided. Instructions may only be given by a knowledgeable person.
- **Workers are responsible for complying with safety regulations.**

Work under observation

- More detailed instructions are provided. Supervision is performed **only** by **a qualified person**.
- Before starting work, the person performing supervision shall ensure that the necessary safety measures have been taken.
- During the work, they shall check compliance with safety regulations as necessary.
- **Workers are responsible for complying with safety regulations.**

Work under supervision

- Work is performed in the constant presence of a person authorized to supervise – **only a qualified person.**
- **The supervisor is responsible for compliance with safety regulations.**

Work on de-energized parts (work on dead parts)

Work on electrical equipment without voltage is considered to be work in which the equipment is disconnected from the voltage and separated from other live parts under voltage by enclosures that protect against accidental contact.

- Five basic steps must be performed in the following order:
  1. Disconnecting the EE from the mains
  2. Securing the EE against being switched back on
  3. Verify that the equipment is de-energized
  4. Earthing and short-circuiting (applies to medium voltage)
  5. Protection in the vicinity of live parts
- Only an authorized person (teacher) may give permission to start work.

Overview of activities on EE (GR 190/2022 Coll. and ČSN EN 50110-1 ed. 3)

Working on live parts

- Persons come into contact with exposed live parts or interfere with the protective space with parts of their body or tools.
- Persons must be instructed or knowledgeable and specially trained.
- Common work under voltage may include, for example, replacing fuses, measuring, testing, including verifying the de-energized state.

Work near live parts

- The worker does not touch live parts and may approach exposed live parts at the outer edge of the protective space.
- Either
  - protection by a obstacles, enclosures, or insulating cover;
  - or protection by a safe distance and, if necessary, supervision.

Act No. 250/2021 Coll., effective from July 1, 2022

Act No. 250/2021 Coll. on occupational safety in connection with the operation of dedicated technical facility and on amendments to related acts

- Decree **No. 50/1978 Coll.** on professional competence in electrical engineering has been repealed.
- Requirements for **the safety of operation of dedicated technical facility (DTF**) and occupational health and safety and the performance of state administration of DTF.
- Rights and obligations of persons performing **operation, assembly, maintenance, inspection, revision, repairs, and filling of containers with gases in DTF.**
- **Method of verifying the professional competence of persons** for activities on DTF and the professional competence for the performance of activities of persons performing operation and work on EE.

Act No. 250/2021 Coll.

Act supplemented by government regulation:

- **Government Regulation No. 190/2022 Coll. on dedicated technical facility and requirements for ensuring its safety.**
- Government Regulation No. 191/2022 Coll. on designated technical gas equipment ….
- Government Regulation No. 192/2022 Coll. on designated technical pressure equipment ….
- Government Regulation No. 193/2022 Coll. on designated technical lifting equipment ...
- **Government Regulation No. 194/2022 Coll. on requirements for professional competence to perform activities on electrical equipment and for professional competence in electrical engineering.**

Act No. 250/2021 Coll. and Government Regulation 194/2022 Coll.

- **Instructed persons** (Art. 4 of GR No. 194/2022 Coll.)
- **Electrician** (Art. 6 of GR 194/2022 Coll.)
- **Supervising electrician** (Art. 7 of GR 194/2022 Coll.)
- **Inspection Technician** (Art. 11 of the Act and Art. 8 of GR 194/2022 Coll.)

Qualifications of workers			Basic requirements		Verification of competence	
Name	**NV 194/2022**	**For activities on the EE**	**Professional qualification**	**Professional experience (explosion without / with)**	**Examination board**	**Expiration of examination**
Instructed person	**Art. 4**	vn	none	none	NO	max. 3 years
Electrician	**Art. 6**	vn	YES or further professional education	according to employer	YES	max. 3 years
Supervising electrician	**Art. 7**	nn	YES	2 / 3 years	YES	max. 3 years
		vn		3 / 4 years		
		lightning rods		2/3 years		
Inspection technician	**Art. 8**	nn	YES	4 / 4+1 years	YES TIČR	5 years
		vn		4 / 4+1 years		
		lightning rods		2 /2+1 years		

Instructed person (according to Art. 4 GR No. 194/2022 Coll.)

Is a professionally qualified person – **instructed in regulations to ensure occupational health** and **safety when** working on electrical equipment and in its vicinity,

- trained in the area of possible sources and causes of risks on and near electrical equipment and made aware of possible threats to electrical equipment,
- familiar with procedures for **providing first aid** in the event of electric shock.
- **No electrical engineering education is required**.
- The trained person performs the following tasks in particular:
  - **independent operation of electrical equipment** without voltage restrictions, with the restriction that they may only touch those parts of the equipment that are intended for operation,
  - work **according to instructions on ELV and LV electrical equipment** de-energized and near live parts,
  - work **under observation on** de-energized **HV EE** and in near its live parts,
  - work under **the supervision near uncovered live parts of LV EE under voltage**, at a safe distance from them, or up to the point of contact with an insulating cover protecting against accidental contact with live parts,
  - work **under the supervision near uncovered live parts of HV EE under voltage,**
  - work on EE in special cases**.**

Electrician (according to Art. 6 GR No. 194/2022 Coll.)

A person with professional qualifications (education) who, after training, has passed an examination of professional competence to perform activities in electrical engineering within a specified scope.

- Must have professional experience in accordance with the organization's regulations and first aid training.
- **May independently carry out every activities on and near electrical equipment independently, with the exception of special cases based on risk assessments.**
- Knowledge is verified by a three-member examination board chaired by a revision engineer.
- The training and scope of the examination of professional competence to perform activities in electrical engineering corresponds to the scope of the professional competence required for the activities performed.

Prohibited work

Other regulations define **prohibited work**, generally under the following conditions:

- If the prescribed safety measures cannot be complied with and their implementation would exceed the acceptable risk limit in the following cases:
  - In unsuitable atmospheric conditions,
  - In confined spaces, or in locations that do not provide sufficient stability for workers or do not allow for escape in an emergency,
  - In areas with an unsuitable environment.
- Work by persons **without the appropriate qualifications** is also prohibited.

Definition of prohibited work according to ČSN EN 50110-1 ed. 3

- Work under voltage:
  - in strong winds,
  - poor visibility, or when
  - persons cannot easily control the tools.
- In the event of an approaching storm, work under voltage must not be started or must be interrupted.

- During their studies and only for school laboratories:
  - They may perform such operation and work on EE that corresponds to their gradually acquired knowledge and physical ability, always under observation or supervision.
  - After instruction and testing, they are considered to be **instructed persons**.

Ensuring safety during operation and work

- Safety messages
- Protective and work equipment
- Technical and organisational measures

Safety message (ČSN ISO 3864)

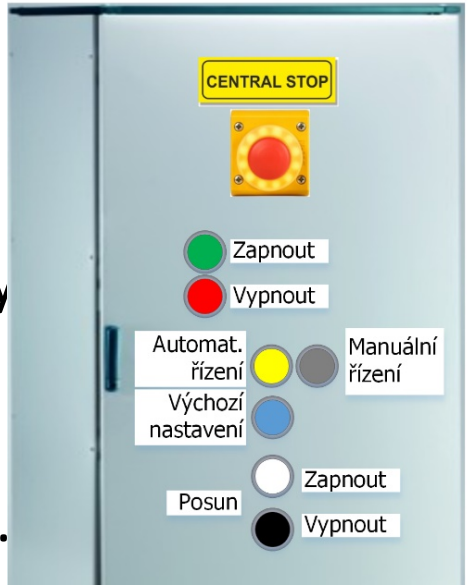
- Graphic
  - Tables and inscriptions
  - Colour safety measures
- Light
- Acoustic

Colour coding on controls:

- **Emergency controls** (STOP/OFF) must be marked **in red**.

  STOP/OFF – white, gray, and black, preferably black (red + emergency stop).

- **START/ON** – white, gray, or black, preferably white, green in the Czech Republic.



Security sign templates

Prohibition signs (Do not do)
Signs prohibiting certain behaviour
e.g. No Smoking

Warning signs (Caution, Danger)
Signs which indicate a specific course of action is to be followed
e.g. Danger high voltage

Mandatory signs (You must do)
Signs which indicate a specific course of action is to be followed
e.g. Safety helmets must be worn

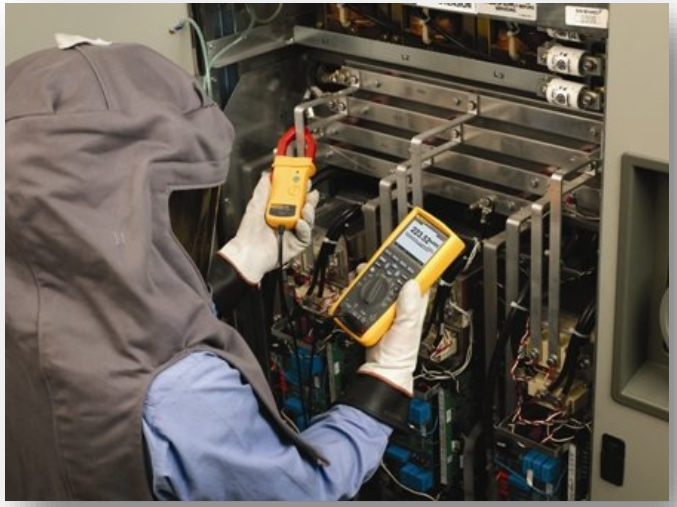
Safe Condition Signs (Safest way)
Signs giving information about safe conditions, doors, exits and escape routes
e.g. Fire exits

Fire signs (Fire fighting equipment)
Signs indicating the location of fire fighting equipment
e.g. Fire point

Protective and work equipment

- **Protective equipment**
  - Insulating gloves, boots, and carpets
  - Insulating helmets and suits
  - Protective goggles and shields
  - Short-circuiting, discharging, and earthing devices ...

  It is necessary to check that they are in good condition before each use



- **Working equipment**
  - Testers, measuring instruments
  - Insulated tools, ladders …

Test rooms and laboratories (ČSN EN 50191 ed. 2)

- Electrical test equipment with risk of electric shock **intended for conducting experiments:**
  - Testing workplace – equipment in a designated area.
  - Test room or experimental workplace (laboratory) – at least one workplace.
  - Temporary test workplace.
- **Hazardous area** – the vicinity of live parts, the boundaries of which must not be crossed unless complete protection against direct contact is ensured.
- Test equipment and hazardous areas must be clearly and **visibly marked**.
- Test equipment must be equipped with switching and operating status indicators, e.g., indicator lights.
- **Fire extinguishing equipment** for extinguishing live equipment must be installed.
- The test object must be isolated from the ground, or the introduction of voltage to foreign conductive parts must be prevented.
  prevent voltage from being introduced to foreign conductive parts.
- **Test rooms** must be separated from workplaces and traffic routes.

Operation of test equipment (ČSN EN 50191 ed. 2)

- A sufficient number of **emergency stop** controls must be installed**:**
  - They must be located in a clearly visible place that is quickly and easily accessible.
  - They must be red, suitably shaped, and clearly distinguishable from other controls.
  - They must not switch off equipment where this could cause further danger, e.g., lighting.
  - If some connection points of test circuits are not emergency shut-off, they must be marked accordingly.
- In testing rooms (laboratories) and temporary testing facilities, instructed persons may work **only under the observation or supervision**.
- **Operating instructions** must be drawn up**.**
- Workers must be verifiably **familiarized** with the workplace.
- The workplace must be **regularly inspected** (at least every 12 months); any defects found must be immediately repaired or reported to the responsible worker.

Operation of test equipment (ČSN EN 50191 ed. 2)

- Workers (students) must be **verifiable familiar** with the workplace with regard to:
  - Laboratory operating rules
  - Location of emergency stop controls
  - Location of first aid kit
  - Location of PFE (portable fire extinguisher)
  - Potential risks of equipment in the workplace

Operation of test equipment (ČSN EN 50191 ed. 2)

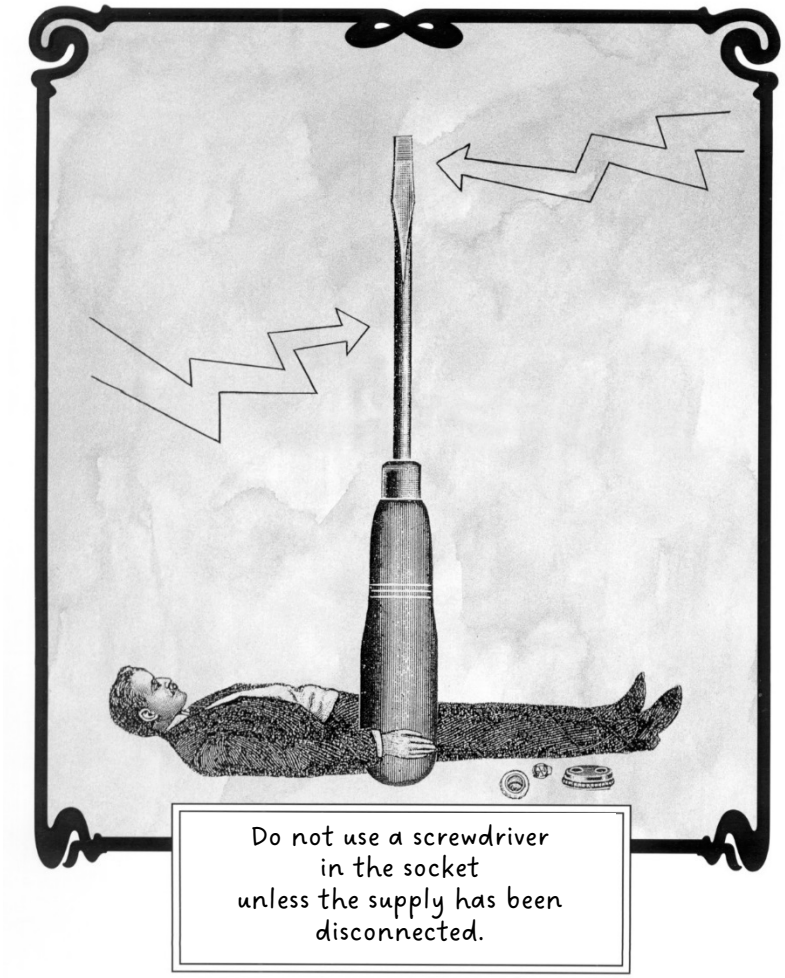
- Before use**,** testing equipment must be **checked for visible defects** or damage **and must not be operated if they show damage** or defects that could endanger the safety of operating personnel.
- **Any damage or defects found must be reported to the responsible person**, and maintenance and repairs may only be carried out by qualified persons.
- The test setup must be designed to prevent voltage from being introduced to surrounding conductive parts.
- Every employee working in the laboratory **must be fully aware of the existing risks** and is obliged to take such safety measures in their work to protect both themselves and other employees from danger.
- Only employees who are employed in hazardous areas or others who have been instructed with local operating regulations may enter these areas. For test equipment operating at voltages higher than 1 kV, the approval of the work supervisor is required.
- **The equipment may only be switched on at the instruction of the work supervisor.**
- **After completion of work, the test equipment must be put into the de-enegized state.**

Quiz

Click the **Quiz** button to edit this object

Review questions – Quiz 3 (Electrical equipment safety)

- Read each question carefully
- You have 30 seconds for each answer
- Press the **Submit** button to submit your answer
- To pass, you must answer at least 85 % of the questions correctly



PART 4

ELECTRIC SHOCK

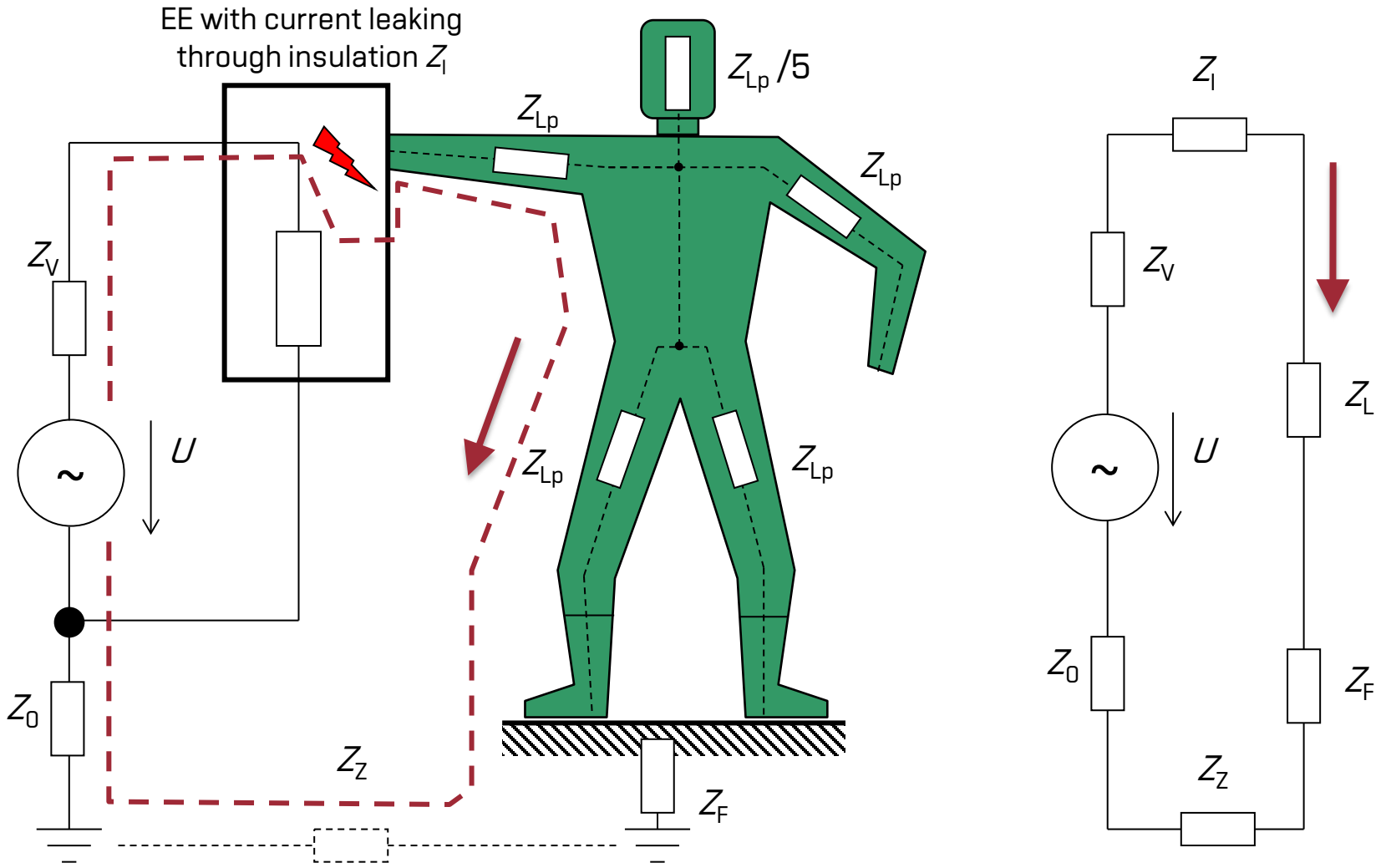
Electric shock

Types of injuries:

- **Electric shock**
- **Electric arc burns – Arc-Flash**
- Fire or explosion caused by electrical energy when operating or working on electrical equipment

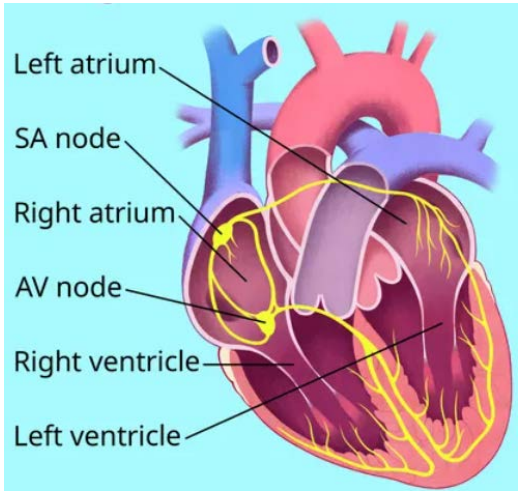
- The electric shock is caused by current flowing through the body or as a result of other effects of current, electric or electromagnetic fields.
- The decisive factors are:
  - the magnitude and path of the current through the body
  - the duration of the current
  - the type of current (direct current, alternating current – frequency)
  - the phase of the cardiac cycle

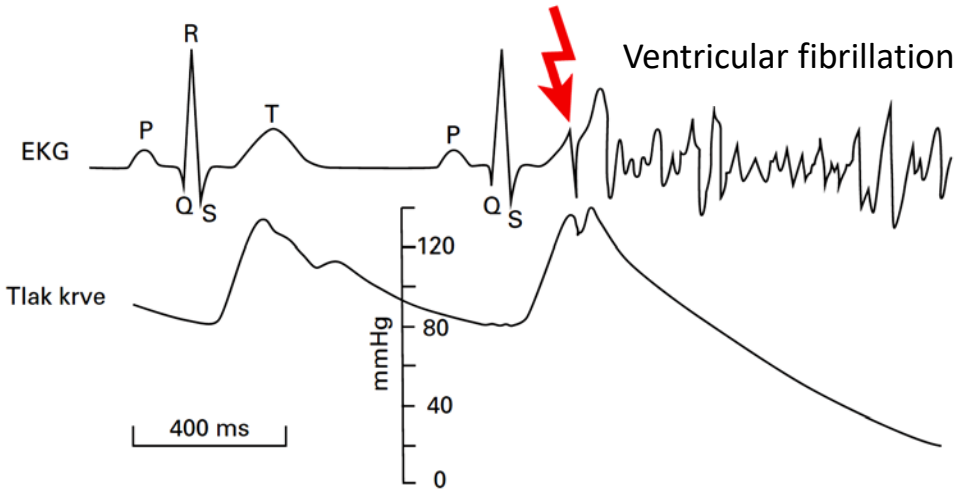
A PERSON TOUCHING ELECTRICAL EQUIPMENT



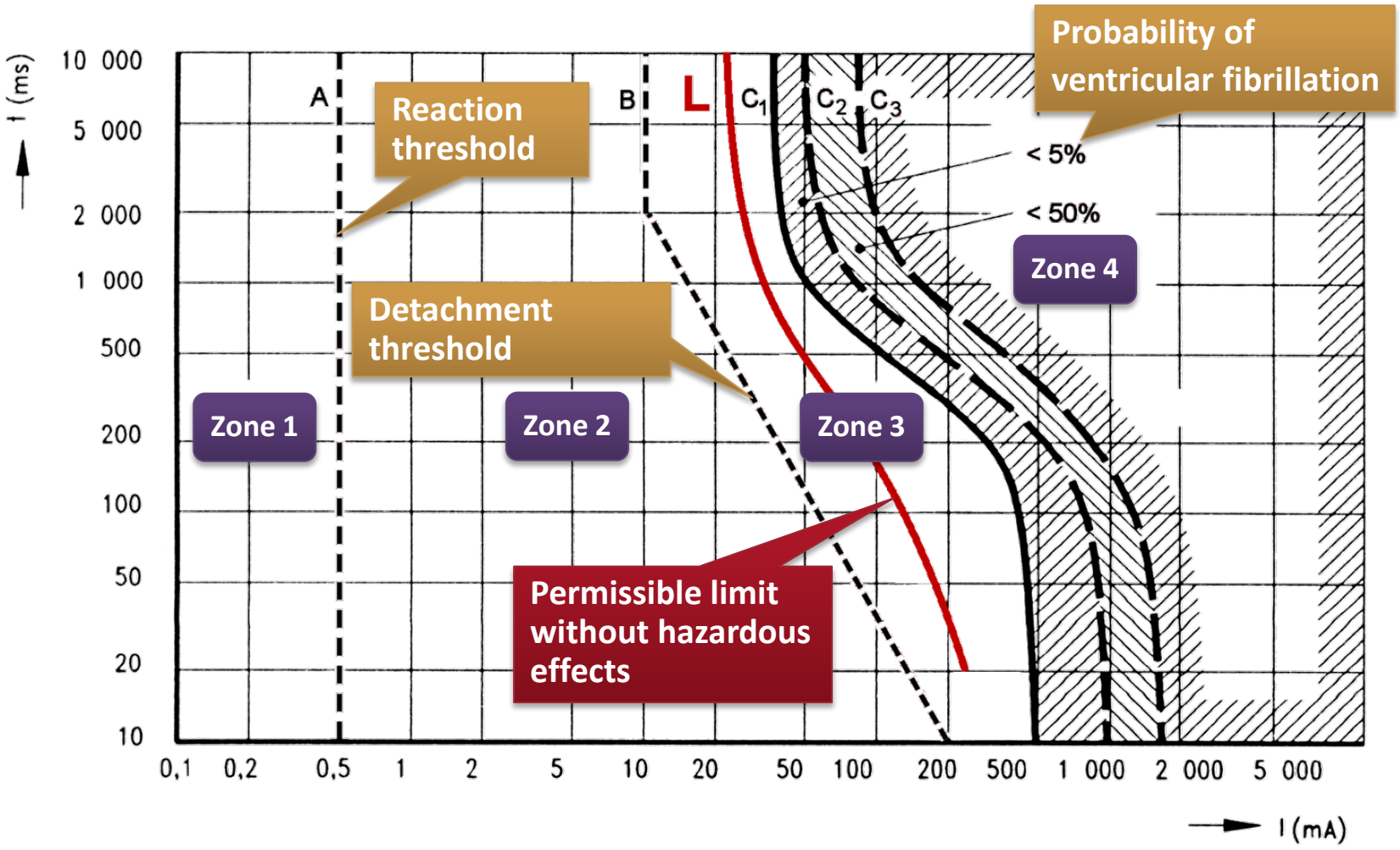
The effect of alternating current on humans

- Currents **between 10 and 30 mA** do not usually lead to death, but prolonged exposure can cause muscle spasms, breathing difficulties, etc.
- Currents **above 30 mA** can be fatal if not quickly disconnected.
- Currents **30 to 500 mA** cause death if they pass for longer than approx. 0.5 s
- Currents **above 500 mA** are usually fatal even when applied for short periods.
- **Ventricular fibrillation** occurs at currents above 500 mA, or at currents as low as 50 mA if the exposure is prolonged. It is considered the main cause of death in electric shock accidents.





Effects of electric current on the human body (ČSN IEC/TS 60479-1)



Applies to alternating current with a frequency of 15 Hz to 100 Hz, left hand - both feet

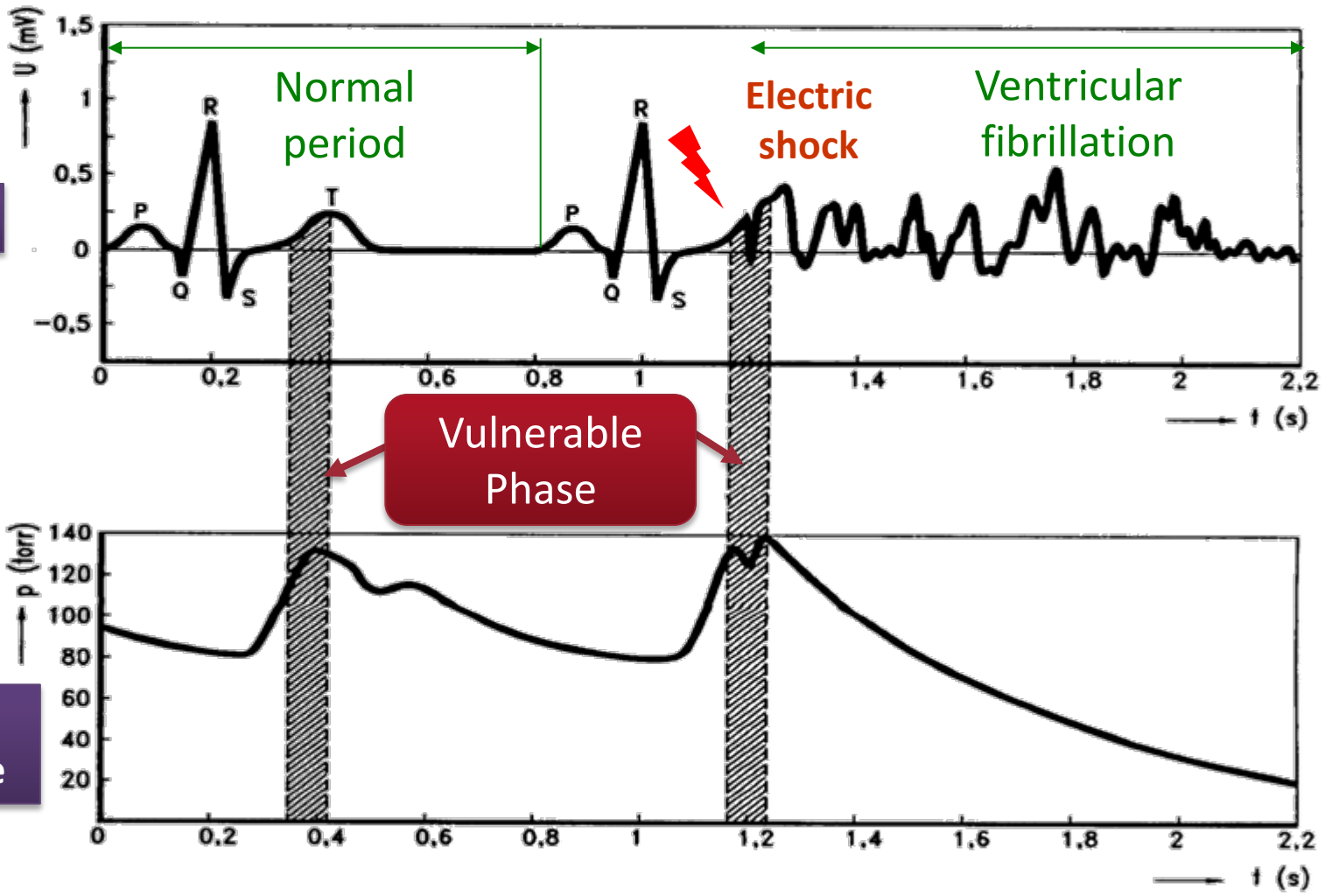
Effects of electric current on the human body (ČSN IEC/TS 60479-1)

The physiological effects of electric current are assessed using threshold values for AC 50 Hz current, left hand - both feet:

- **perception threshold** minimum value at which a perceptible sensation is elicited
- **reaction threshold (line A)** minimum value that causes involuntary muscle contraction
- **detachment threshold (curve B)** maximum value at which the person holding the electrodes can release them
- **ventricular fibrillation threshold (curve C)** minimum value that causes ventricular fibrillation
- The lines in the figure define zones of physiological effects:
- **Zone 1** (up to line A, i.e. < 0.5 mA) Usually no reaction.
- **Zone 2** (≥ 0.5 mA, up to curve B) Usually no harmful physiological effects. Muscle contractions.
- **Zone 3** (between curves B and C1) Usually no damage to the body. Muscle spasms, breathing difficulties, reversible heart rhythm disorders including atrial fibrillation, transient cardiac arrest without ventricular fibrillation may occur.
- **Zone 4** (from curve C1) In addition to the effects listed for zone 3, ventricular fibrillation occurs with a probability of up to 5 % (to line C2), with a probability of up to 50 % (to line C3), with a probability of over 50 % (beyond line C3), with increasing current and time, as well as respiratory arrest and burns.

The trigger characteristics of protective devices (fuses, circuit breakers, residual current devices) must respect the physiological effects of current. Therefore, a **limit curve L** has been agreed upon, determining the permissible duration of current exposure without hazardous effects. It is located in zone 3 with a margin below the threshold of ventricular fibrillation.

Cardiac cycle



Arc-flash

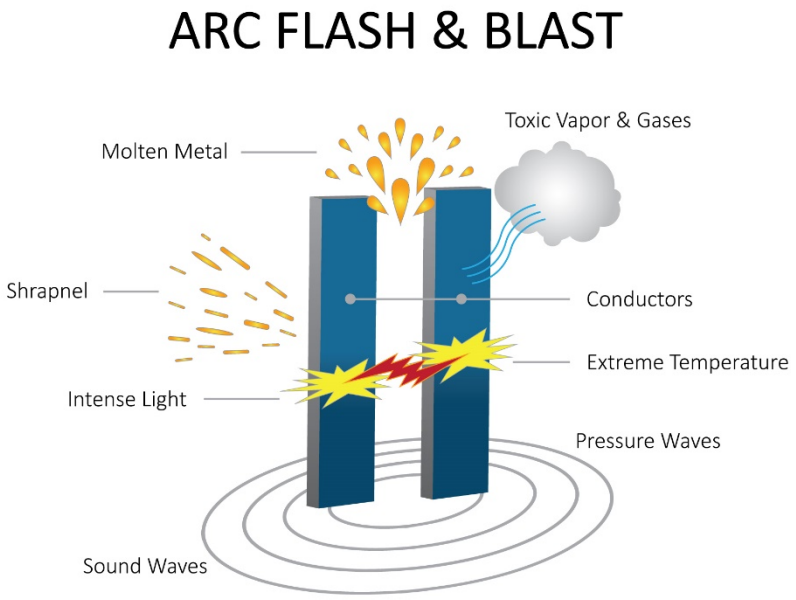
Arc flash is a phenomenon in which energy is released very quickly because of an arc short circuit.

- can occur in distribution systems with voltages above 120 V~ and 50 V=.
- burns from electric arcs still occur, despite advances in the construction and design of switchgear.

The standard states that if a workplace is located near electrical equipment or live parts, an arc flash hazard assessment and evaluation must be performed.

ARC-FLASH

- Consequences of Arc-flash:
  - radiated heat,
  - noise,
  - explosive expansion of the surrounding air due to heating,
  - melting of conductors and metal parts in the vicinity of the arc.
- Depends mainly on:
  - the magnitude of the short-circuit current at the point,
  - the setting of the trigerring characteristics of the protective device.



Quiz

Click the **Quiz** button to edit this object

Review questions – Quiz 4 (Electric shock)

- Read each question carefully
- You have 30 seconds for each answer
- Press the **Submit** button to submit your answer
- To pass, you must answer at least 85% of the questions correctly

Here lies P.J.,
good husband, good father,
but bad electrician

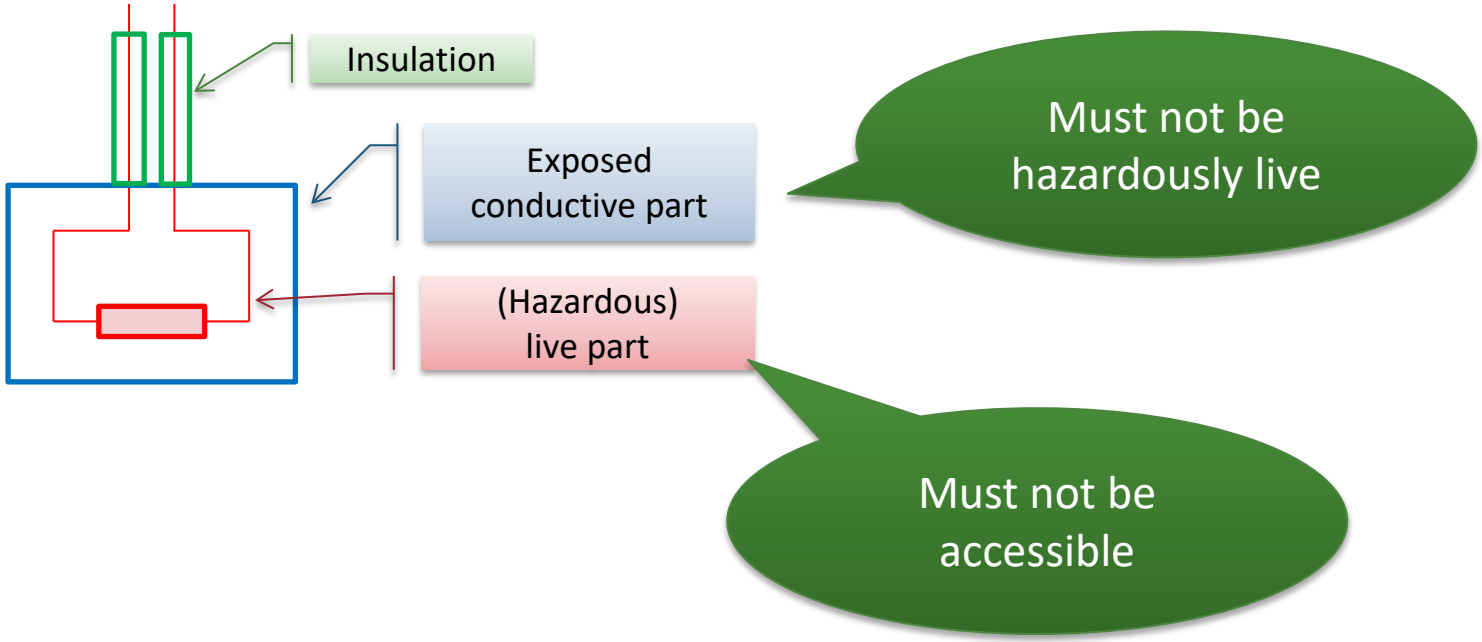
Part 5

Protection against electric shock

Protection against electric shock

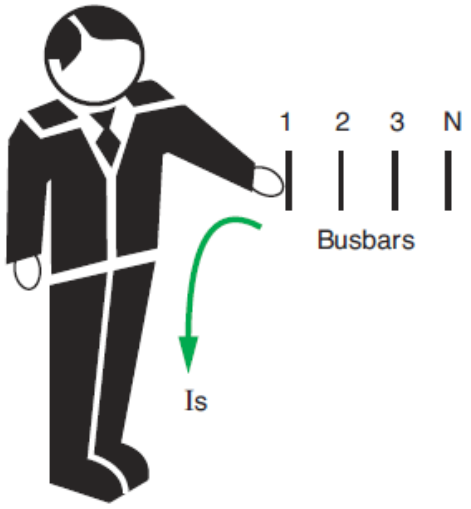
Basic principle of protection against electric shock:
hazardous live parts must not be accessible
and accessible conductive parts must not be hazardously live:

- under normal conditions,
- or under single fault conditions.



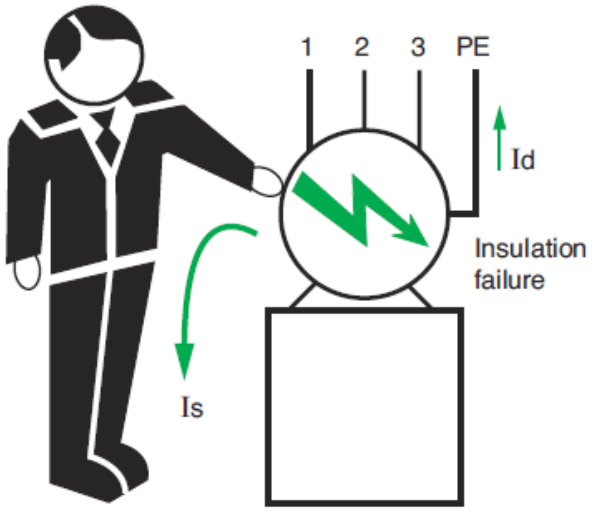
Touching live and Exposed conductive parts

Touching a hazardous live part (direct touch)



Is: Touch current

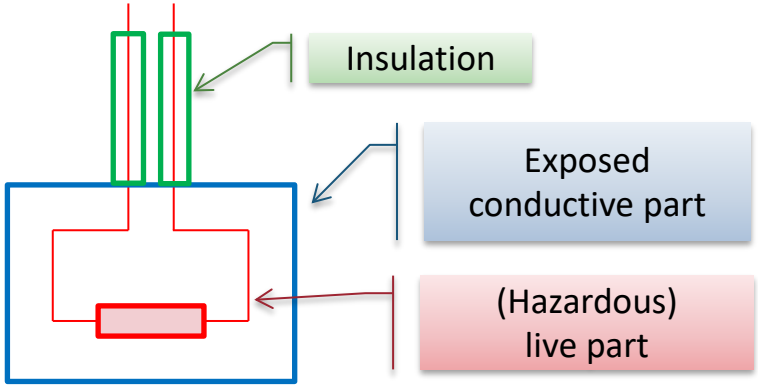
Hazardous touch of an exposed conductive part (indirect touch)



Id: Insulation fault current

A device that is live
looks the same as one that is not,
but feels different to the touch...

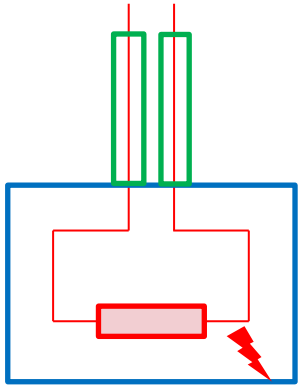
Normal condition and fault condition of EE



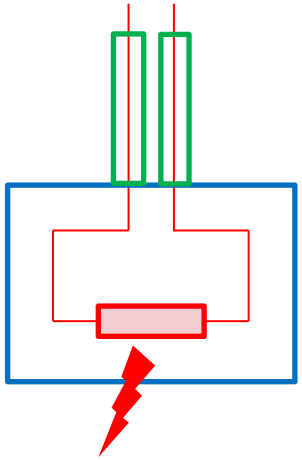
Normal condition

- No dangerous live parts accessible to touch
- Accessible parts are not dangerously live

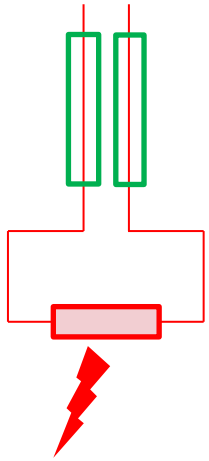
Single fault condition



The accessible conductive part became dangerously live
as a result of a fault in the basic insulation (i.e., insulation between live and non-live parts)



A dangerous live part has become accessible,
e.g., as a result of damage to the enclosure.



An accessible live part that is not dangerous becomes dangerous live
failure of steady-state current or energy limitation

Protection against electric shock

Basic principle of protection against electric shock:

A) Under normal conditions

- Preventing contact with dangerous live parts (**direct contact**) – enclosures, insulation, placement out of reach, etc.
- Use of safe extra low voltage (SELV)

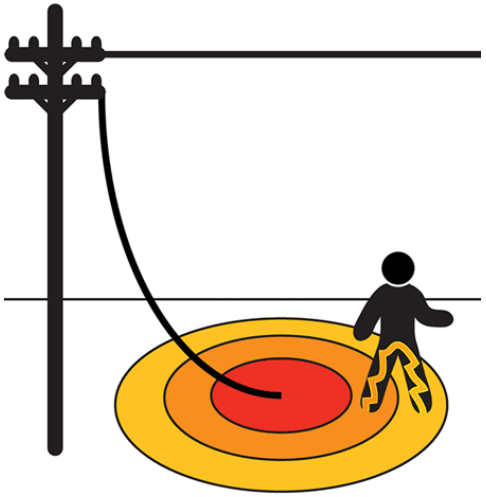
B) In the event of a single fault

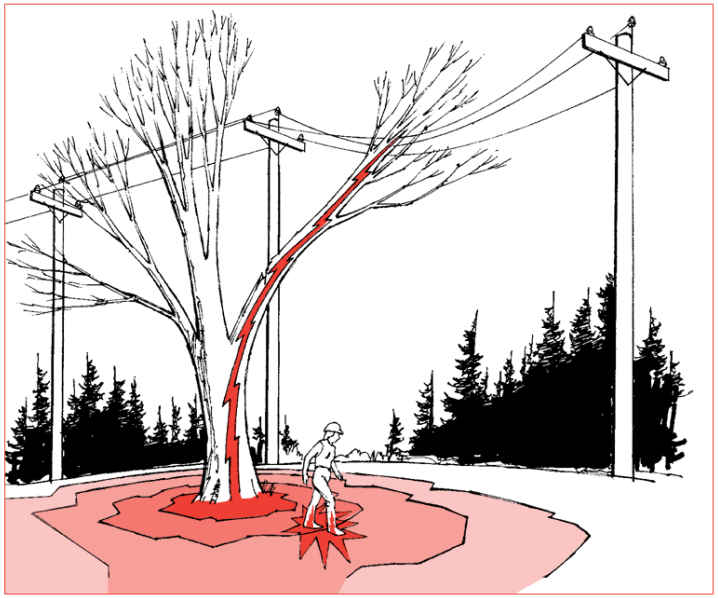
- Limiting the current/energy passing through the body to a safe value
- Limiting the duration of current flow through the body (in the event of **indirect contact**) by early disconnection from the source

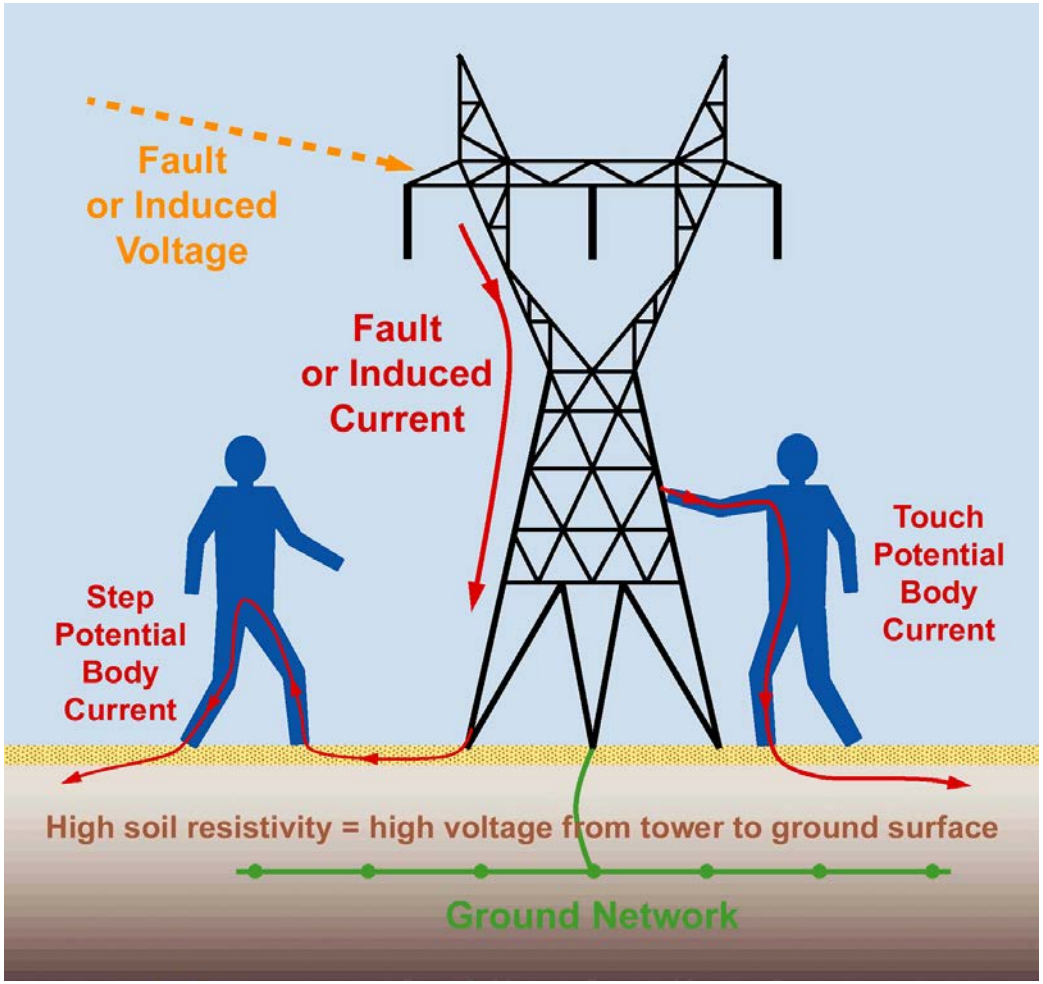
Terminology

- **Basic protection**
  - During normal EE operation
- **Fault protection**
  - Under single fault conditions
- Parts **simultaneously accessible to touch**
  - Less than 2.5 m away
- **Extraneous conductive part**
  - Not part of the electrical installation, but may carry electrical potential.

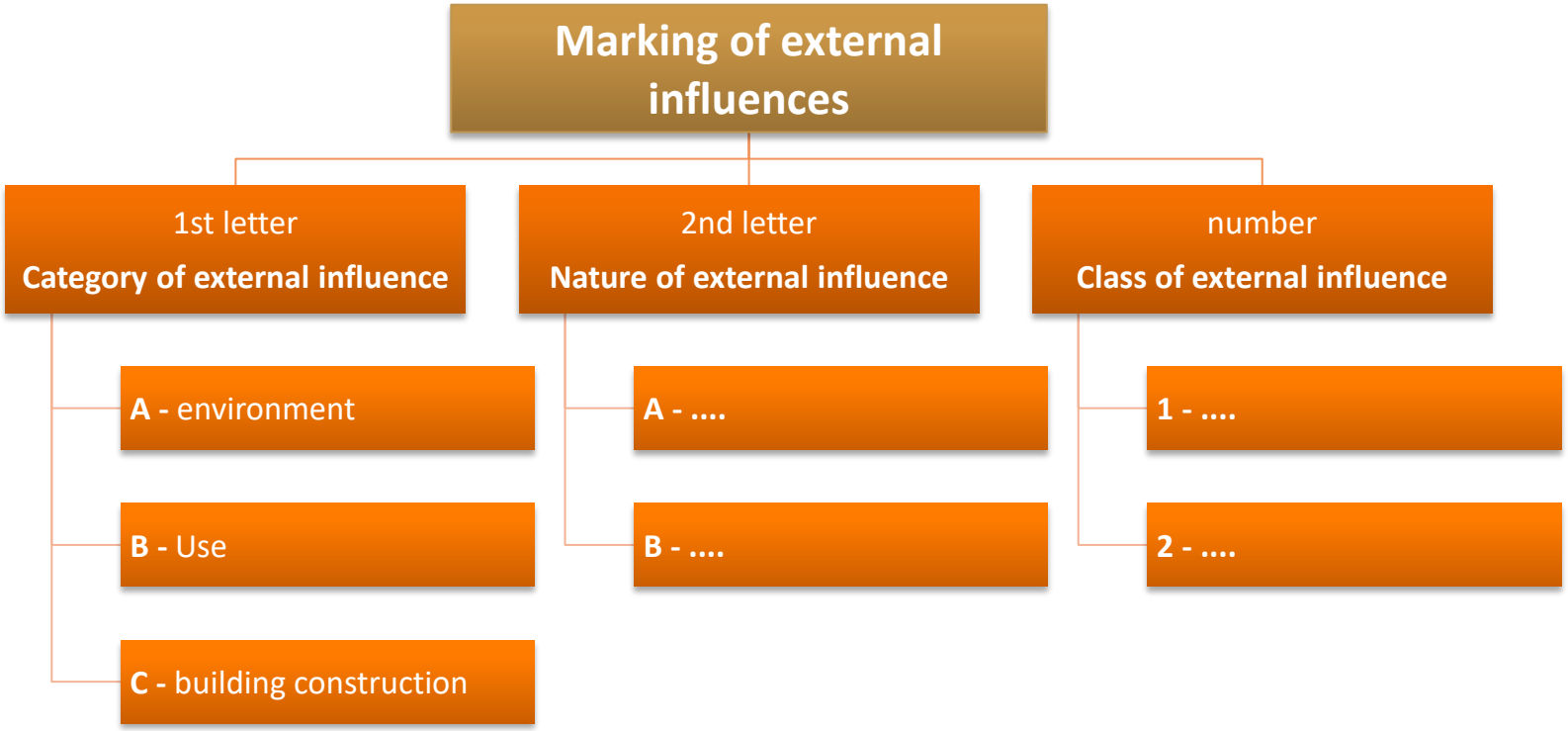
Step voltage generation







CLASSIFICATION OF EXTERNAL INFLUENCES (ČSN 33 2000-5-51 ED. 3)



Example:

- AD1 The probability of water occurrence is negligible
- AD2 Possibility of falling drops
- AD3 Possibility of water falling at an angle of 60° from the vertical
- ...
- AD8 Possibility of permanent and complete submersion

Measures of protection against electric shock (ČSN EN 61140 ed. 3)

Basic protection measures	Measures of protection in case of failure	Enhanced protection measures
• Basic insulation • Enclosures • Obstacles • Protection by position • Voltage limitation (ELV) • Limiting steady-state current and energy/ charge	• Automatic disconnection from the power source • Supplementary insulation • Protective earthing and bonding • Simple circuit separation • Non-conductive surroundings	• Double or reinforced insulation • Protective circuit separation

During **normal operation**
Prevents contact with hazardous live parts

Previously:
- protection against direct contact
- protection against contact with live parts

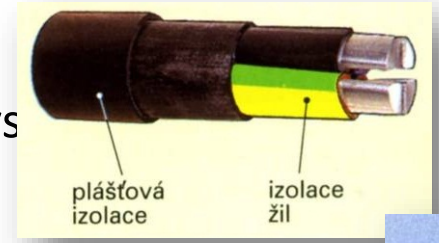
During **a single (first) fault**
Prevents hazardous contact with exposed conductive parts

Previously:
- protection against indirect contact
- protection against contact with exposed conductive parts

During **normal operation and even one (first) fault**
Prevents hazardous contact with live and exposed conductive parts

Basic protection measures

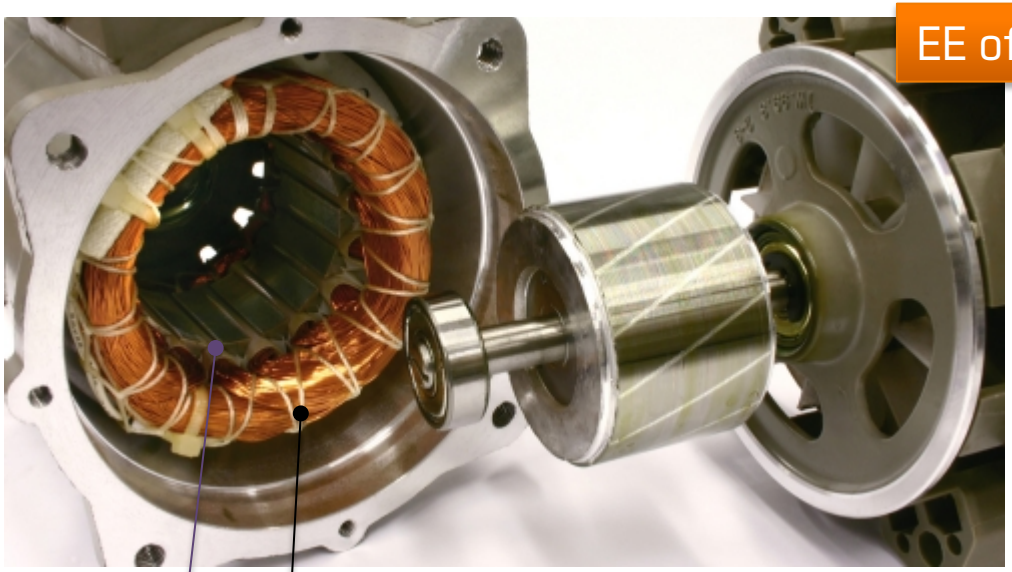
- **Basic insulation**
  - Insulation of live parts of the electrical sys
  - May **only** be **removed by destruction**



- **Enclosures**
  - **Are part of the EE**
  - Must comply with **IPxxB (IP2X) protection, and for horizontal top IPxxD (IP4X)**
  - Enclosures must be sufficiently mechanical resistant
  - Removable **only with a key or tool**

- **Obstacles**
  - **Not part of EE**
  - Protect only **against accidental contact**
  - Can be removed **without the use of a tool**
  - Only for **qualified persons in electrical engineering**

Classifications of insulation

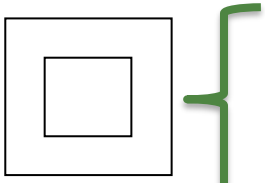


EE of Protection class I

Live part
(with functional insulation)

Basic insulation

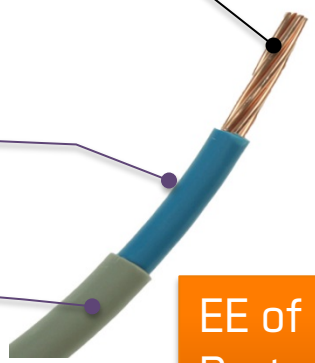
Live part



Basic insulation

Supplementary insulation

Double insulation

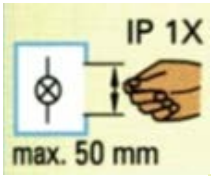


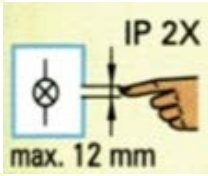
EE of Protection class II

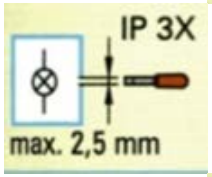
PROTECTION OF ELECTRICAL EQUIPMENT
IP – INGRESS PROTECTION (ČSN EN 60529)

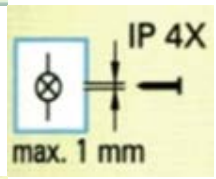
IP **X**X(X) – first digit means degree of protection againts

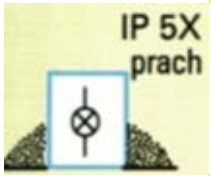
- the ingress of foreign solid objects, and
- contact with hazardous parts (live, rotating, etc.)

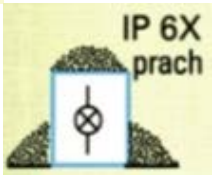










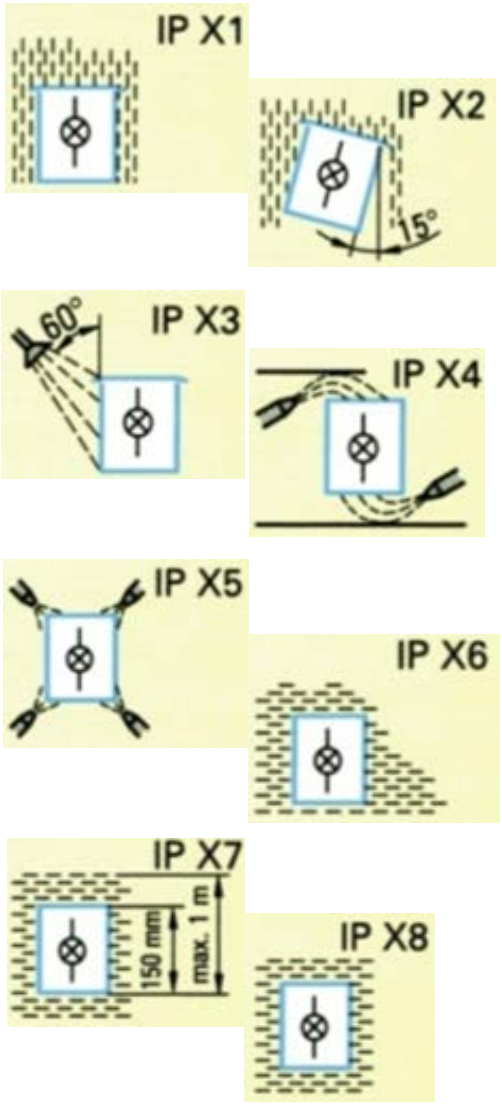


First digit	Protection of equipment against the ingress of solid objects (must not penetrate)	Protection of persons against contact with hazardous parts
0	unprotected	
1	with a diameter greater than 50 mm	from contact with the back of the hand
2	with a diameter greater than 12.5 mm	before touching with a finger
3	with a diameter greater than 2.5 mm	before touching with a tool
4	with a diameter greater than 1 mm	before touching with a wire
5	from dust (dust accumulation)	
6	dustproof (dust ingress)	

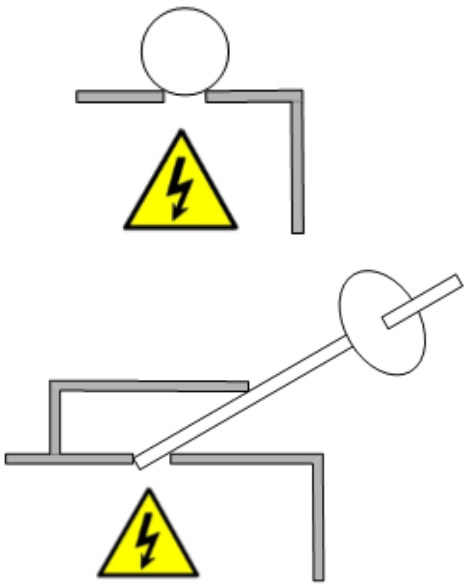
IP X**X**(X) – second digit means degree of protection againts

- water ingress

Second digit	Protection against water ingress
0	unprotected
1	vertically dripping (condensation water)
2	dripping at a 15° angle
3	sprinkling, rain (at an angle of up to 60° from the vertical)
4	splashing (any direction)
5	spurting
6	intense gushing (waves)
7	temporary submersion (limited by pressure and time)
8	permanent immersion (possible intrusion cannot disrupt EE operation)
9	spurting high-pressure hot water



IP XX(**X**X) - Additional letter means protection againts hazardous contact



Letter	Protected against hazardous contact	Probe
A	back of the hand	50 mm diameter ball
B	finger	diameter 12 mm, length 80 mm
C	tool	diameter 2.5 mm, length 100 mm
D	wire	diameter 1 mm, length 100 mm

IP 2X socket

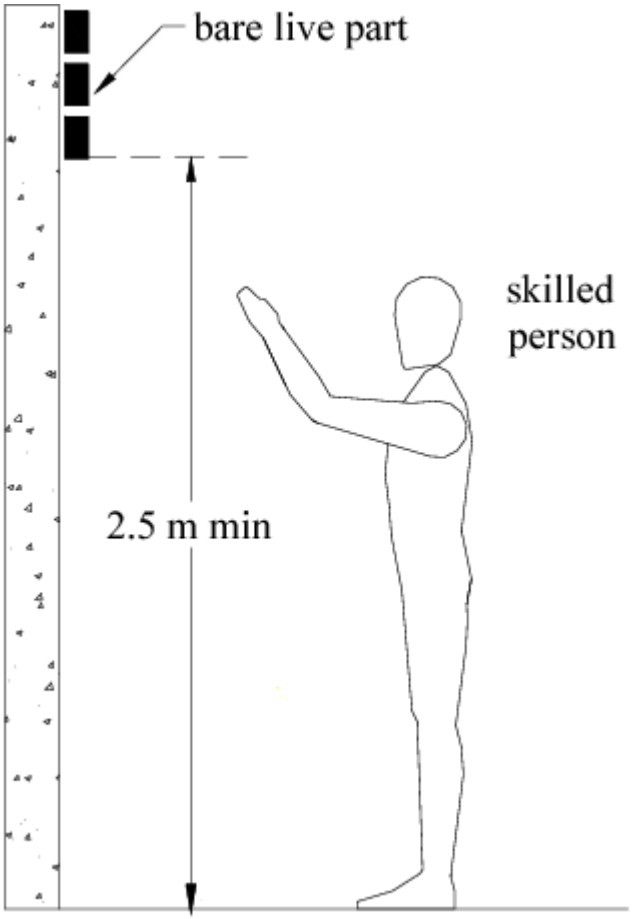
IP 44 socket

IP 55 socket

IP 66 socket

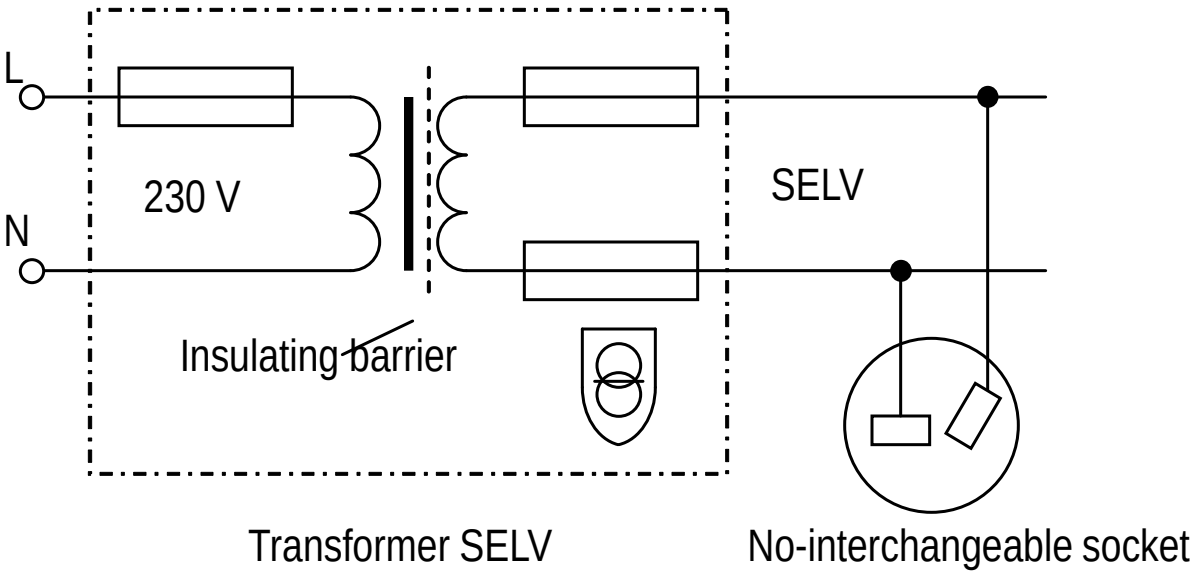
Basic protection measures
- protection by location

- Lays in placing the hazardous live parts **out of reach**



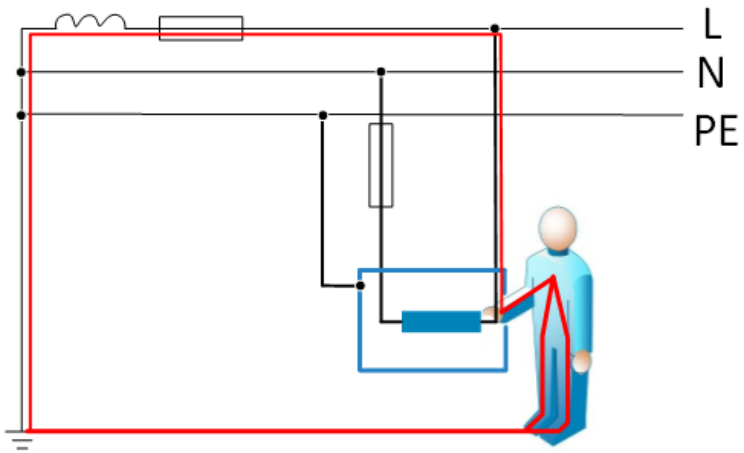
Basic protection measures
- protection by voltage limitation (SELV and PELV)

- Limiting voltage to **a safe extra low voltage**
  - ELV (Extra Low Voltage)
  - Maximum 50 V~, 120 V=
  - As a source: battery, safety protective transformer
  - The voltage is so low that the current flowing through the body cannot reach hazardous levels



LIMITS OF SAFE EXTRA LOW VOLTAGES (ELV) (ČSN 33 2000-4-41 ED.3)

Dry conditions



Touch of non-living parts

- Body impedance: $Z_T = 750\ \Omega$
- Impedance of footwear and floor: $Z_F = 1000\ \Omega$
- Current without serious effects for up to 5 s: $I_T = 30$ mA
- Touch voltage that does not cause harm:

$$U_d = (Z_F + Z_T) \cdot I_T = 52{,}5\ \text{V}$$

→ **Limit value for continuous touch voltage 50 V**

Intentional contact with live parts

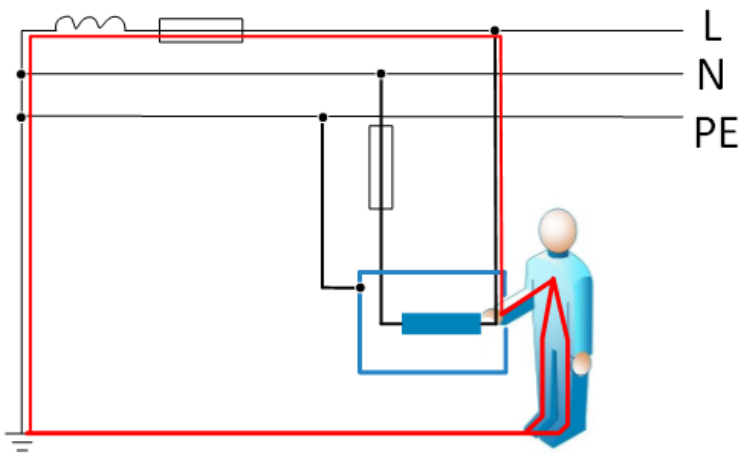
- Detachment threshold: $I_T = 15$ mA
- $U_d = 26.25$ V

→ **Conventional value is 25 V**

SAFE LOW VOLTAGE LIMITS (ELV) (ČSN 33 2000-4-41 ED.3)

Wet conditions

- Assuming that only the impedance of the human body is effective, the impedance of footwear and flooring is zero: $Z_F = 0\ \Omega$
- At low voltages, the impedance of the body is approximately: $Z_T = 1200\ \Omega$
- The current allowing disengagement within 2 s is: $I_T = 10$ mA



$$U_d = (Z_F + Z_T) \cdot I_T = 12\ \text{V}$$

Environment	Basic protection	effective alternating (V_{ef})	DC (V)
Dry	Insulation, enclosures	50	120
	Not required	25	60
Other (wet)	Not required	12	30
When submerged	Insulation, enclosures		

BASIC PROTECTION MEASURES
- LIMITATION OF STEADY CURRENT AND ENERGY

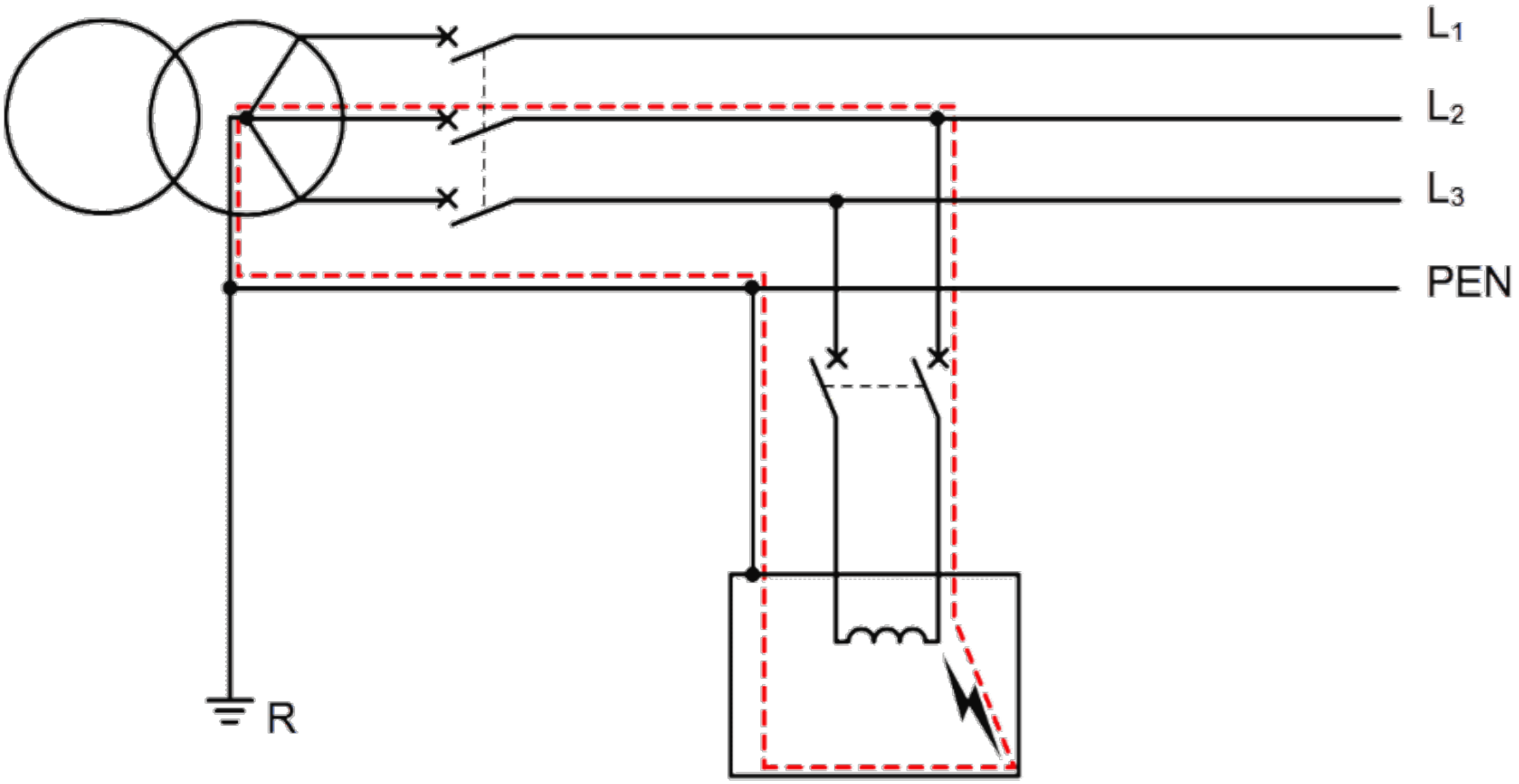
- Current flowing through persons or animals limited to a value that cannot be hazardous or perceptible.
- Power supply from a limited current source.
- The current between parts that can be touched at the same time flowing through a resistance of 2 kΩ (simulates body impedance) must not exceed the values given in the table.
- Higher values are permitted for devices designed to elicit a pain response, e.g., electric fences.
- Today, stored energy is used instead of accumulated chargé (ČSN EN 61140 ed. 3).

Conditions	Limit	Limit of current *I*		Limit of stored energy E (accumulated charge Q)
		AC ~	DC =	
Normal	Perception	0.5 mA	2 mA	5 mJ (0.5 mC)
Abnormal and specific	Pain	3.5 mA	10 mA	0.5 mJ (50 mC)

Organization of protective measures against electric shock (ČSN EN 61140 ed. 3)

Protective measures	Basic protection	Protection in case of failure	Additional protection
Protection by automatic disconnection from the power source	Basic insulation, barriers, covers	Automatic disconnection + Protective bonding	Additional protection with residual current device
Protection with double or reinforced insulation	Basic insulation	Supplementary insulation	(or Reinforced insulation)
Protection by electrical separation	Basic insulation, enclosures	Simple circuit separation + ungrounded protective bonding	-
SELV protection	Voltage limitation (ELV)	Simple separation from other ELV circuits and earth	Protective separation of circuits other than SELV
PELV protection	Voltage limitation (ELV)	Simple separation from other ELV circuits	Protective separation of non-ELV circuits
Protection by limiting steady-state touch current and energy	Limitation of steady-state current and energy	-	Protective separation from hazardous live parts

PROTECTION BY AUTOMATIC DISCONNECTION FROM THE POWER SUPPLY (EE PROTECTION CLASS I) - FAULT CURRENT PATH



- **It is prohibited** to fuse or switch PE or PEN conductors

Content

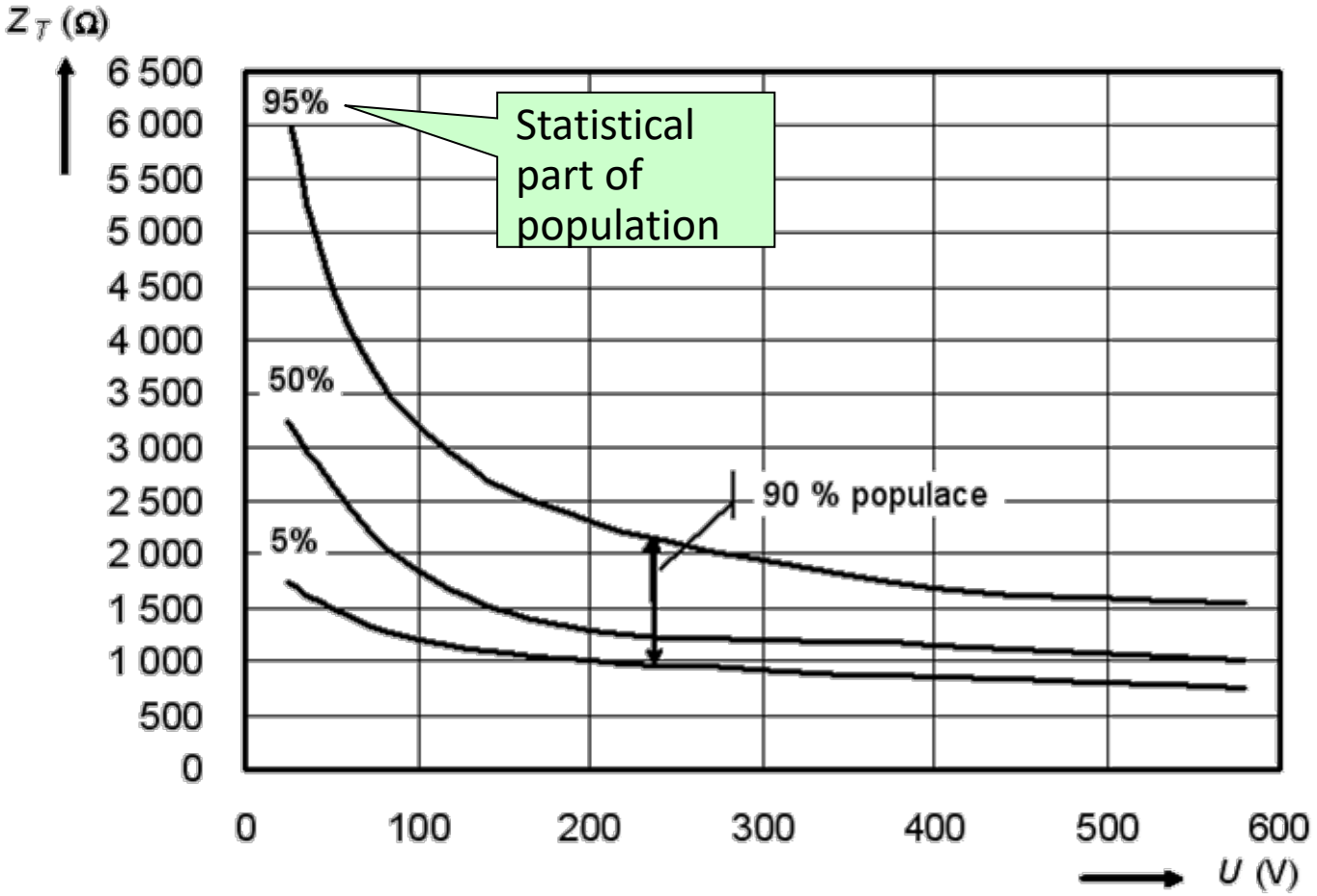
- Disconnection times in the event of an EE failure
- Protective devices
  - Fuse
  - Circuit breaker
  - Residual current device (RCD)
- Protective bonding and earthing of exposed conductive parts
- Protection design in various networks

Definitely not like this…

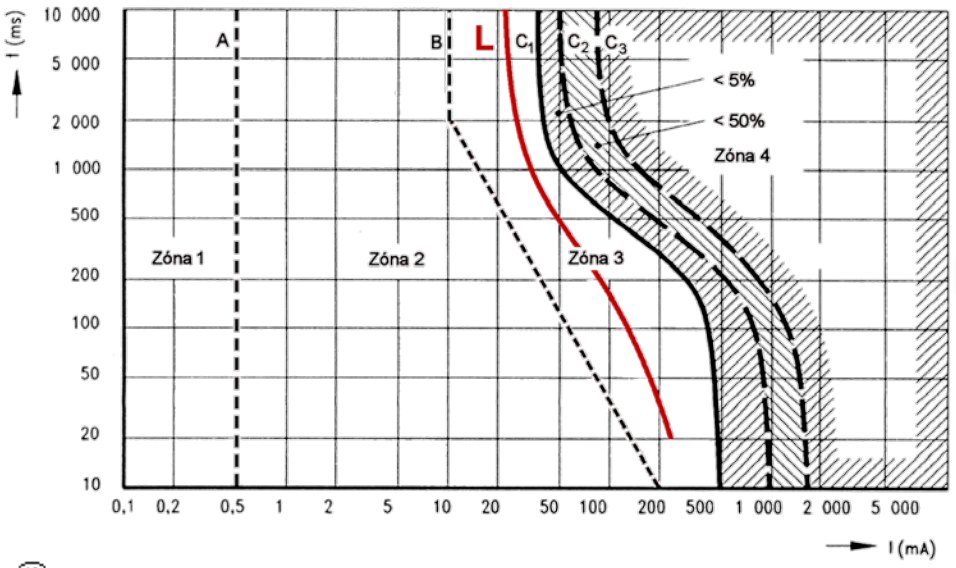
Dependence of human body impedance on voltage

Impedance (alternating resistance) of the human body Z_T

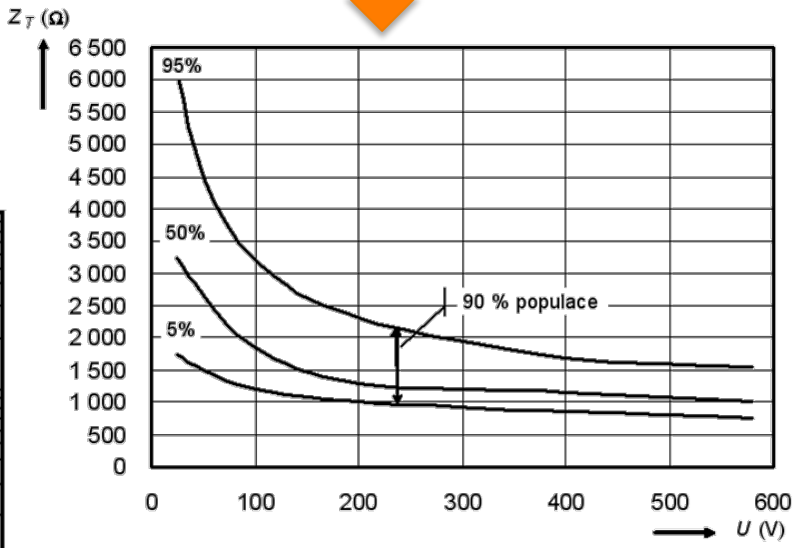
- Applies to 50 Hz alternating current and to the left hand – both feet trajectory

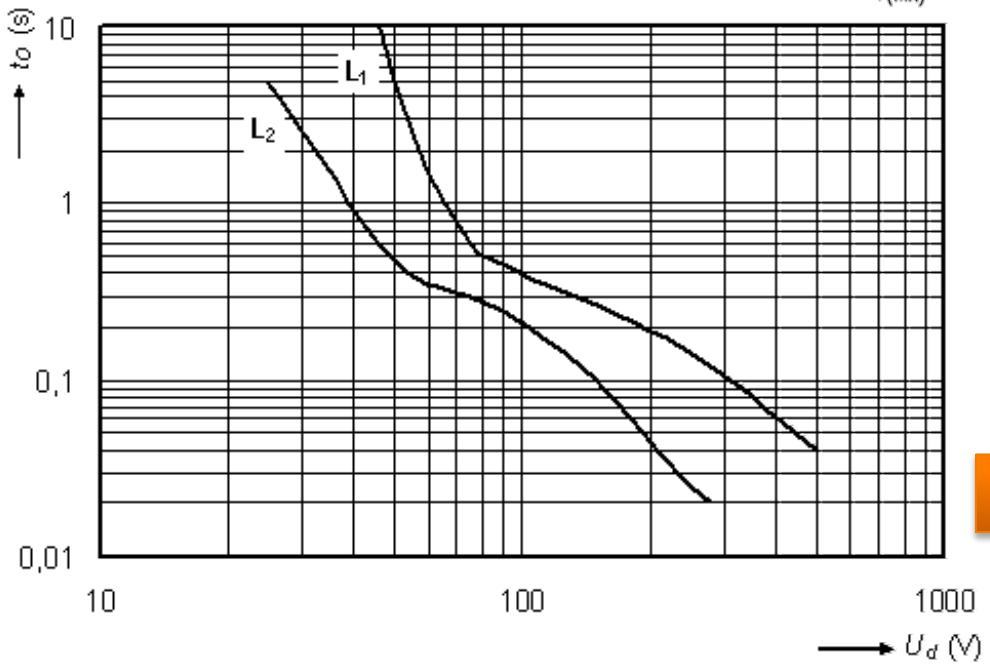


Conversion of the L curve from current to touch voltage



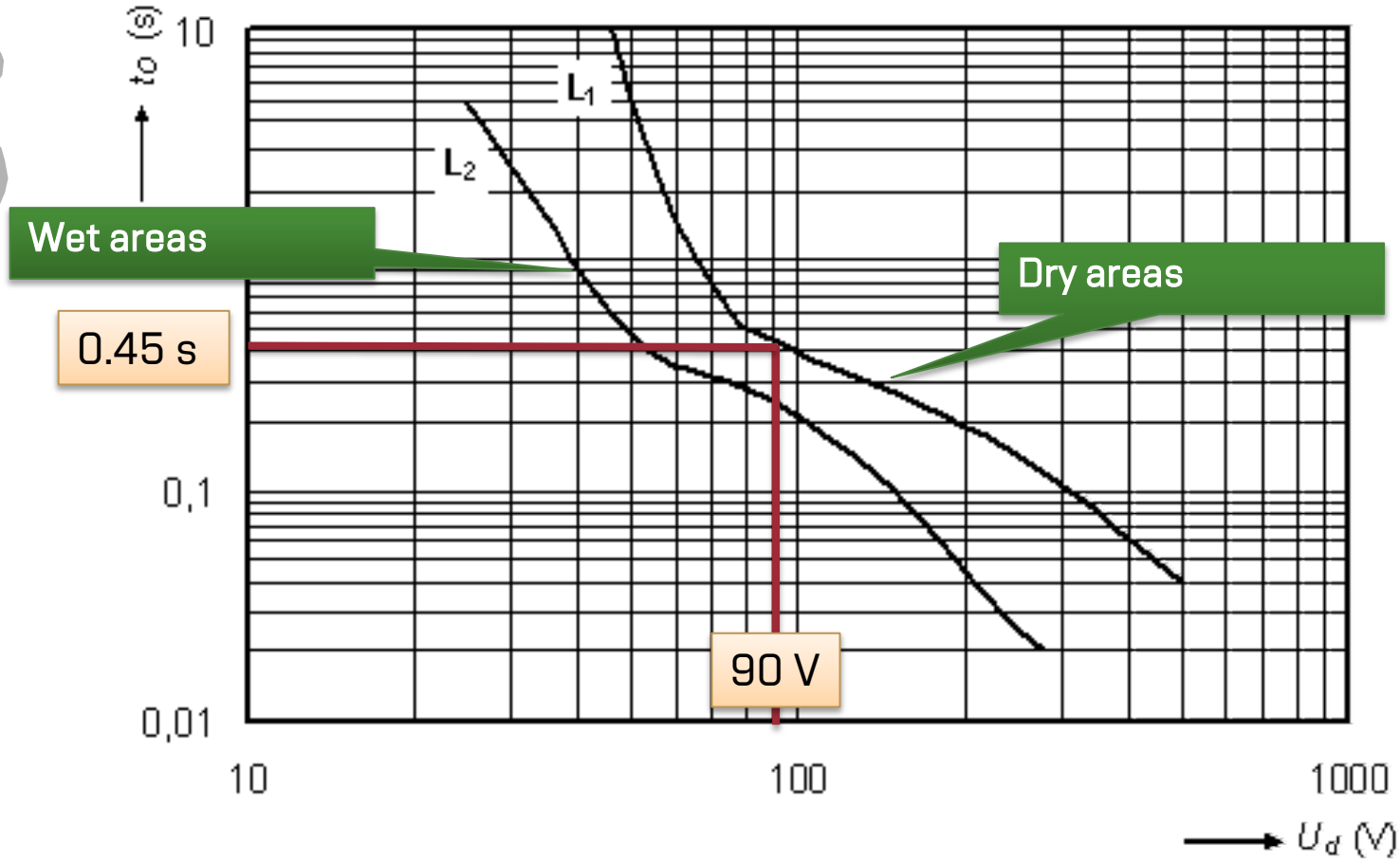
Z_T =2000 Ω is used for dry areas and Z_T =1000 Ω is used for wet areas.





$$U_d = Z_T \cdot I$$

Limitation of the duration of alternating touch voltage



For TN 230V, a touch voltage of 90 V is assumed in the event of a fault → **disconnection time up to 0.4 s** (or up to 5 s in some cases)

Limitation of the duration of alternating touch voltage

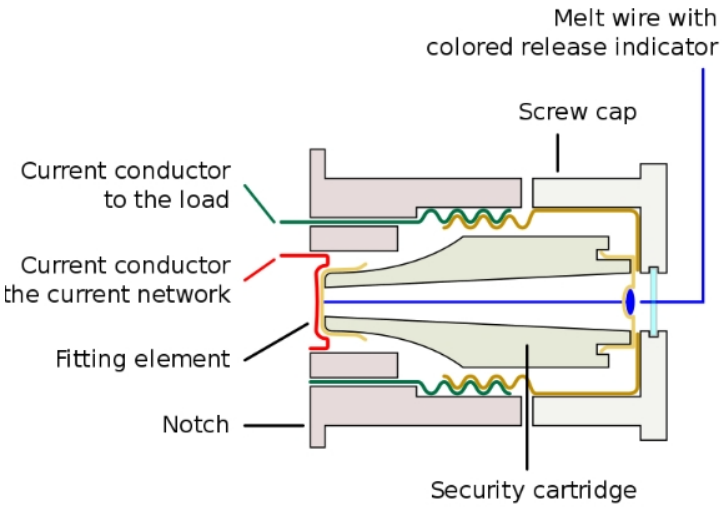
- Risk of injury due to the magnitude and duration of touch voltage in the event of an EE fault.
- This protective measure requires coordination of the network design and its earthing method, as well as the design of the EE (protection class I).
- The working conductors are disconnected. The disconnection must be sufficiently fast so that the touch voltage generated during a fault cannot cause a hazardous physiological effect.

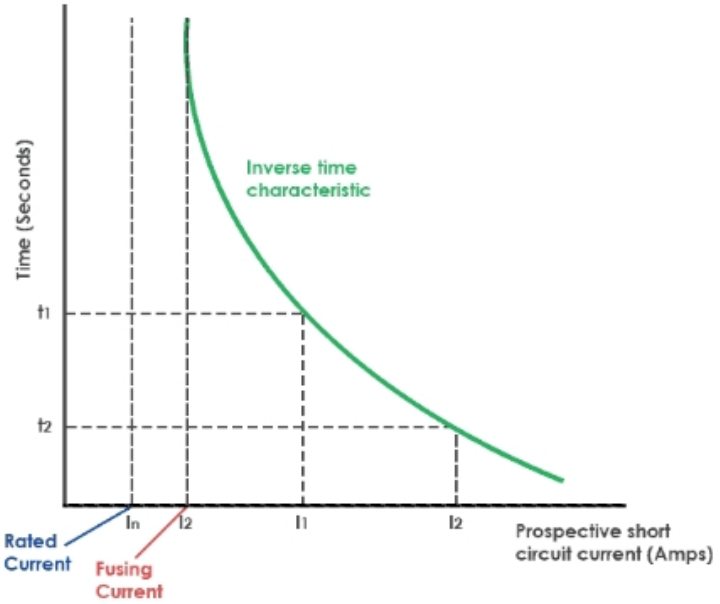
	Terminal circuits up to 32 A (with a socket up to 63 A)							**Distribution and other circuits**
	50 V – 120 V	**121 V – 230 V**		**231 V - 400 V**		**Above 401 V**		
	AC	AC	DC	AC	DC	AC	DC	
TN	0.8 s	0.4 s	5 s	0.2 s	0.4 s	0.1 s	0.1 s	**5 s**
TT	0.3 s	0.2 s	0.4 s	0.07 s	0.2 s	0.04 s	0.1 s	**1**

(The voltage values in the table are given relative to earth.)

PROTECTIVE DEVICES - FUSE

- Artificial weakest point of an electrical circuit
- It is destroyed when switched off and must be replaced

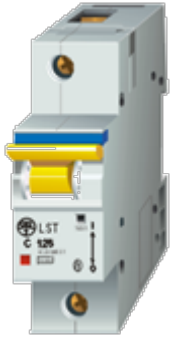


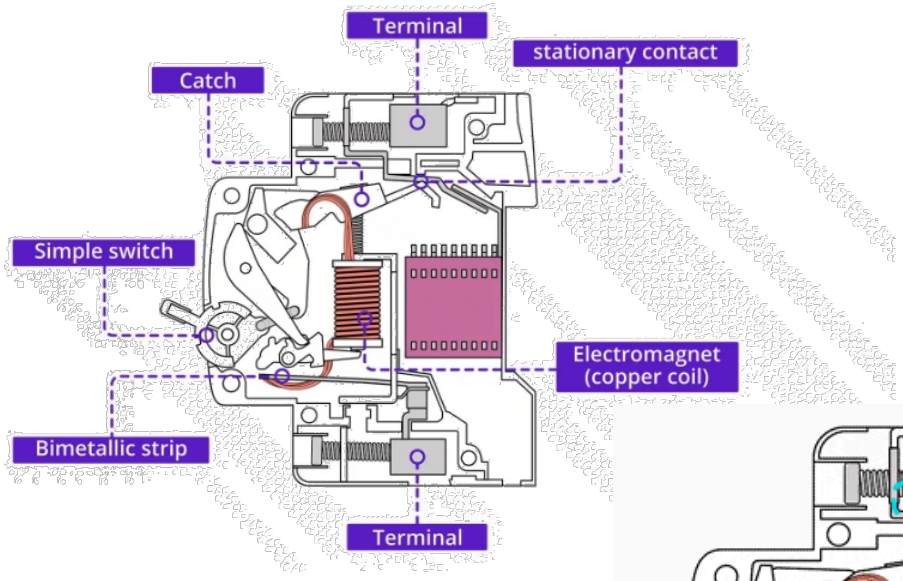


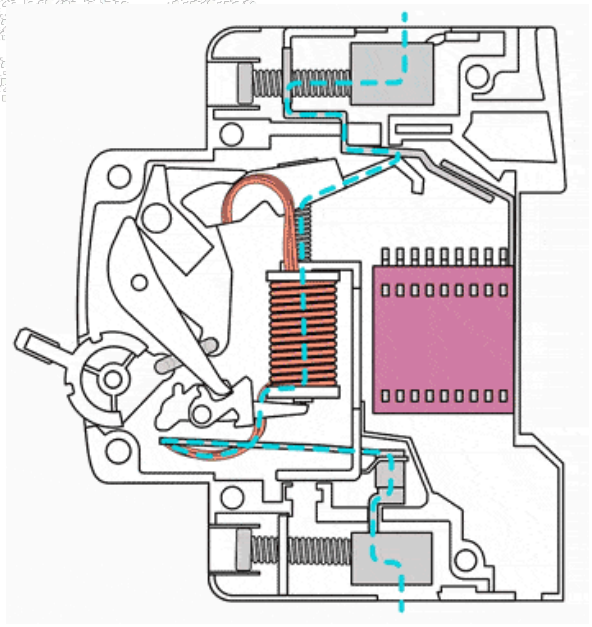
- To switch off within 0.4 s (requirement for TN networks), approximately **5 times** the rated current is required

PROTECTIVE DEVICES - CIRCUIT BREAKER

- Can be switched on again after switching off
- Contains overcurrent and short-circuit trigger





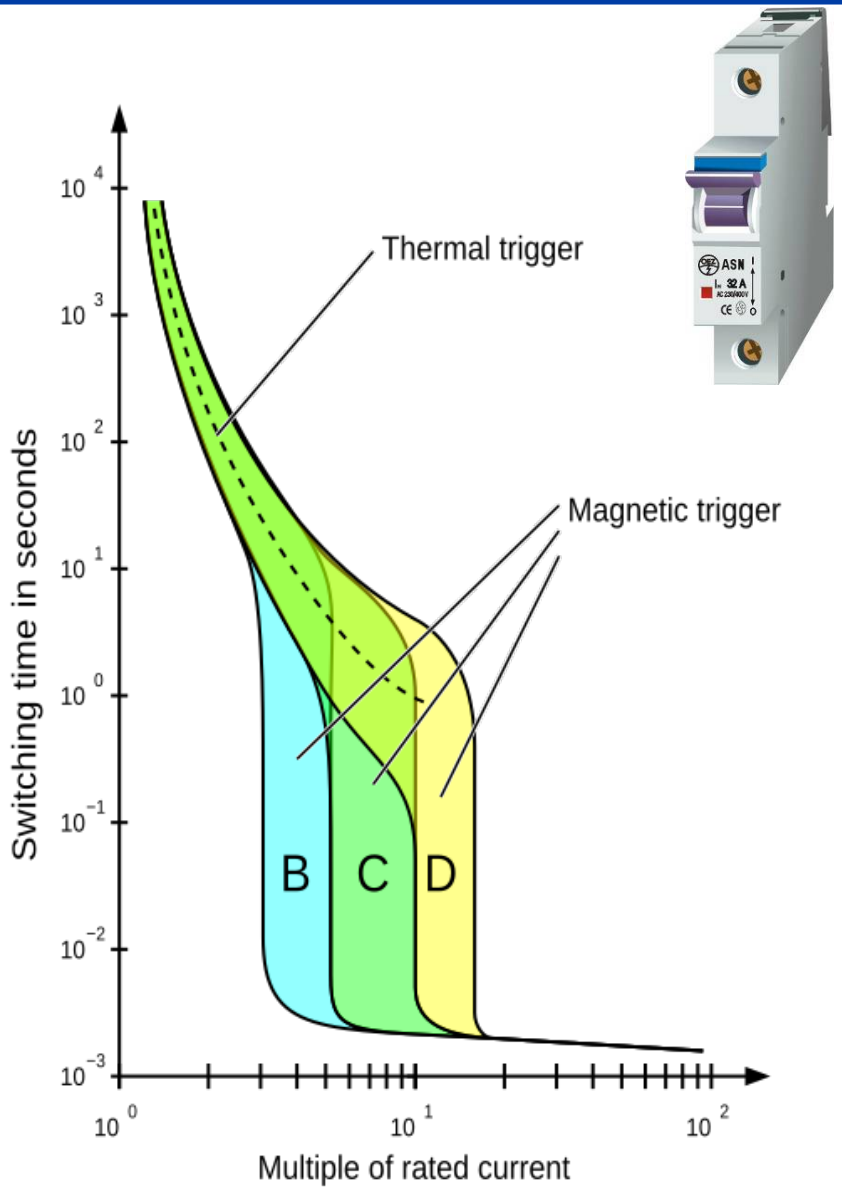


PROTECTIVE DEVICES - CIRCUIT BREAKER

- The disadvantage of a circuit breaker compared to a fuse is its lower short-circuit current withstand capability

Tripping characteristics

- **B** for resistive loads - trips within 0.1 s at 3-5 times the rated current.
- **C** universal circuit breaker (light bulbs, motors with easy start-up) - trips within 0.1 s at 5-10 times the rated current.
- **D** motor circuit breaker (for motors with heavy start-up) - trips within 0.1 s at 10-20 times the rated current.

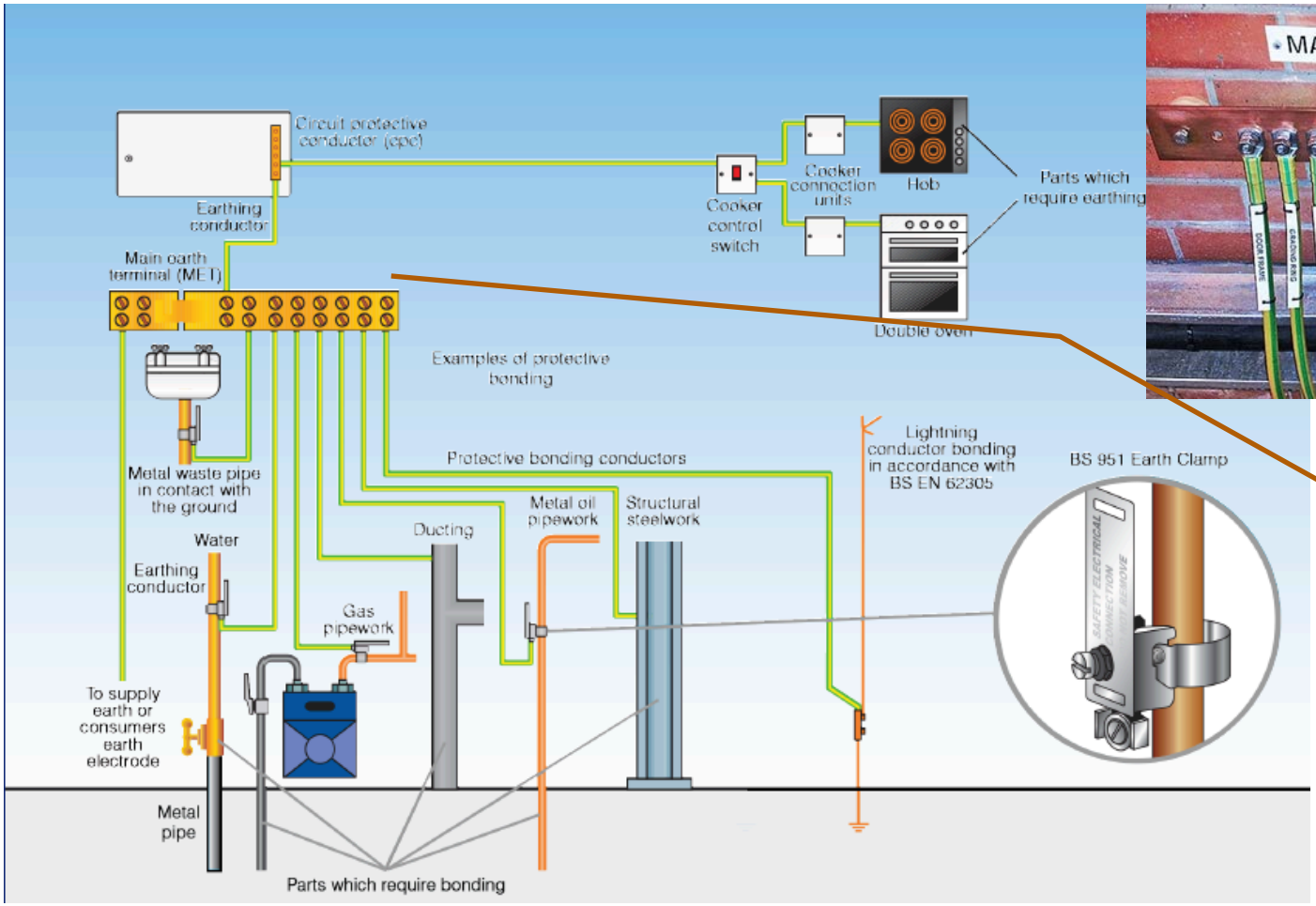


Protective bonding and earthing

- is a necessary condition for automatic disconnection
  - all exposed conductive parts are at earth potential
  - fault current is diverted by the bonding system
- implemented by **the main earthing terminal (busbar)**, bonding:
  - Protective conductors (PE, PEN)
  - Earthing of building
  - Metal pipes and structural parts
  - Main fittings of reinforced concrete structures ...
  - Functional earthing, if present (surge arresters, etc.)

- **Supplementary bonding**
  - If the conditions for automatic disconnection cannot be met in part of the installation
  - Connects exposed conductive parts of the electrical installation and other conductive parts that are simultaneously accessible to touch – bringing them to the same potential

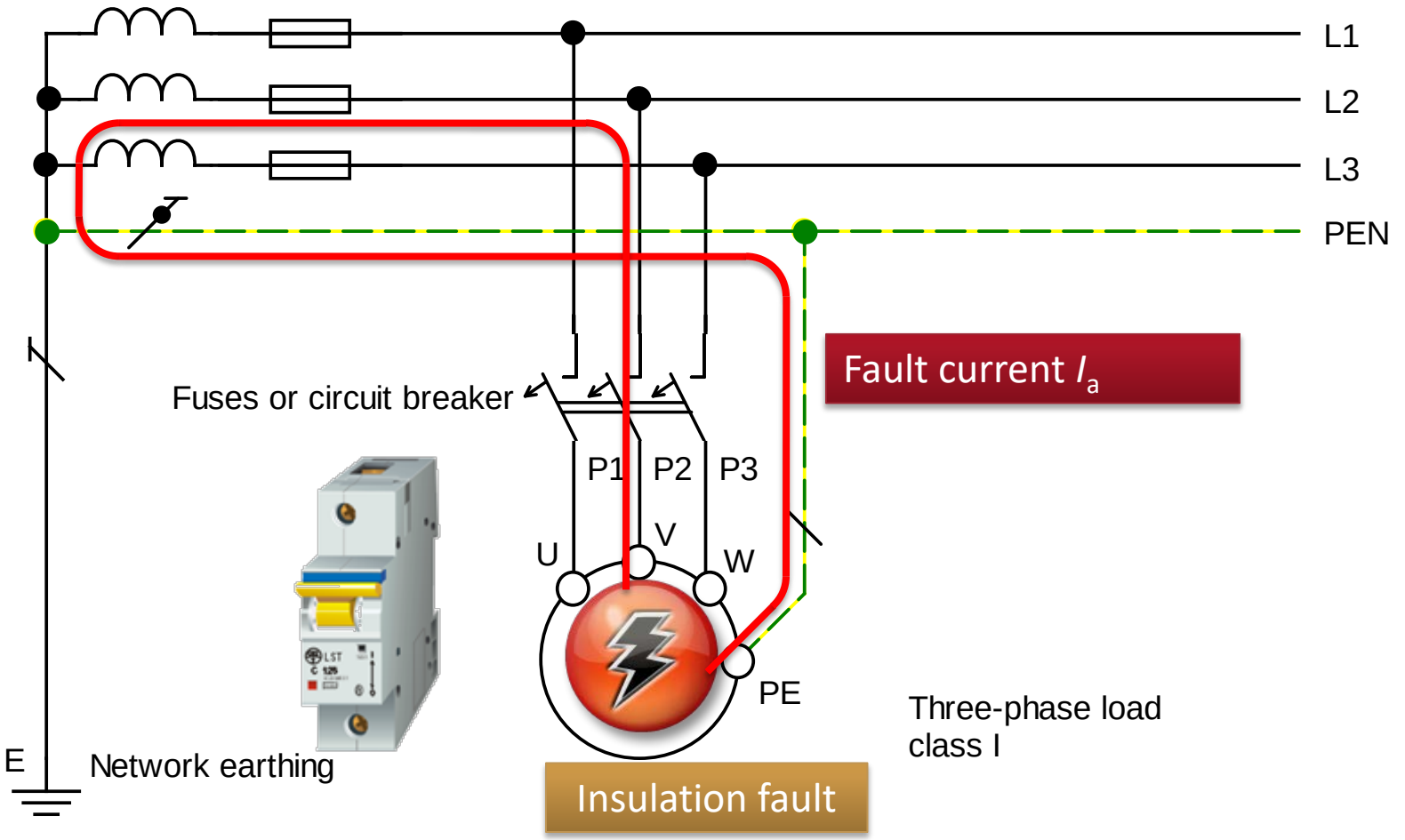
Protective bonding and earthing



Main earthing terminal

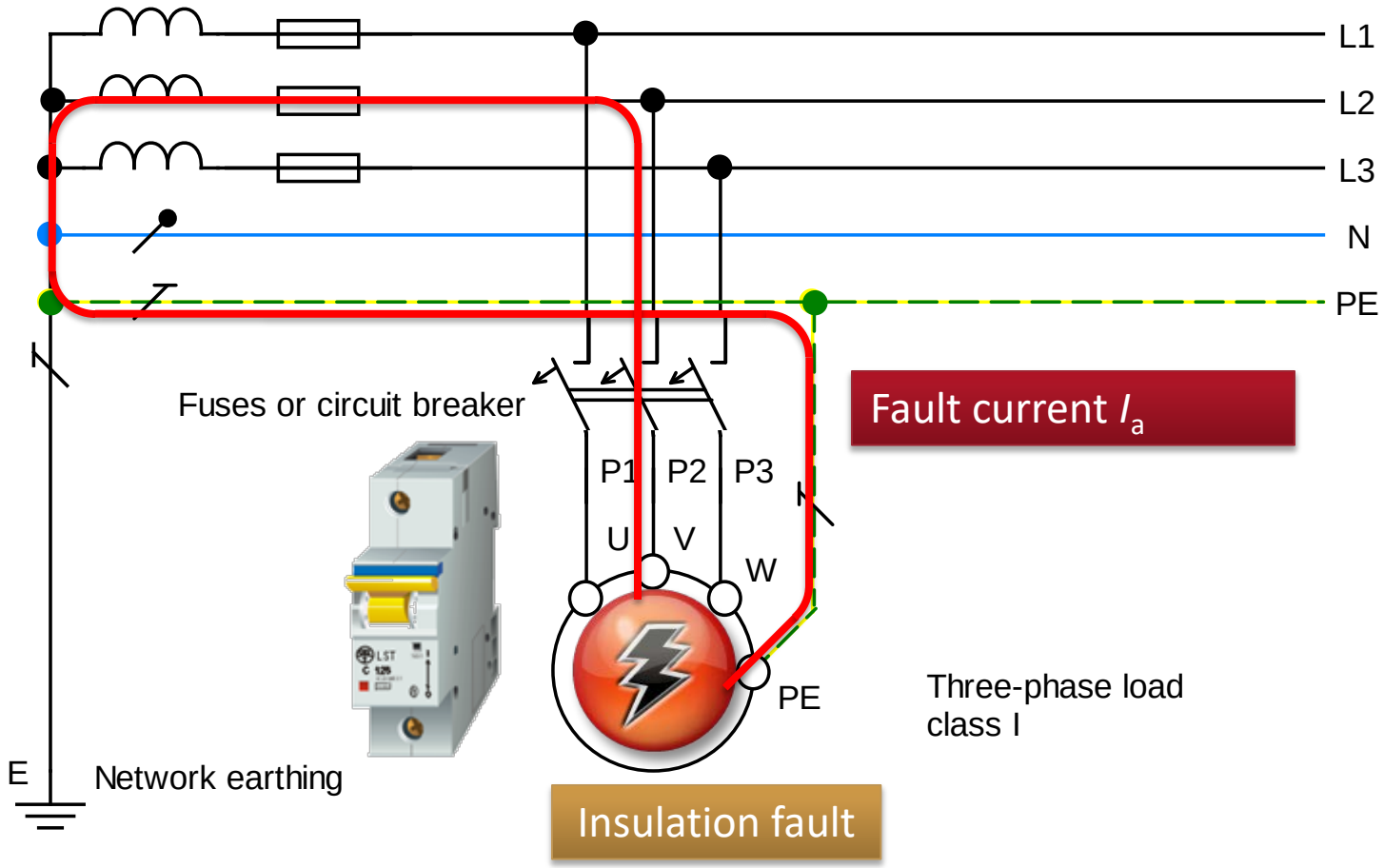
If there are suitable metal structures (rails, metal pipes, etc.) at the installation site, they can be used as casual protective conductors after being connected to the PEN protective conductor. **Gas pipes, metal ladders, and certain other special structures must not be used** as casual protective conductors.

PROTECTION BY AUTOMATIC POWER SUPPLY DISCONNECTION IN TN-C NETWORKS



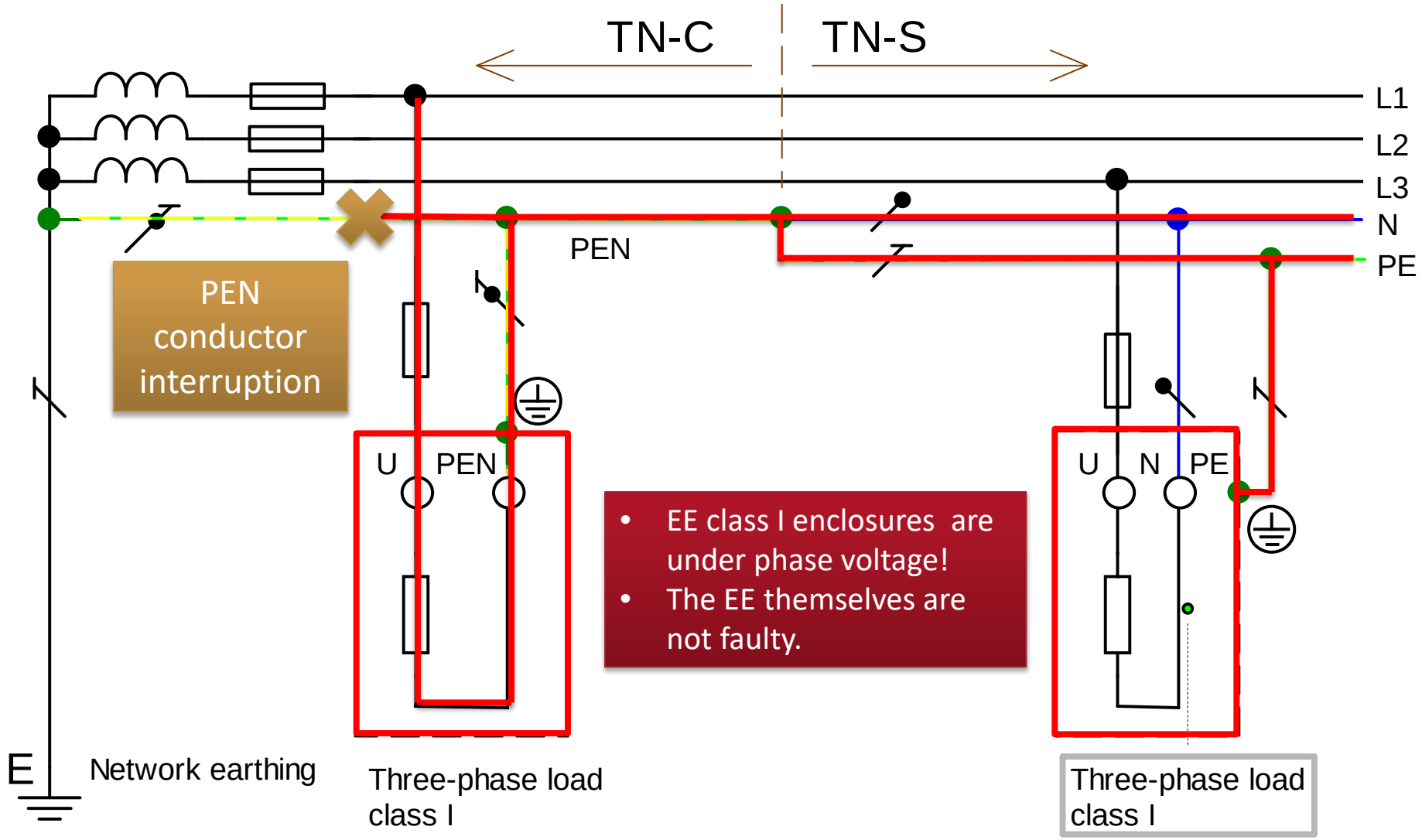
- To switch off within 0.4 s, approximately 5 times the rated current of the protective device (fuse or circuit breaker) is required
- Therefore, a low impedance "protective loop" is required, max. units Ω.

Protection by automatic power supply disconnection in TN-S networks

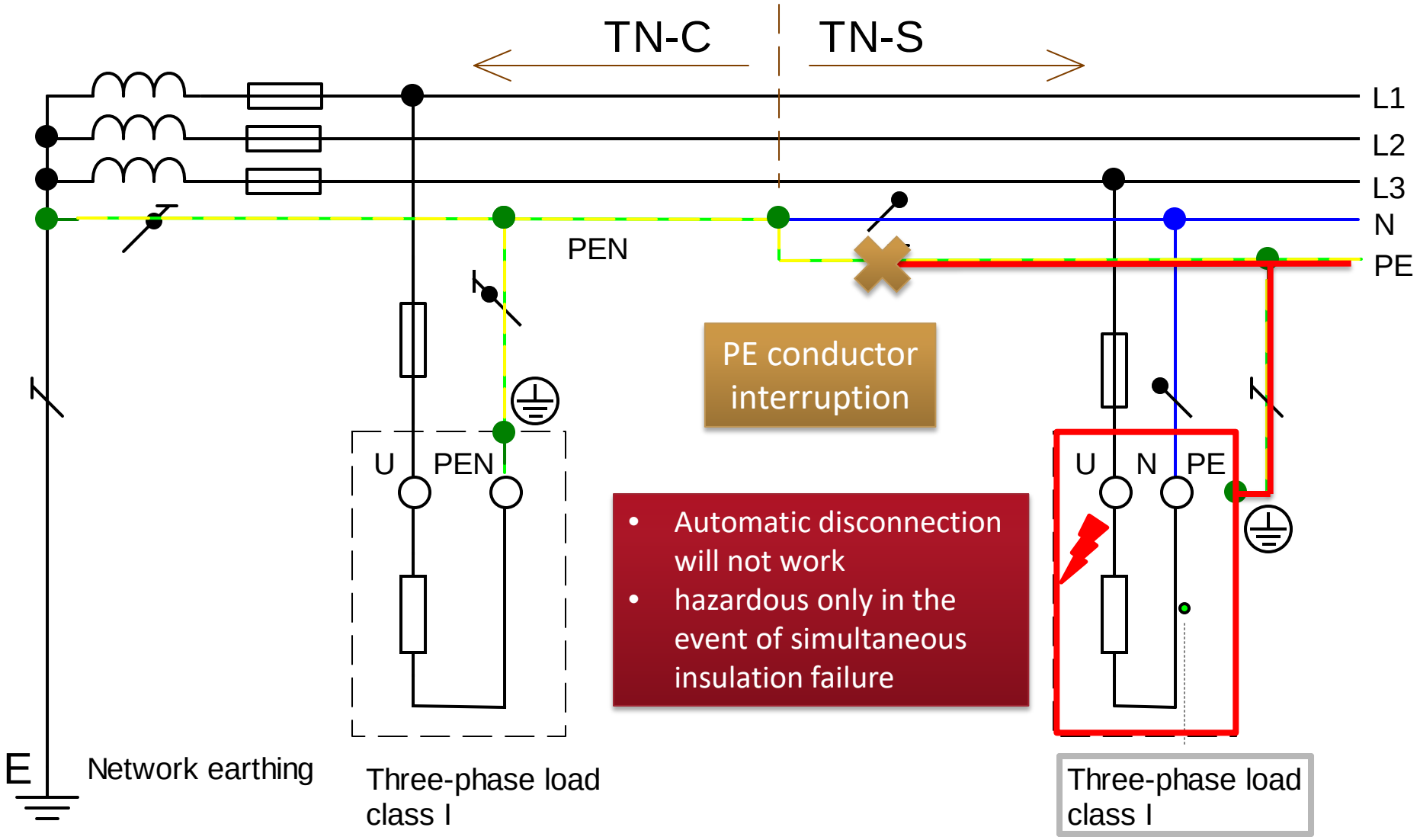


- No current flows through the PE conductor during normal operation, so it has earth potential
- Interruption of the protective conductor **does not compromise safety** as in TN-C

PEN CONDUCTOR FAULT



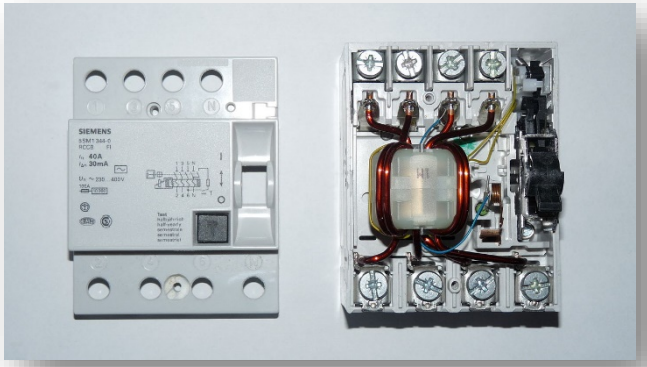
PE CONDUCTOR FAULT

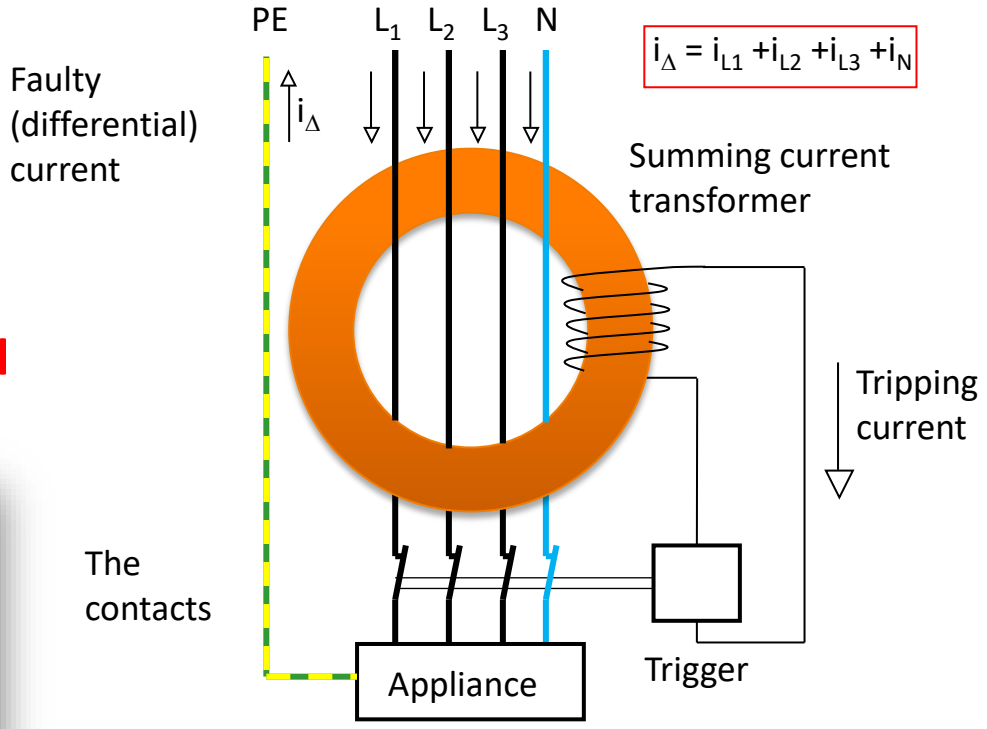


PROTECTIVE DEVICES - RESIDUAL CURRENT DEVICE (RCD)

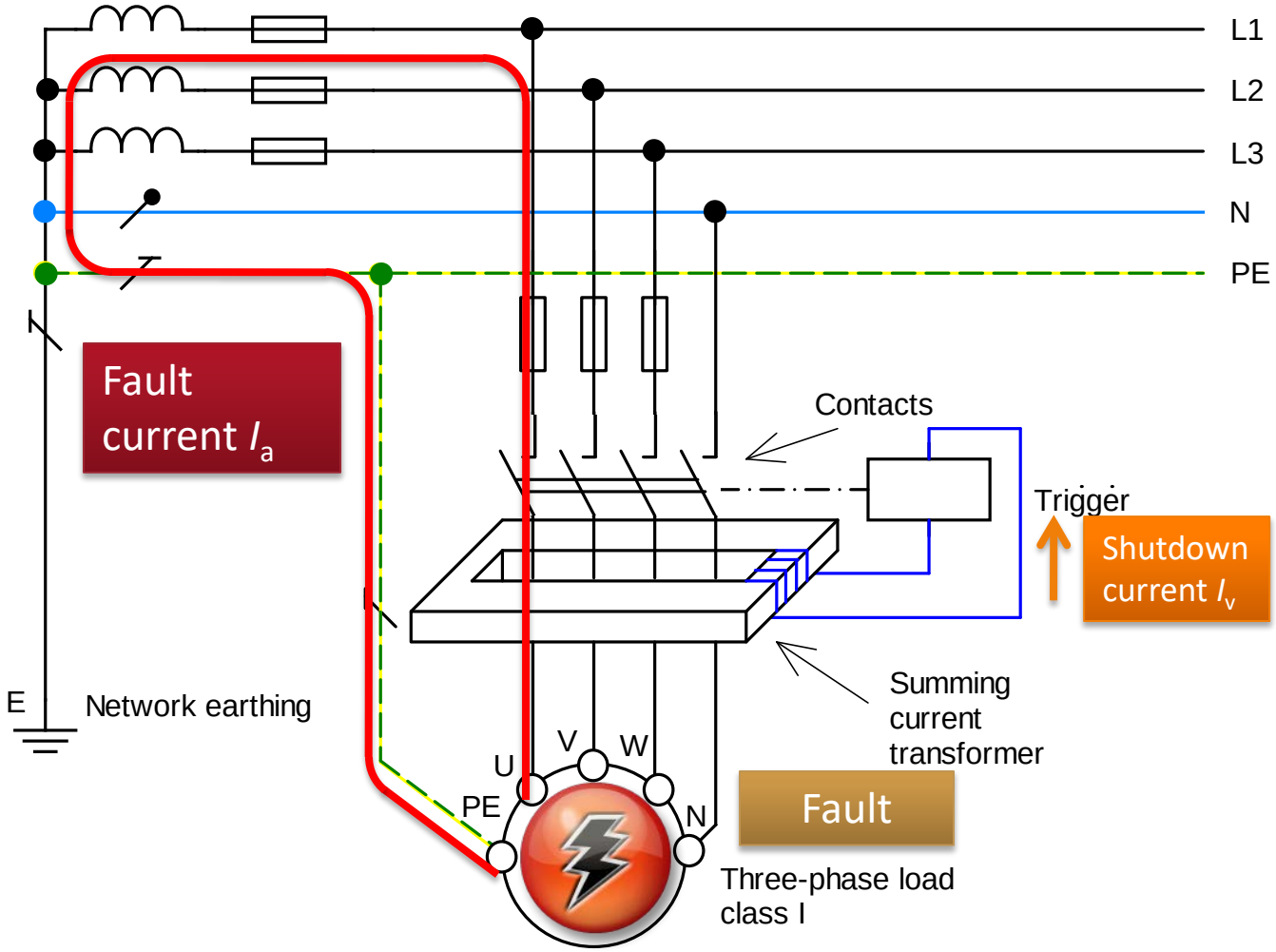
- RCD does not protect against overcurrents!
- Switches off when the **differential current** exceeds I_Δ
- **All working conductors** (phase and neutral) pass through the RCD; the protective conductor must be routed outside

- **Cannot be used in a TN-C network**; the RCD requires a separate protective conductor (PE)
- RCD with $I_{\Delta n}$ **not exceeding 30 mA** is also used as **additional protection**



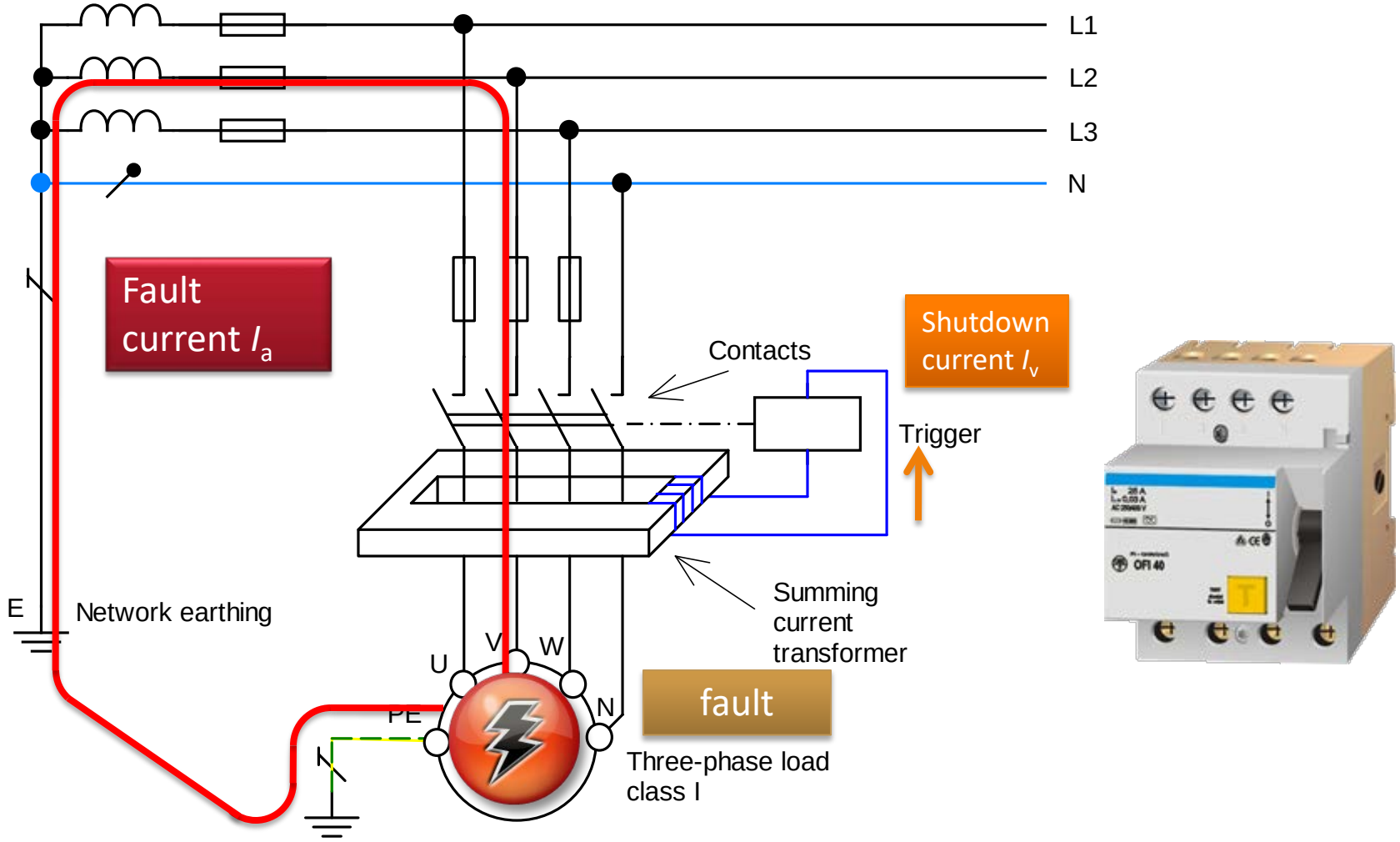


Protection with a residual current device in TN-S networks



- A small fault current (around 100 mA) is sufficient to switch off within 0.4 s
- No destructive damage to the device

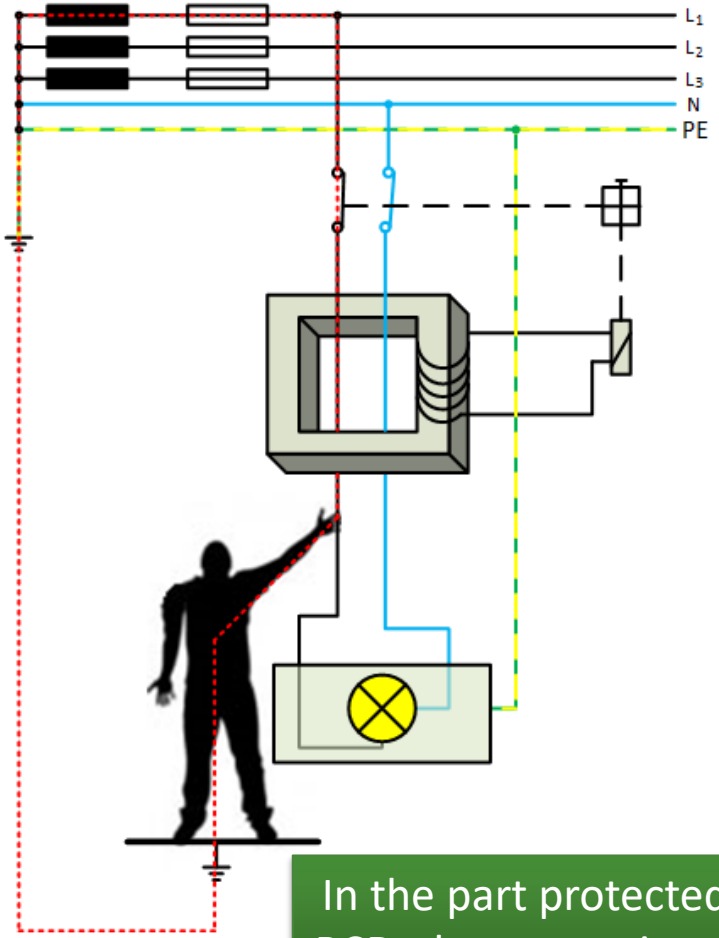
Protection with a residual current device in TT networks



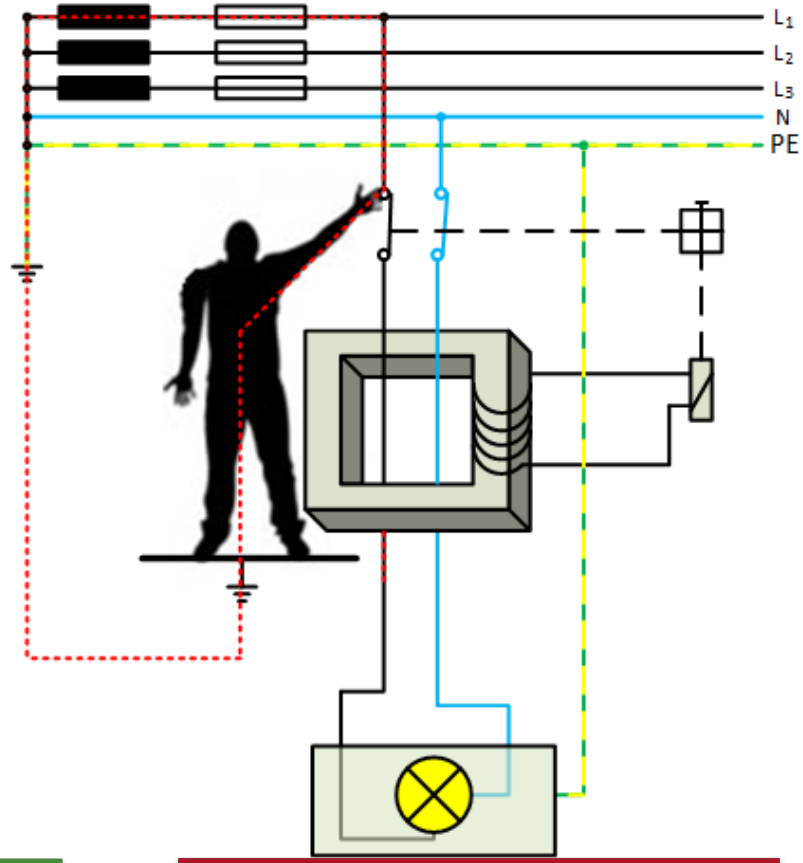
- A small fault current (around 100 mA) is sufficient to switch off within 0.2 s
- No problem with earthing resistance

CONTACT WITH LIVE PARTS

- The RCD also has another function – it provides **additional protection** against direct contact with hazardous live parts.



In the part protected by the RCD, the person is protected



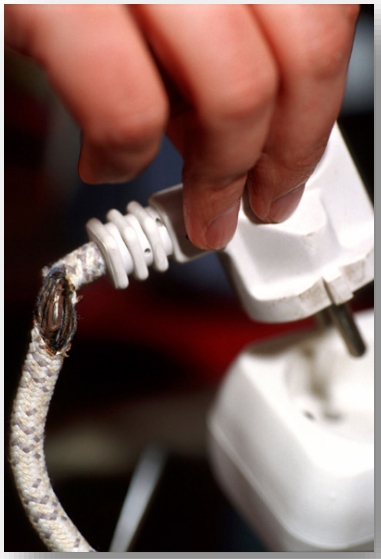
In the area in front of the RCD – the person is not protected

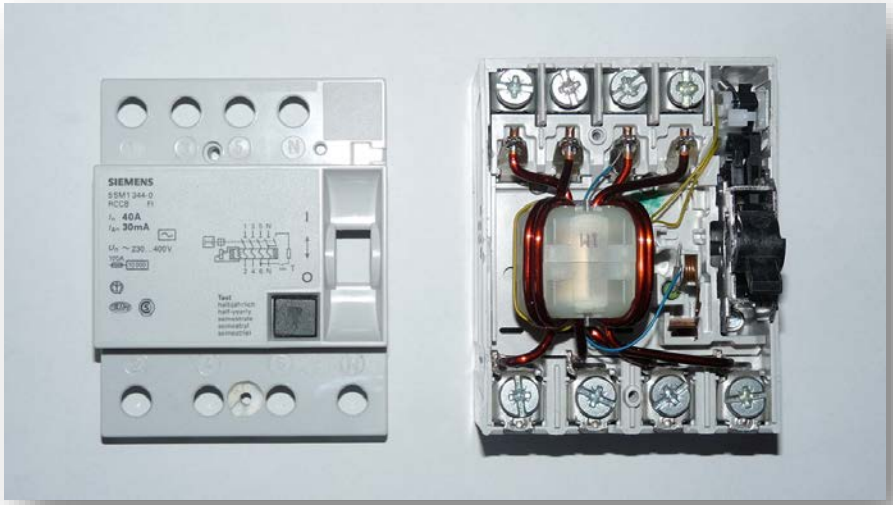
Additional protection with a residual current device

Mandatory use of a residual current device as additional protection:

According to ČSN 33 2000-4-41 ed. 3, it is necessary to use RCD with $\mathbf{I_{\Delta n} \leq 30\ mA}$

- for general-purpose sockets with a rated current of up to 32A (there are exceptions) used by laypersons
- for lighting circuits in separate households
- mobile devices with a rated current of up to 32A
- rooms with a bathtub or shower (exception – water heater)
- electrical installations for swimming pools and fountains
- electric floor and ceiling heating systems

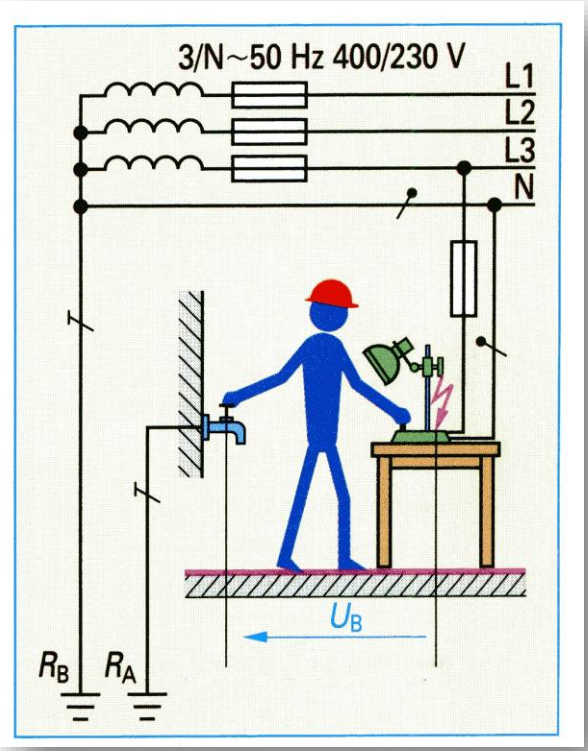




Protection in case of failure to comply with the automatic disconnection condition

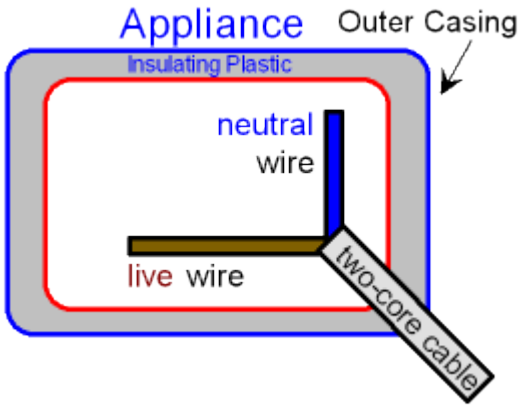
If it is not possible to achieve the prescribed disconnection time, the **following measures must be taken:**

- additional bonding must be provided and
- the voltage between parts that are simultaneously accessible to touch must not exceed 50 V_{AC} or 120 V_{DC} .



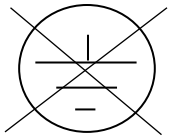
Protection with double or reinforced insulation (EE protection class II)

Protective measure	Basic protection	Protection in case of failure	Additional protection
Protection with double or reinforced insulation	Basic insulation	Additional insulation	(or Reinforced insulation)



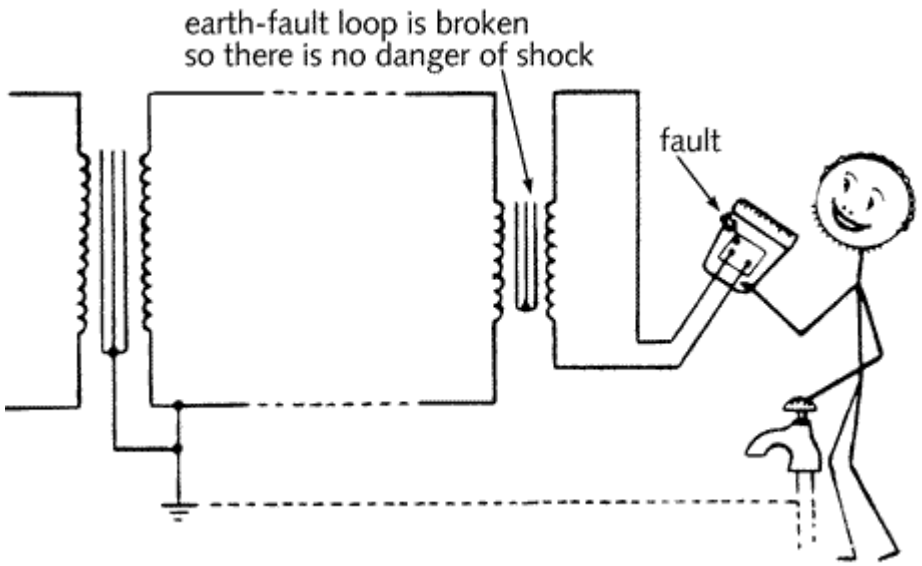
Protection by double or reinforced insulation (EE protection class II)

- EE has **basic insulation** and **supplementary insulation**, or **reinforced insulation**
- **It does not have means for connecting a protective conductor**
- If the enclosure itself is supplementary insulation:
  - It must provide at least IPXXB or IP2X protection
  - It must be capable of withstanding mechanical, electrical, or thermal stresses that may occur.
  - No conductive parts that could be live may pass through the enclosure
  - When mechanical parts pass through the cover (e.g., hinges, controls), it must be ensured that, in the event of a malfunction, protection against electric shock is not compromised
  - A mark must be placed in a visible location on the surface and inside of any conductive enclosure.



PROTECTION BY ELECTRICAL SEPARATION

Protective measure	Basic protection	Protection in case of failure	Additional protection
Protection by electrical separation	Basic insulation, obstacles, enclosures	Simple circuit separation + unearthed protective bonding	-



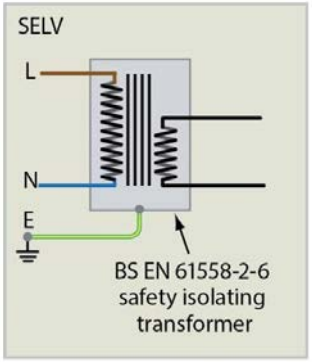
PROTECTION BY ELECTRICAL SEPARATION

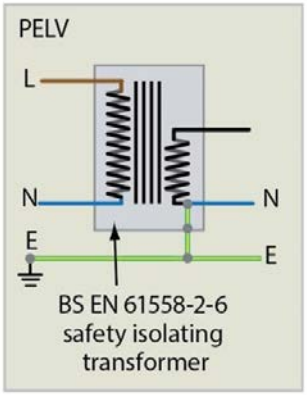
- Power supply via **an isolation power supply with** at least simple isolation
- Separated circuit voltage **max. 500 V**
- Live parts of the isolated circuit must not be connected to earth or to parts of other circuits
- Recommended **limitation to only 1 appliance**
- Maximum length of isolated line 500 m
- Product of U.l ≤ 100,000
- Exposed conductive parts of the isolated circuit must be **bounded without being grounded**
- Sockets of the separate circuit must have a protective contact connected to the bonding system

SELV AND PELV PROTECTION

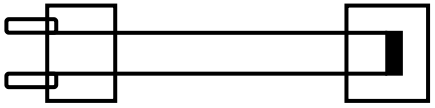
Protective measures	Basic protection	Protection in case of failure	Additional protection
SELV protection	Voltage limitation (ELV)	Simple separation from other ELV circuits and earth	Protective separation of circuits other than SELV
PELV protection	Voltage limitation (ELV)	Simple separation from other ELV circuits	Protective separation of non-ELV circuits

- Independent or isolated barrier sources.
- **Separation from other circuits** at the double insulation level.
- **Non-interchangeable sockets and plugs without protective contacts**.
- **At voltages below 25 V~ or 60 V=, basic protection is not required (under normal conditions)**.
- SELV = no part of the circuit **may be connected to earth** or to parts of other circuits.
- PELV = **single-pole earthed and bonded**.





EE PROTECTION CLASSES

Class	Label	Principle	Basic protection	Fault protection	Note
0			Basic insulation	-	Does not have protective measures in case of failure. Not approved in the Czech Republic.
I	 1)		Basic insulation	Protective bonding	Connection of the exposed conductive parts of the EE to the PE conductor of the network
II	 2)		Basic insulation	Supplementary or reinforced insulation	Double or reinforced insulation
III	 2)		Voltage limitation (ELV)	Protective separation from other	The socket must be non-interchangeableConnection to a low voltage power source (SELV)

[1] The mark shall be permanently placed to an exposed conductive part at the point designated for connection of the protective conductor.

[2] The mark shall be permanently placed to the surface of the object, for example on the type label.

Protection class I equipment - examples

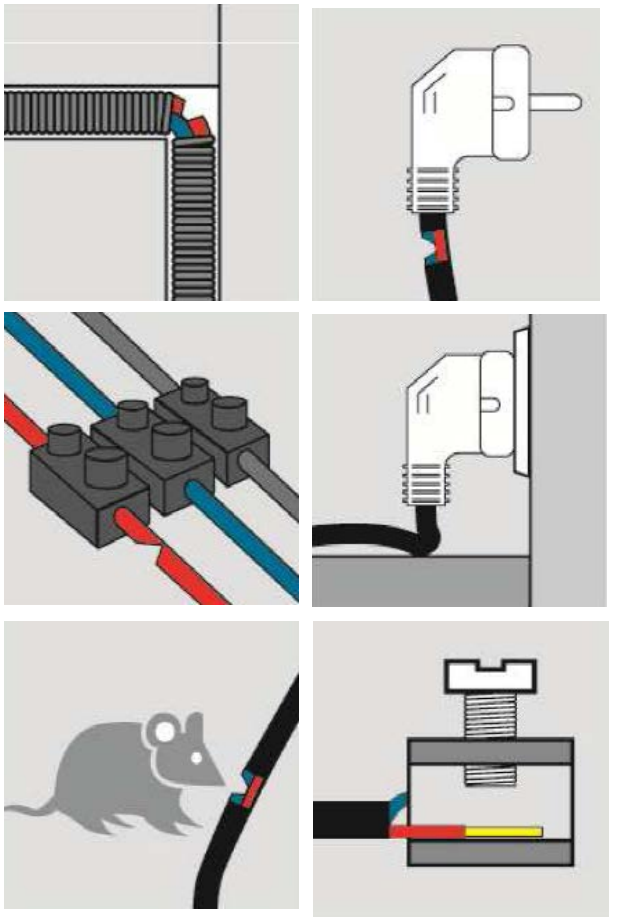
Protection class II equipment - examples

Protection class III equipment - examples

AFDD - Arc Fault Detection Device

The AFDD device is designed to detect both serial and parallel arcs, thereby preventing fires.

- It disconnects earlier than conventional protective devices.
- They operate on the principle of detecting high-frequency oscillations in voltage and current waveforms.



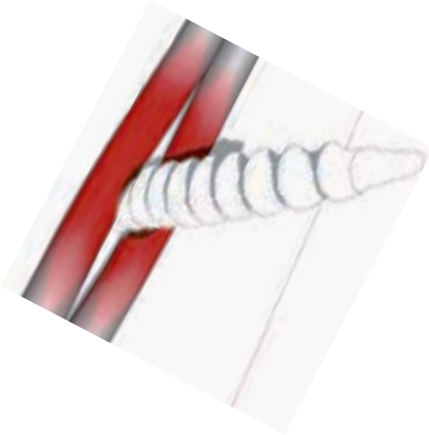
AFDD - Arc Fault Detection Device

Series arc

- limited by load impedance,
- protective devices do not respond,
- RCD does not respond either,
- more frequent occurrence.

Parallel arc

- quickly turns into a short circuit,
- with increased resistance, there are small currents
- between the working conductors (L, N) without RCD response.

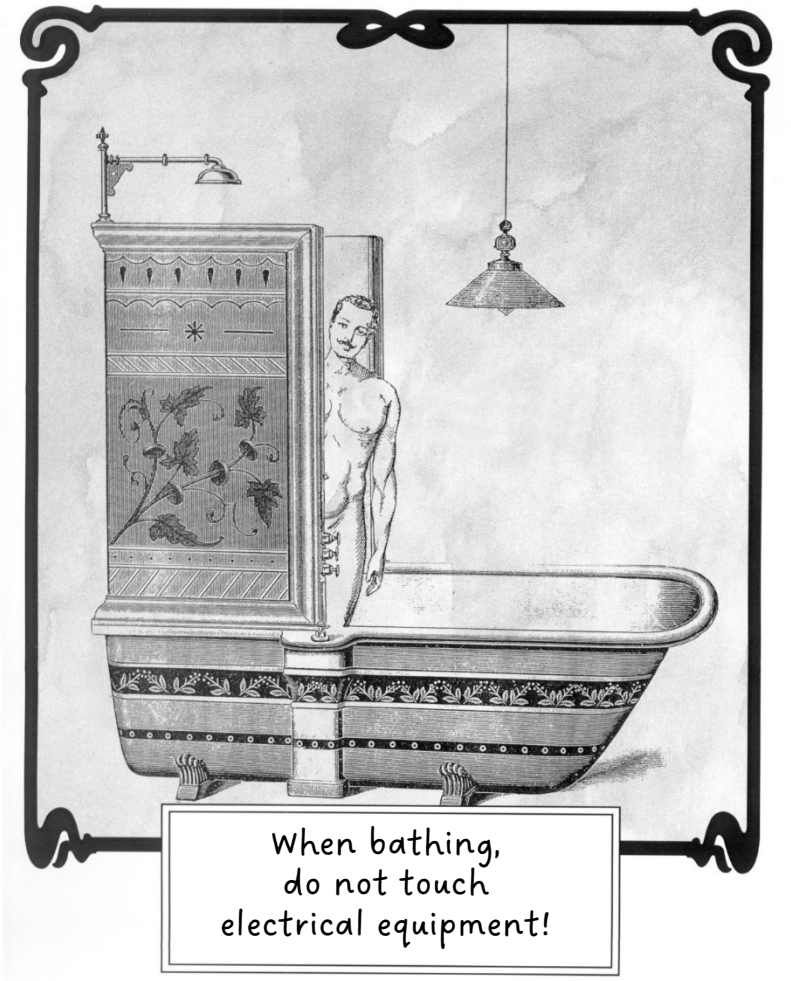


Quiz

Click the **Quiz** button to edit this object

Review questions – Quiz 5 (Protection against electric shock)

- Read each question carefully
- You have 30 seconds for each answer
- Press the **Submit** button to submit your answer
- To pass, you must answer at least 85% of the questions correctly



PART 6

FIRST AID

Lay first aid

Lay first aid is defined as **a set of simple and effective measures that limit the extent and consequences of a sudden threat to or impairment of a person's health or life**.

- It is care provided to the affected person by a layperson before the arrival of emergency medical services or other qualified personnel.
- It must be provided **quickly and effectively** but must not directly endanger the health or life of the rescuer.
- Every citizen of the Czech Republic over the age of 18 is obliged to provide first aid, provided that this does not endanger their own health or life.

Goals of first aid:

- save lives
- prevent deterioration of health
- ensure professional treatment (call the emergency medical services)

Obligation to provide first aid

- The Criminal Law (Section 150) imposes an obligation on all people to provide first aid to a person in distress.
- You do not have to help if your own life is at risk.
- There is no need to fear criminal consequences for imperfectly provided first aid (goodwill to help is appreciated).
- Paramedics are obliged to provide first aid on the basis of their medical profession, otherwise they will be punished with twice the prison sentence of other people and a ban on working for up to one year.
- Failure to provide first aid by a driver of a vehicle involved in a traffic accident is punishable by imprisonment for up to 5 years or a ban on driving (Section 151 of the Criminal Law).

If we are clearly trying to save a life, there is nothing to lose, and no one can blame us (legally or morally) for doing so.

Life-threatening conditions

The following conditions are life-threatening:

- Bleeding
  - Possibility of bleeding to death within 2 minutes (within 1 minute for large arteries)
  - Loss of 1 liter of blood in an adult is life-threatening
- Respiratory arrest (and assumed circulatory arrest)
  - Death within 3-5 minutes
  - Due to brain death
- Unconsciousness
  - Death within 15 minutes
  - Risk of tongue obstruction, suffocation by blood or saliva...
- Burns
  - Burns covering > 15% of the body surface area are life-threatening (in children and seniors > 10%)
- Trauma
- Shock

Consequences of electric shock

- Burns to the skin and internal tissues
- Spasms leading to fractures of the vertebrae and long bones
- Heart rhythm disorders, including fibrillation
- Respiratory and cardiac arrest

- Secondary injuries (after falling or being thrown)

Rescue procedure

- **Technical first aid**
  - Interrupting the accident
  - Rescue of the affected person
- **Determining the extent** of injuries
  - Vital functions: *consciousness, spontaneous breathing, and blood circulation*
  - Other serious injuries such as bleeding
- **Calling for medical assistance**
- **Providing lay first aid**

In the FEEC building, it is also necessary to inform the reception desk (on the T8 and T10 – dial 6110 and on T12 and T14 – dial 6112).

- This is important in order to secure access for emergency responders and to obtain an AED (automated external defibrillator).
- **All reception desks of FEEC buildings** at Brno University of Technology are equipped with AEDs

Safety

- When providing first aid, it is important to remember safety – both your own and that of the affected person.
- It is necessary to identify any potential hazards and protect yourself against them, for example:
  - Move the affected person away from the source of the accident
  - On the road, secure the accident site with a warning triangle
  - Wear latex gloves – protection against infection (between rescuer and injured person)

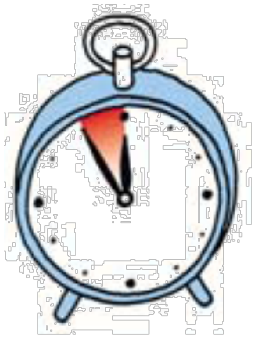
Assessing the condition of the injured person

- **Occurrence of severe bleeding**
  - If we see bleeding, it means that **circulation is fine**.
  - We must stop the bleeding (otherwise circulation will not remain normal for long).
- **State of consciousness**
  - If the affected person is responsive, circulation and breathing are fine.
  - If **the affected person is unresponsive**, we must check their breathing.
- **Breathing**
  - If **the affected person** is **conscious but breathing poorly**, their vital functions are relatively okay for now, but there is an immediate risk of failure.
  - If the affected person is "unconscious" (unresponsive) but breathing normally (even after repeated checks), their circulation is also fine.
  - If **the affected person is "unconscious"** (unresponsive) and **not breathing normally** (or **not breathing at all**), their vital functions have failed, and they are in a state of "clinical death" – we will begin CPR.

- Checking for a pulse is NOT part of the initial lay examination!

Resuscitation

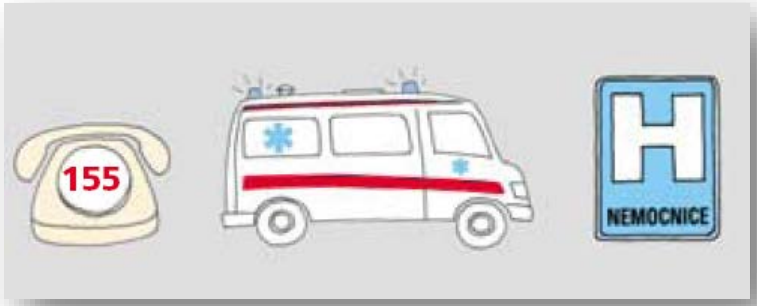
The examination of the affected person should be quick (within 30 seconds) and resuscitation must be started immediately!



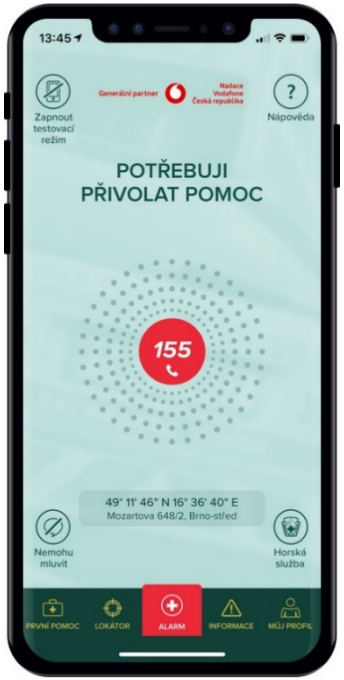
- **Resuscitation should not be initiated** solely:
  - certain signs of death, such as postmortem spots or rigor mortis
  - if the injury is incompatible with life
  - if the rescuer would put themselves at risk
  - DNR (do not resuscitate) - decision of the medical team
  - terminal stage of incurable diseases - decision of the medical team
- **Resuscitation may only be terminated**:
  - after basic life functions have been restored
  - after the injured person has been handed over to the care of paramedics
  - after the rescuer is exhausted
- If the injured person regains consciousness after resuscitation, **they must continue to be monitored and must remain lying down**

Calling for medical assistance

- National emergency number **155**
  - Czech Republic Emergency Medical Service
- European emergency number **112**
  - Integrated Rescue Service
  - Emergency calls in EU countries
  - Can locate the caller (landline precisely, mobile phone approx. 300 m)
  - Works even without a SIM card
- **Záchranka** mobile app (*http://www.zachrankaapp.cz*)
- Mountain rescue service 1210



- Arrival within 20 minutes



Calling for medical assistance: location

- Landmarks in the countryside or city (bus stop, church, train station, shop, hotel, etc.)
- Street lamp numbers
- Railway crossing numbers

Calling for medical assistance: message content

- Type of injury
- Condition of the injured person
  - Conscious or unconscious
  - Breathing
  - Other injuries
- Assistance provided
- Place and time of accident
- Terrain features
  - access roads
  - Helicopter landing area (30×30 m)…
- Ask for advice
- **Do not hang up!**
- **Use the speaker on your cell phone!**

Bleeding

- Blood leakage from the vascular system
- Classification of bleeding according to origin
  - **Arterial** – oxygenated (light-coloured) blood spurts from the wound in pulses
  - **Venous** – deoxygenated (dark) blood flows from the wound
  - **Capillary** (capillary) - minor bleeding on the periphery
- Classification of bleeding
  - **External bleeding** – the skin is broken, blood is visible
  - **Internal bleeding** – skin integrity is not broken, blood is not visible, hematoma formation, pain, symptoms of shock development
  - Bleeding from natural body orifices – bleeding, e.g. from the nose or mouth

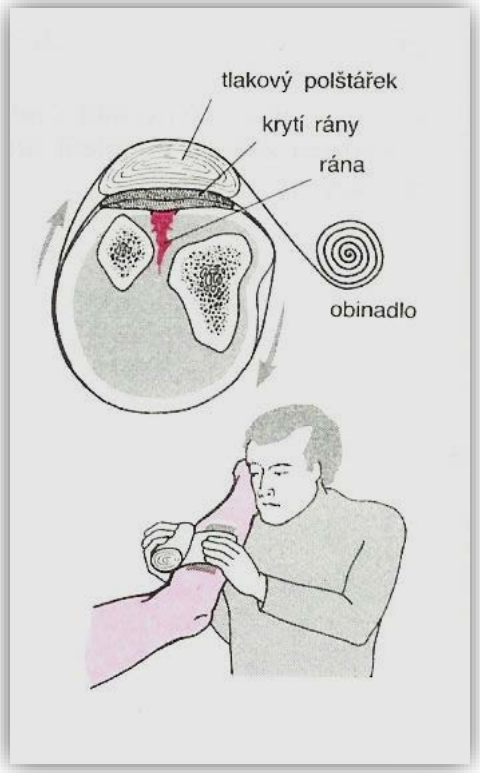
Stopping arterial bleeding

- Temporary bleeding control:
  - Elevate the affected limb
  - Plugging the wound with your fingers
  - Temporary use of a tourniquet
  - Pressing the pressure point (no longer recommended)

- Permanent stopping of bleeding
  - Use of a pressure bandage
  - Use of a tourniquet (only for specific conditions!)

PRESSURE BANDAGE

- It restricts or stops extensive bleeding (both arterial and venous).
- It consists **of three layers**:
  - covering (sterile, cleanest)
  - pressure (absorbent material)
  - fixation (bandage)
- When applied correctly, it will stay on the wound, will not rotate, and will apply pressure
- The area under the pressure bandage will be pale, but the pulse can be felt



TOURNIQUET

Can **only** be applied **in the following indications**:

- **massive bleeding** from the brachial or femoral artery
- traumatic **amputation**
- **if the second layer of** the pressure bandage **is leaking**
- open fracture with massive bleeding
- foreign body lodged in a wound with massive bleeding

- **crush syndrome** (syndrome caused by burial, i.e., crushing of soft tissues of the limb)
- **temporarily** (before applying a pressure bandage, or when there are more injured people than rescuers)

TOURNIQUET

- Use **only on limbs** (thighs or arms – not calves or forearms!)
- Not near joints, always **over clothing**!
- Width 5-6 cm, length 125 cm, do not use thinner ones!
- Record **the time of application**
- Elevation of the limb
- Cooling of the limb

- **DO NOT RELEASE** during definitive treatment! (risk of kidney failure due to the release of waste products from the tissues into the circulation)

First aid for internal bleeding

Internal bleeding cannot be stopped with **lay first aid**. It is necessary to prevent the development of shock and call for emergency medical assistance.

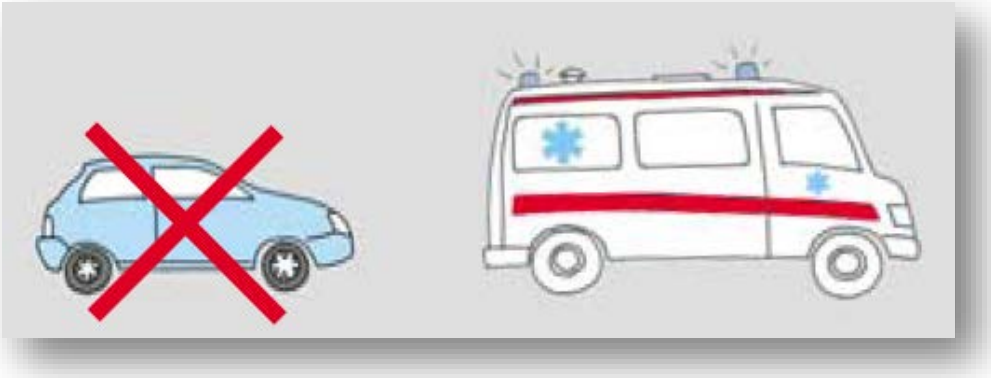
- Anti-shock measures (see below)
- Position according to the location of bleeding (based on the subjective feeling of the affected person)
- Check vital signs
- Call for emergency medical assistance

First aid procedure: the affected person is **conscious**

When conscious:

- Do not allow the affected person to stand up, walk, smoke, etc.
- Do not give them any liquids
- Protect them from hypothermia
- Do not leave the affected person and repeatedly check their consciousness (e.g., by talking to them)
- Do not move them but always call for medical assistance

- Even if the affected person is breathing after an electric shock, remains conscious, and is not visibly injured, **it is still necessary to call for medical assistance.**



First aid procedure: the affected person is unconscious and breathing

Unconsciousness:

- Do not move the affected person unless they or the rescuer are in danger from the environment
- Loosen clothing around the neck, chest, and waist
- Place the affected person in the recovery position only if necessary (treatment of multiple casualties).

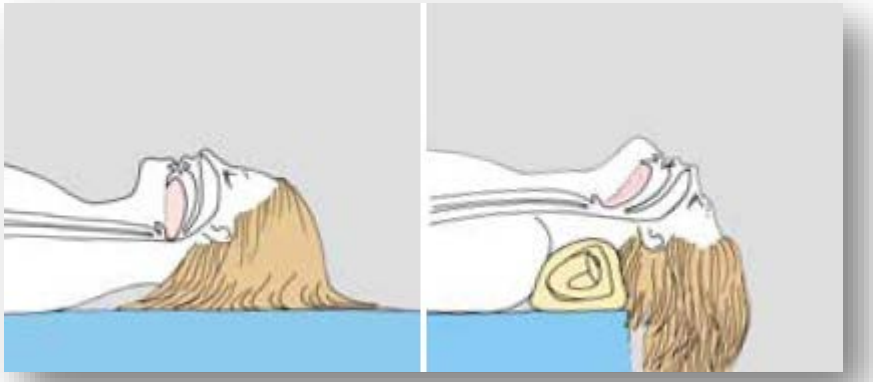
First aid procedure: the affected person is unconscious and not breathing

Respiratory arrest/cardiac arrest:

- In the event of breathlessness**, we automatically assume cardiac arrest!**
- Do not move the injured person unless they or the rescuer are at risk from the environment.
- Do not delay treatment of non-life-threatening injuries.
- We immediately clear the airways and begin cardiopulmonary resuscitation – CPR (also known as BLS – Basic Life Support).

Clearing the airways

- Lay the affected person **flat on their back** on a firm surface
- Remove any visible obstructions from the mouth
- **Tilt** the affected person's **head back**



- Check for spontaneous breathing
- If the affected person is not breathing, **begin resuscitation**

CPR - CARDIOPULMONARY RESUSCITATION

- Find the imaginary line connecting the nipples.
- Press your chest down as soon as possible to a sufficient depth and quickly!
- With both arms straight, press down on the sternum to a depth of **4 to 5 cm** at a rate of about **100 to 120 compressions per minute**.
- In children, the depth of compression is less
- **Don't waste precious time!**

CPR – PROCEDURE (CONTINUED)

- For children, start with 5 breaths
- We perform 30 chest compressions
- Followed by 2 quick breaths from your lungs into the child's lungs, while closing the nasal passage with one hand and keeping the head tilted back
- The volume of the breath depends on the size of the person, approximately 500-600 ml for an adult
- Continue with another series of 30:2
- Laypeople who are not trained do not need to perform artificial respiration (without prior training, they may worsen the patient's condition)

30:2

Shock

Shock is a sudden life-threatening condition caused by a disruption in the supply of oxygen and nutrients to tissues. It can be caused by many traumatic and non-traumatic factors.

Traumatic causes:

- Loss of more than 1 liter of blood
- Burns covering >10% of the body surface area (children and seniors) or >15% (healthy adults)
- Other traumatic conditions

Non-traumatic causes:

- Anaphylactic or septic shock
- Dehydration due to diarrhea or vomiting
- Heart disease

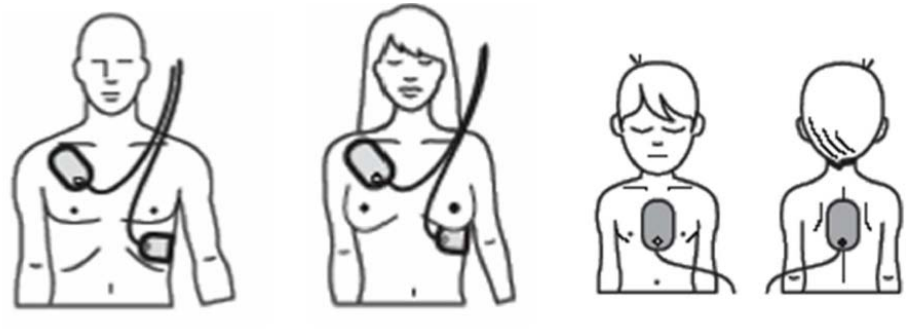
Anti-shock measures

- Pain relief
  - by treating injuries
  - immobilization of injured parts
  - no medication!
- Transport
  - leave to professional help
  - only in necessary cases (threat from surroundings)
- Tranquility
  - we calm the affected person
  - we ensure a calm environment
- Warmth
  - thermal insulation mat
  - blanket
- ~~Fluids~~
  - must not be given!
  - at most, we can moisten the lips

AED - Automated External Defibrillators

An AED is a device that can also be used by laypeople:

- It can recognize the rhythm suitable for defibrillation on its own.
- enables defibrillation to be performed safely
- it guides the user through the process with voice and text instructions



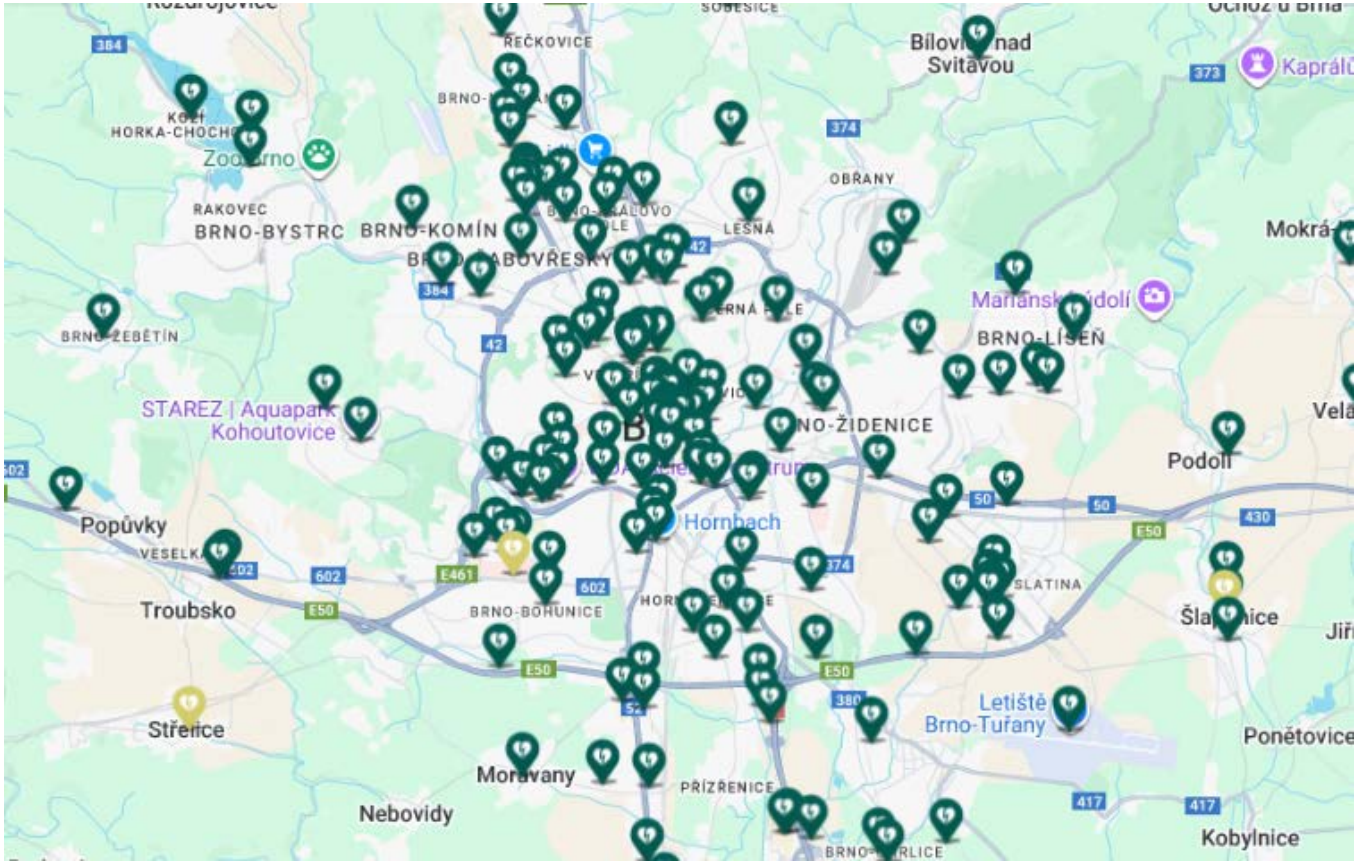
AED – AVAILABLE AT FEEC RECEPTION DESKS

Use the AED if **breathing** has **stopped!**

AEDs are available at:

- Voice guidance throughout CPR
- Non-interchangeable electrode system
- Check for correct massage with a sensor built into the electrodes
- Recording of the resuscitation process in memory with subsequent protocol

AED locations in Brno



[AED map online]

Quiz

Click the **Quiz** button to edit this object

Review questions – Quiz 6 (First Aid)

- Read each question carefully
- You have 30 seconds for each answer
- Press the **Submit** button to submit your answer
- To pass, you must answer at least 85% of the questions correctly

DONE!

- Congratulations, you have successfully completed the study material and thus completed the **mandatory training** within the meaning of Art. 9 GR 194/2022 Coll.
- You can now proceed to take the **test**, which is available in e-learning – subject **RSAF**

  Suggestions or comments: Miloslav Steinbauer

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