SAPIENZA
UNIVERSITÀ DI ROMA

Safety of Industrial Plants

Lecture 8
Electrical hazards

Contents and Goals

- Contents
  - Harmful effects of electrical discharges;
  - electrical faults;
  - electrical protections
- Goals
  - Learn to evaluate and control the electrical risk
- Professional Figures of reference
  - All

Electrical risk

- The electrical risk is related to the possibility of accidents linked to the uncontrolled passage of electric current.
- The electrical risk is widespread
  - distribution to 20,000 V
  - End uses at 220 V or 380 V

- The danger of electrical phenomena is not well known

Electrical risk

- There are 8 million Italian houses (2/3 of the total of those built before 1990) with electrical plants below standards.
- There are over 45,000 domestic accidents, often fatal, deriving each year from problems linked to the electrical system.

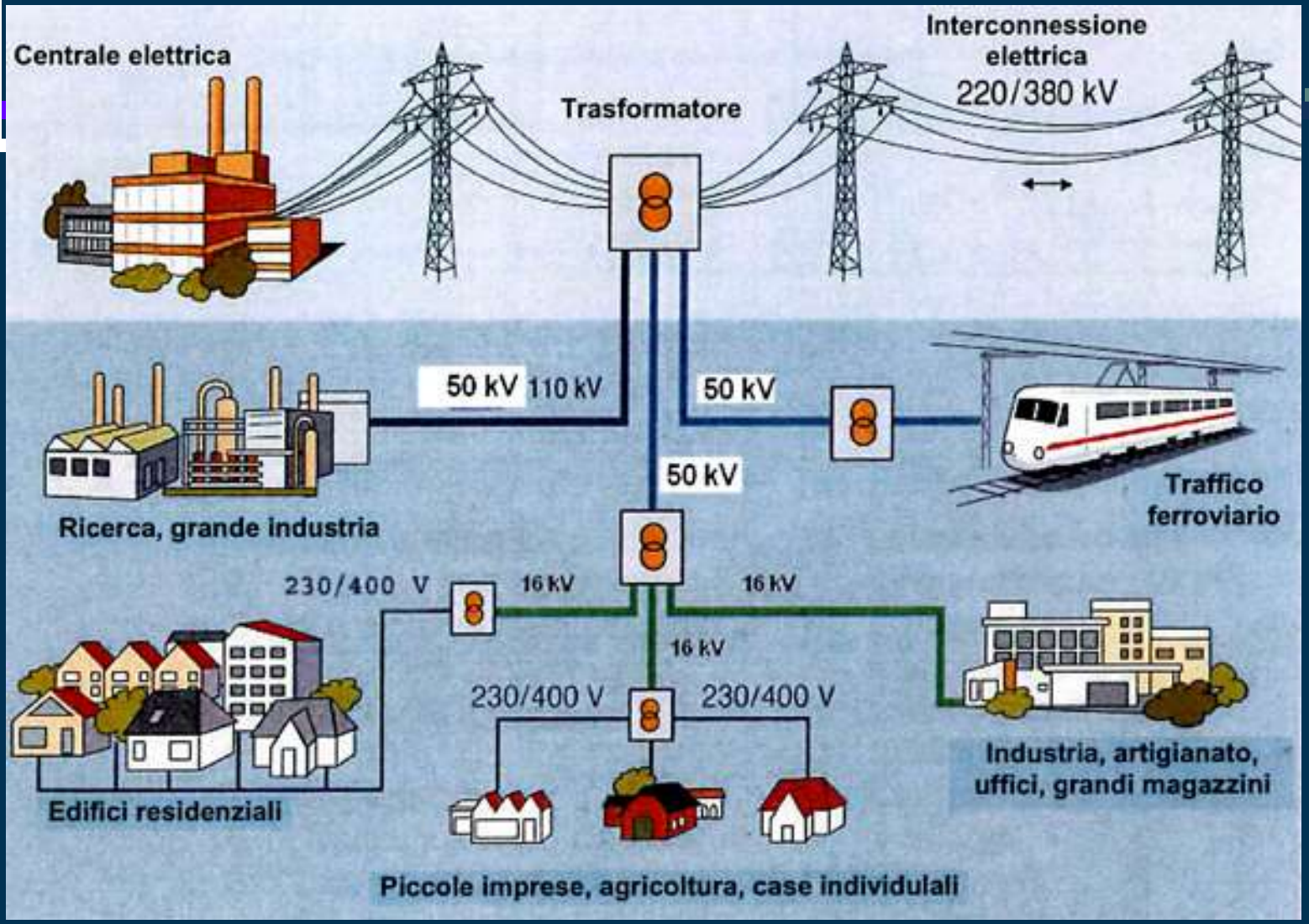
Electrical risk

Self-test:

- Is the electrical system more than 10 years?
- Aren't the safety shields inside the inlet holes of the electrical system visible ?
- Aren't switches and sockets well fixed to the walls?
- Aren't the electrical cables well protected and isolated and are they exposed ??

-Have the sockets of your home been provided with the central hole or the side tab (ground) to allow the equipment to be connected to the electrical grounding system?
- In the bathrooms, are sockets and switches located less than 60 cm from the bathtub and the shower?
- Are slippers, multiple sockets and adapters permanently used?

If the answer to, at least, two of the above questions is "YES"…


Centrale elettrica
Trasformatore
Interconnessione elettrica
220/380 kV
50 kV
110 kV
50 kV
50 kV
Ricerca, grande industria
Traffico ferroviario
230/400 V
16 kV
16 kV
16 kV
230/400 V
230/400 V
Edifici residenziali
Industria, artigianato, uffici, grandi magazzini
Piccole imprese, agricoltura, case individulali

Electrical risk

- If we consider a common electrical system for civilian use:
  - P = VI
  - V = 220 V
  - P = 3000 W

  I = P / V = 3000 / 220 = 14 A

- A differential switch / circuit breaker is calibrated to interrupt the power in 0.5 s with a current of 30 mA

14 A / 30 mA = 467

THE NOMINAL CURRENT OF A COMMON ELECTRICAL SYSTEM FOR PRIVATE USES IS ABOUT 500 TIMES THE FATAL CURRENT

Electrical risk

- It is necessary:
  - Designing in accordance with the rule of art
    - CEI standards (CENELEC, IEC)
    - Risks analysis
  - Realising in accordance with the rule of art
    - DLgs 626/96: electrical equipment for use between 50 and 1000 V AC must be marked CE
    - Using material of suitable IP degree
  - Always provide essential electrical protections
    - Electrical grounding system
    - Differential switch or circuit breaker
  - Maintenance and periodical testings

Electrical risk

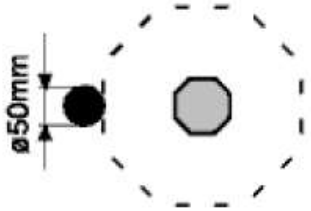
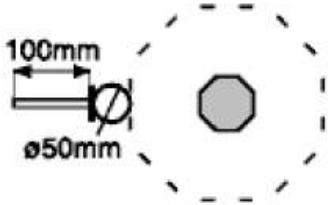
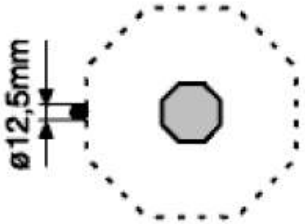
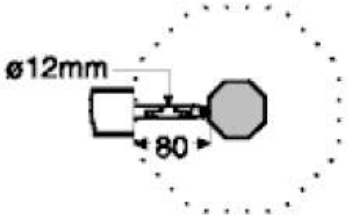
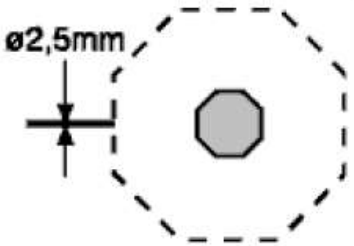
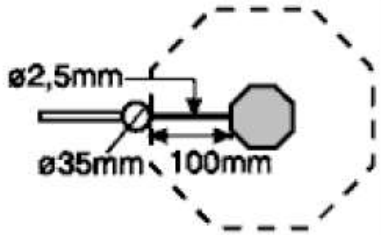
- The CEI EN 60529 standard establishes the classification of the protection degree for the material enveloping the electrical equipment.
- The IP Degree (International Protection Degree) applies to electrical equipment with rated voltage up to 72.5 kV.
- The IP Degree is a two-number code and some additional letters.

Electrical risk

- The first number of the IP code indicates
  - the protection of persons against contact with dangerous parts
  - the protection of materials from the entry of solid foreign materials
- The second number of the IP code indicates the protection against harmful ingress of water.
- The additional and supplementary letters provide information on the material :
  - Additional letter: to use where the protection of persons from contact with hazardous parts is higher than that of entrance of solids required by first characteristic number
  - Supplementary letter: for further information

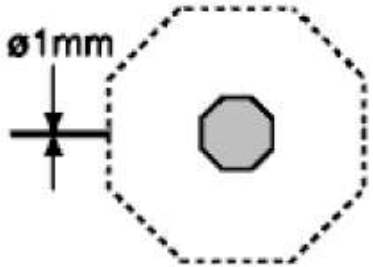
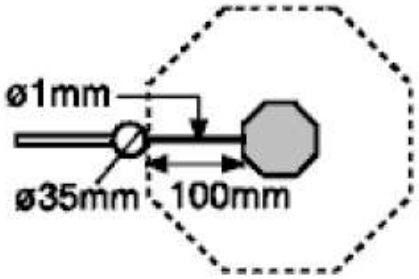
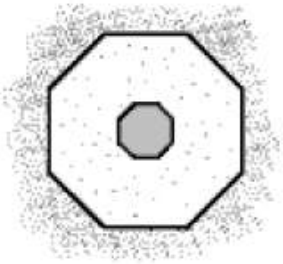
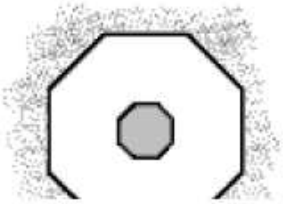
Electrical risk

1st number

IP	Corpi solidi estranei	Accesso a parti pericolose	Significato
0			Nessuna protezione
1			Protetto contro i corpi solidi superiori a 50mm (esempio: contatti involontari della mano)
2			Protetto contro i corpi solidi superiori a 12mm (esempio: dito della mano)
3			Protetto contro i corpi solidi superiori a 2,5mm (arnesi, fili)

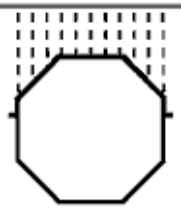
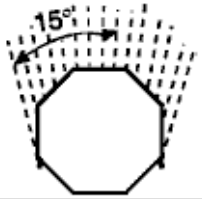
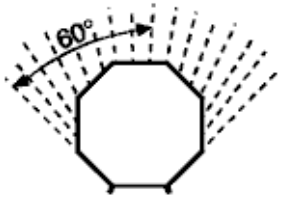
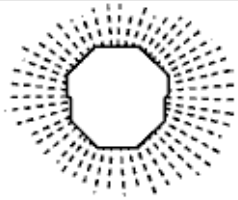
Electrical risk

1st number

IP	Corpi solidi estranei	Accesso a parti pericolose	Significato
4			Protetto contro i corpi solidi superiori a 1mm (arnesi fini, fili sottili)
5			Protetto contro le polveri (nessun deposito nocivo)
6			Totalmente protetto contro le polveri

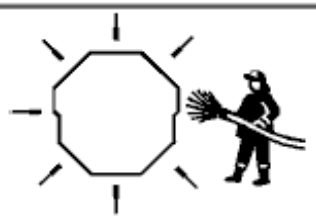
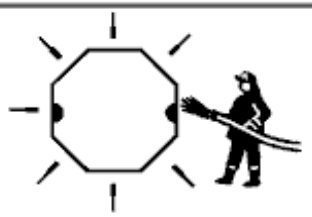
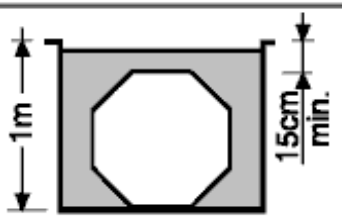
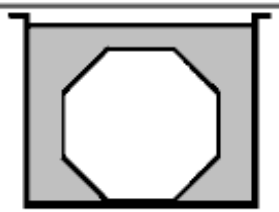
Electrical risk

2° number

IP	Prove	Significato
0		Nessuna protezione
1		Protetto contro le cadute verticali di gocce d'acqua
2		Protetto contro le cadute di gocce d'acqua fino a 15° dalla verticale
3		Protetto contro le cadute d'acqua a pioggia fino a 60° dalla verticale
4		Protetto contro gli spruzzi d'acqua da tutte le direzioni

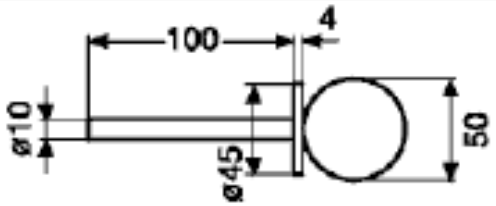
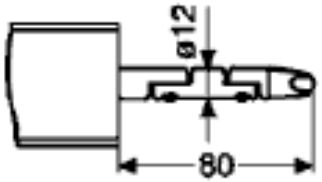
Electrical risk

2° number

IP	Prove	Significato
5		Protetto contro i getti d'acqua con lancia da tutte le direzioni
6		Protetto contro le proiezioni d'acqua simili a onde marine
7		Protetto contro le proiezioni d'acqua simili a onde marine gli effetti dell'immersione
8		Protetto contro le proiezioni d'acqua simili a onde marine gli effetti della sommersione

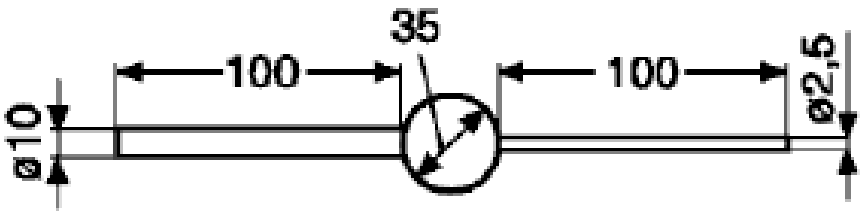
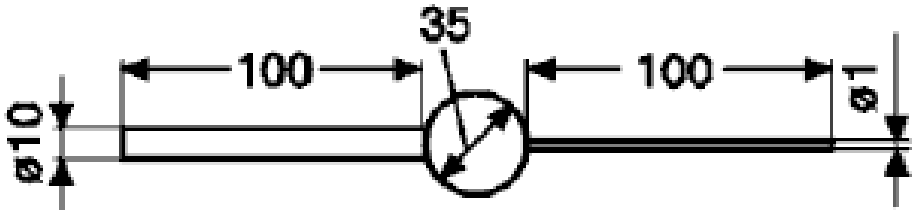
Electrical risk

Additional letter

Lettera	Significato
A	 Protetto contro l'accesso con il dorso della **mano**. Il calibro di accessibilità di diametro **50mm** deve mantenere un'adeguata distanza dalle parti pericolose.
B	 Protetto contro l'accesso con un **dito**. Il dito di prova articolato di diametro **12mm** e di lunghezza 80mm deve mantenere una adeguata distanza dalle parti pericolose

Electrical risk

Additional letter

Lettera	Significato
C	 Protetto contro l'accesso con un **attrezzo**. Il calibro di accessibilità di diametro **2,5 mm** e di lunghezza 100mm deve mantenere una adeguata distanza dalle parti pericolose
D	 Protetto contro l'accesso con un **filo**. Il calibro di accessibilità di diametro **1,0 mm** e di lunghezza 100mm deve mantenere una adeguata distanza dalle parti pericolose

Electrical risk

Lettera	Descrizione
H	Apparecchiature ad alta tensione
M	Provato contro gli effetti dannosi dovuti all'ingresso d'acqua, quando le parti mobili dell'apparecchiatura (per es. rotore di una macchina rotante) **sono** in moto
S	Provato contro gli effetti dannosi dovuti all'ingresso d'acqua, quando le parti mobili dell'apparecchiatura (per es. rotore di una macchina rotante) **non sono** in moto
W	Adatto all'uso in condizioni atmosferiche specifiche e dotato di misure o procedimenti protettivi addizionali

Supplementary letter

Harmful effects coming from electrical accidents

- Effetts on things
  - Heating and aging;
  - Thermal fatigue;
  - Failure of the insulation;
  - Ignition, Fire, etc.;
  - Electromagnetic induction;
  - Electromagnetic Interference
- Effetts on people
  - Tetanisation affecting muscles;
  - Ventricular fibrillation;
  - Breathing stopped;
  - Burns;
  - Electrolysis

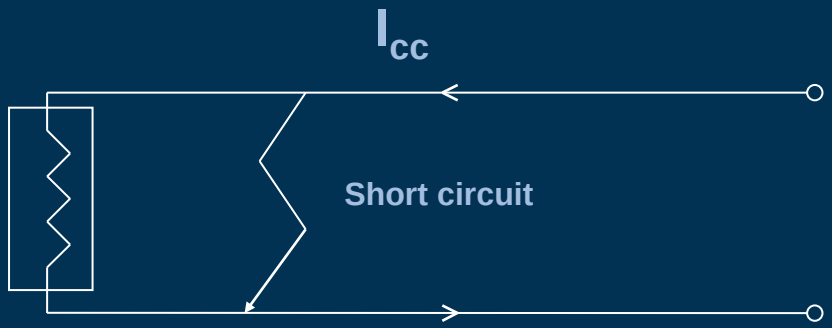
Electrical faults

- Short circuit
- Thermal overload
- Arc flash
- Leakage of current

- Direct contacts
- Indirect contacts
- …

Electrical faults

- Short circuit
  - It is a phenomenon that produces the sudden passage of very high current values (hundreds of times higher than the rated current)



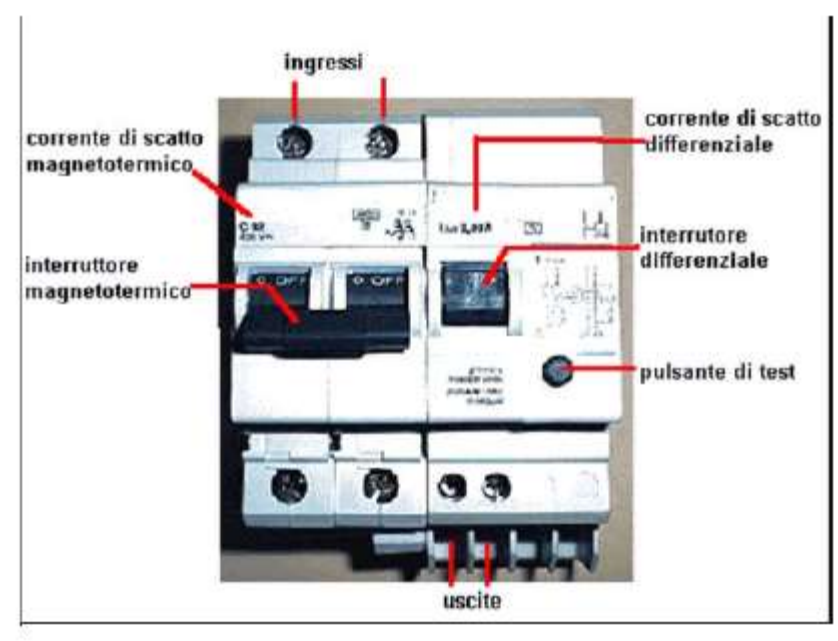
MAGNETIC SWITCH

Electrical faults

- Thermal overload
  - It is a gradual heating phenomenon determined by the passage of a current exceeding the rated values (sometimes exceeding the rated current)
  - It occurs when the system is overloaded
  - It is also an indicator of the respect of the supply contract

THERMAL SWITCH

Electrical faults

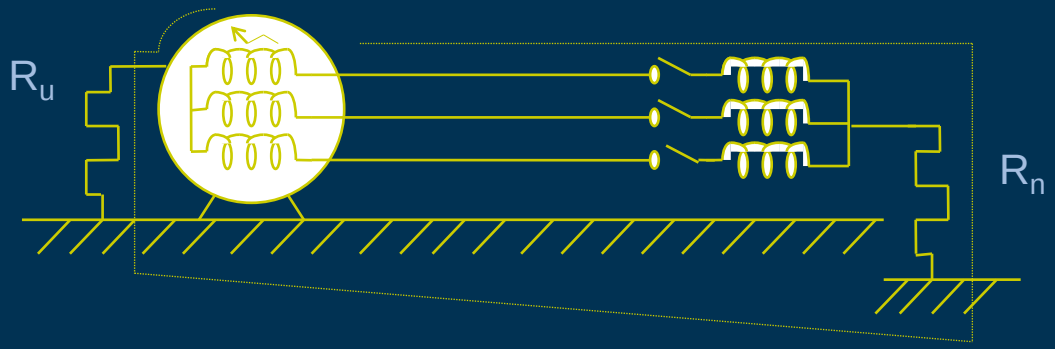


Electrical faults

- Arc flash
  - It is an uncontrolled passage of current
  - It occurs when the voltage between the two masses exceeds the dielectric of the medium interposed
  - It is typical of all the switches
  - Cutting the arc is more difficult in DC
    - **SWITCH IN VOLUME OIL**
      - oil evaporates cooling the area
      - oil is a good dielectric
    - **SWITCH KNIVES**
    - **MAGNETIC BLOW**
      - Coil in series to the main circuit
      - Electromagnetic breath transversal to the arch

Electrical faults

- Leakage of current
  - It is a passage of current through the masses of electrical equipment which are thus i tension
  - It is given by
    - failure of the insulation
    - deformation of the conductors



Electrical faults

- Leakage of current
  - The operator can be interested by **important currents** as a result of an **indirect contact**

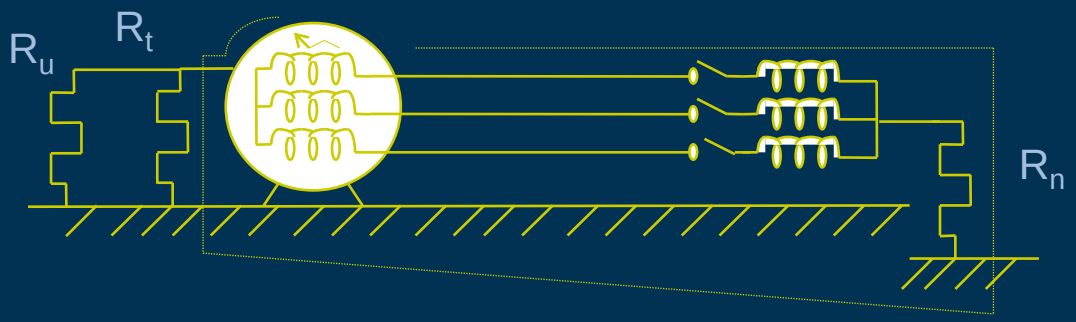
$$I = \frac{E}{R_u + R_n}$$

  - if $R_n = 30\ \Omega$ and $R_u = 1500\ \Omega$ and $E = 380$ V

I = 248 mA > > 30 mA

Electrical grounding system

- The electrical grounding system offers an alternative circuit to human body safeguarding the man



Electrical grounding system

- DPR 547/55 (Title VII - Arts. 271 – 326)/Dlgs 81/08
  - The metal parts of the installations at high voltage (> 400 V AC), subject to contact of persons and for insulation fault or other causes might be under voltage, must be connected to the ground
  - The ground connection must be done even for low-voltage installations located in places normally wet or very damp or in the immediate vicinity of large metal masses
- L 46/90 (Article 7)/DM 37/08
  - The electrical installations must be equipped by electrical grounding system and circuit breakers with high sensitivity or other equivalent protection systems. All the installations made on the date of entry into force of this law shall be adequate, within three years, in accordance to what disposed by this article.
    - (extended deadline to 12/31/98 by art. 31 of Law 08/07/97 n. 266)

Electrical grounding system

- DPR 547/55 (Title VII - Arts. 271 – 326)/Dlgs 81/08
  - Concerning the electrical connections at ground conductors with appropriate size for the intensity of the current to the ground (not less than 16 square millimeters, for those made by copper, and 50 square millimeters, for those made by iron or galvanized steel) shall be used.
  - for visible traits of ground copper conductors, sections smaller than 16 square millimeters but not less than the section of the conductors of the electric circuit, to a minimum in each case of 5 square millimeters can be tollerated

Electrical grounding system

- DPR 547/55 (Title VII - Arts. 271 – 326)/DLgs 81/08
  - The sink for the ground plate must be - for construction material, shape, size and location, appropriate to nature and ground conditions for all the leads to the ground by a resistance not exceeding 20 ohms voltage per users plants up to 1000 Volts
  - For higher voltages and for cabins and electrical workshops, the sink has to present the least safety resistance, which has to be adequate to the characteristics and peculiarities of the plants
  - Gas pipes (compressed air and alike) are not admissible as sinks for ground sockets. Water pipes, if they are part of large networks and the attack of the ground is reported upstream of possible derivations, are allowed for voltage systems not exceeding 1000 V.

Electrical grounding system

- According to the CEI Standard:
  - Maximum current load

$$I = 10 + 10 / T$$

    - I is expressed in mA
    - T is expressed in s

  - Step voltage and contact voltage
    - Up to 1000 V:

65 V

    - More than 1000 V:

65 V

125 V if faults
are deleted within 1 s

Electrical grounding system

- Step voltage can be particularly high in the vicinity of the discontinuity of the electrical grounding system: it is necessary to
  - burying the plant in depth
  - tilt the plant in the vicinity of the discontinuities

- To reduce the contact voltage

Very thick meshed nets

Electrical grounding system

- According to the CEI Standard :
  - The grounding resistance must be such as to allow the occurrence of the maximum of the condition of indirect contact:

50 V in 5 s

R_T I ≤ 50 V

if I = P / V = 3000 / 220 = 14 A

R_T ≤ 50 / 14 = 3 Ω

WITH SWITCH DIFFERENTIAL

I = 30 mA

R_T = 1700 Ω

COORDINATION OF PROTECTIONS

Electrical grounding system

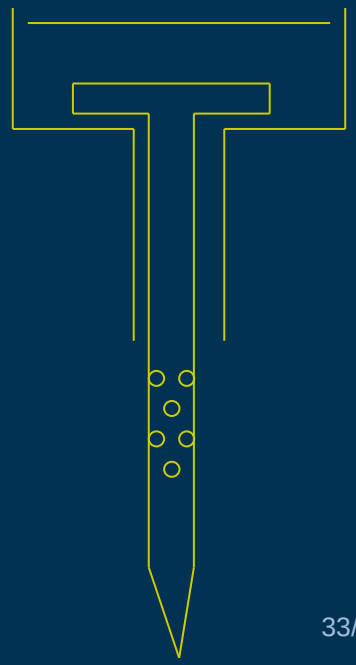
- The sinks of the electrical grounding system may be:
  - Cylindrical
  - Plate
  - Net
- In the case of grounding cylindrical rod sink:

$$\mathbf{R_T = \rho / L}$$

  - ρ = 2.000 ÷ 100.000 Ω cm
  - if R_T = 20 Ω

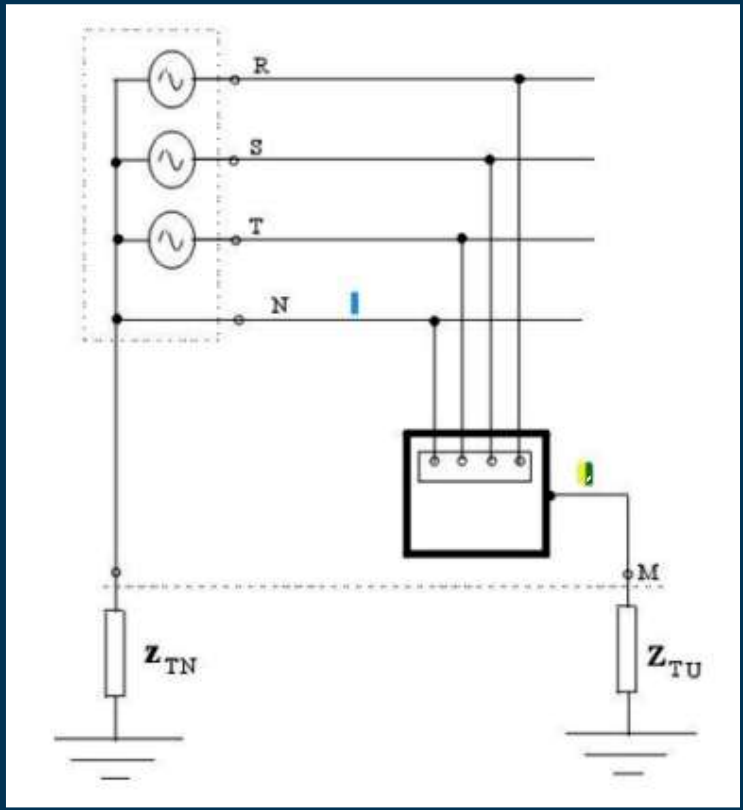
$$\mathbf{L = 50\ m}$$

ground meshed net



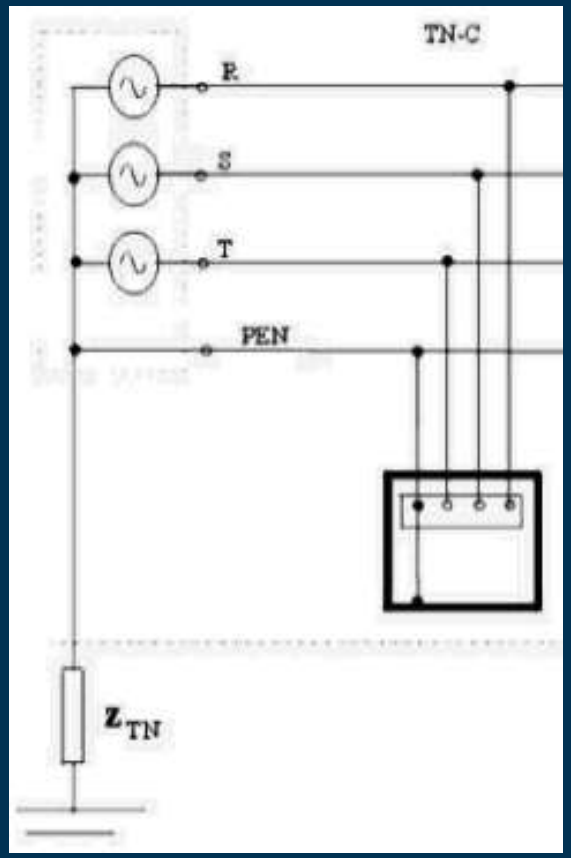
Electrical configurations

- Configuration T-T
  - The neutral of the secondary transformer is connected to the ground with its own line
  - Masses of users connected to the ground with its own line
  - Separated electrical grounding system



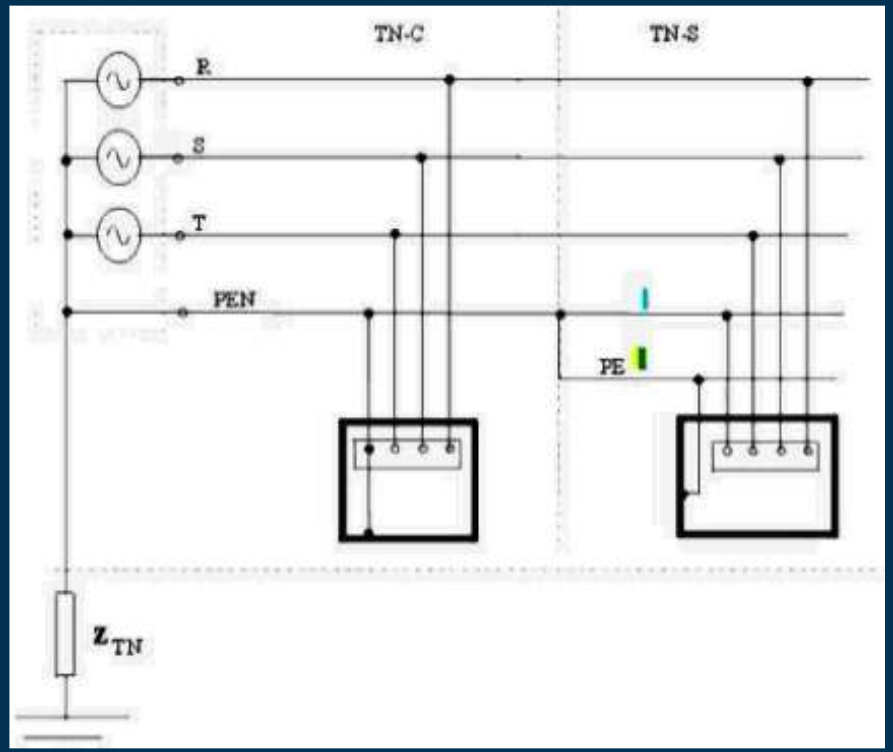
Electrical configurations

- T-Nc Configuration (common)
  - The neutral of the secondary transformer is connected to the ground
  - The Masses of users are connected to the ground with the same line
  - Coincident electrical grounding systems



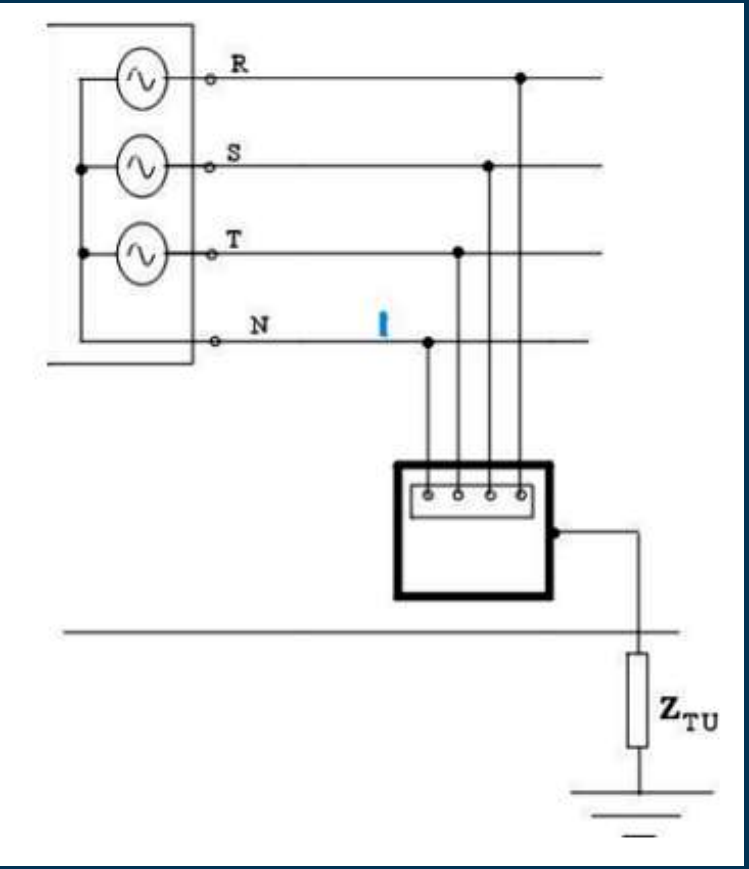
Electrical configurations

- T-Ns Configuration (separated)
  - The neutral of the secondary transformer is connected to the ground
  - The Masses of users are connected to the ground with a separated line
  - There is only one grounding electrical system
  - Generally, systems are TN-C in the stretch from the transformer to the framework; TN-S from the general framework on.

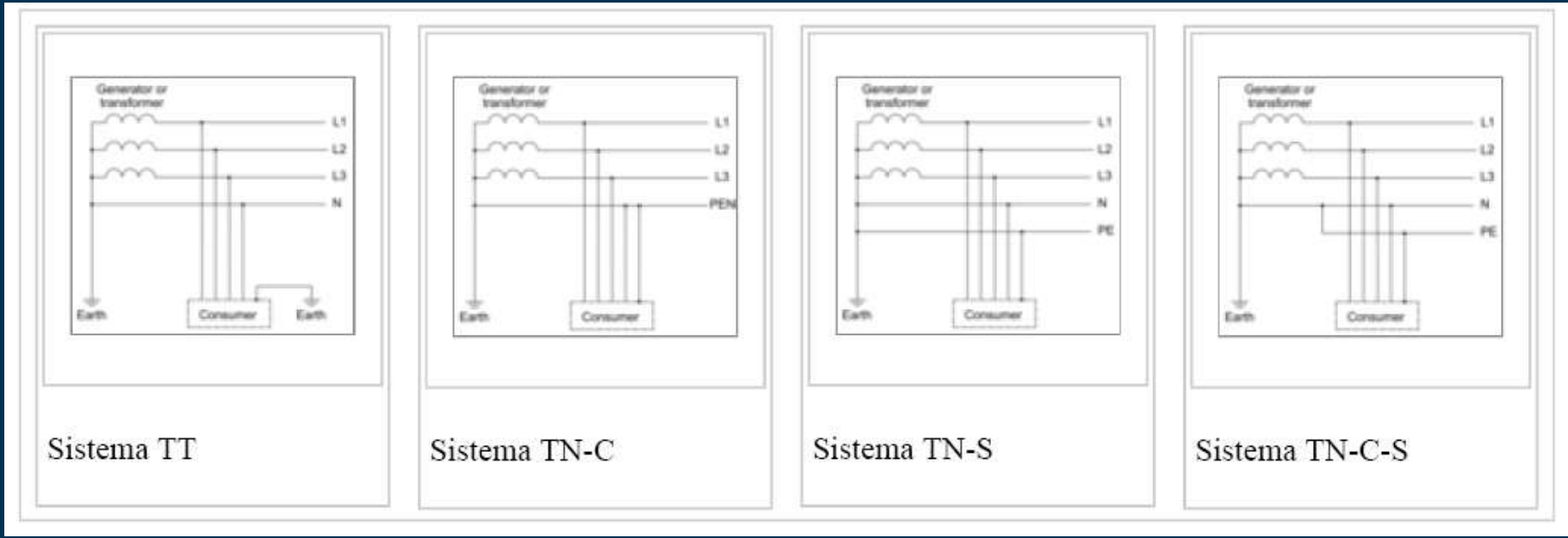


Electrical configurations

- IT Configuration (separated)
  - The neutral of the secondary transformer is separated
  - The Masses of users are connected to the ground with their own line



Electrical configurations



Electrical configurations

- TT Configuration
  - The neutral is grounded in the cabin and at several points along the line of distribution
  - The electrical system for private use is usually grounded through its own plant and with its own sink
  - This system (TT) is compulsory in Italy for all private uses in low voltage
  - In case of ground faults of a device, it creates a reverse current through the ground which causes the tripping of circuit breakers or protection differentials

Electrical configurations

- TN Configuration
  - The large users receive electricity directly in medium voltage and shall turn it with their own medium voltage cabs
  - In this case, the neutral of the transformer is directly connected with the electrical grounding system of the building, forming the ground-neutral system (TN)
  - In particular it is possible to obtain the connection of the grounding protective of the equipment directly to the neutral (TN-C) or with two separated lines for neutral and earth (TN-S) interconnected in the cab
  - The TN-S system provides greater safety because the neutral cable could - being crossed by current - be subject to overloading and therefore to a deterioration over the time
  - There is also a hybrid solution (TN-C-S system) in which two separated lines are interconnected at an intermediate point outside the cab

Electrical configurations

- TN Configuration
  - In general, TN systems offer a higher protection degree than those TT
  - If a phase conductor comes in contact with the metal mass of a unit, this mass being practically connected directly with the neutral wire, the ground fault is equivalent to a short circuit fault
  - This involves the establishment of a high fault current that produces the intervention of the **magnetic switch** or the **protection fuse**
  - If the electrical grounding system were a TT type, the fault current may be insufficient to make these devices active
  - The choice of a TN system, however, does not exempt from the requirement of the installation of the differential switch, since the ground fault can also occur through contact resistance that does not guarantee the short circuit, such as the human body

Electrical configurations

- IT Configuration
  - In the case of a failure, because of "'isolation" of the transformer, a low, and therefore not dangerous, current will flow; the switch does not open and other users connected to the network will continue to be powered
  - Such a system is very useful in systems where a constant supply of power is required, such as in hospitals
  - Once the fault occurred, it is necessary to act promptly to isolate it to prevent - in the case of another damage to a device of the same system - tripping the circuit and interrupt the service

Classes of electrical insulation

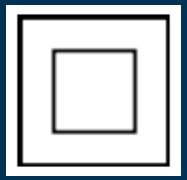
- The insulation electrical classes (IEC) define the degree of ground connection required by electrical equipment
- **Class 0**
  - The devices in this class are devices in which **protection against electric shock is based on the main insulation** (ie the live parts, necessary to prevent electrical shock)
  - **There is no device to connect to any accessible conductive parts to the ground conductor**
  - In case of failure of the main insulation, protection depends on the environment surrounding the equipment
  - The devices of Class 0 are no longer manufactured and they dissapeared from international standardization
  - In some countries, this type is still present, in particular in older installations
  - In many countries, including Italy, their use in connection to the electrical network, is prohibited, as a single fault can cause electrocution of the user and other accidents

Classes of electrical insulation

- **Class 1**
  - The protection against electric shock does not rely only on the main insulation, but also on an additional safety measure consisting by the connection of the conductive parts to a protective conductor marked by the double yellow / green color, so that the accessible conductive parts cannot go under tension in the event of failure of the main insulation
  - A failure in insulation in these devices can lead a phase conductor in contact with the housing causing a flow of current through the protective conductor
  - The methods to avoid the shock of the user who may come into contact with the metal part grounded are as follows:
    - Adequate dimensioning of the ground electrode, and the relative plant, so as not to allow a voltage, caused by the leakage current to the ground and the resistance it encounters in the path, to more than 50 V
    - Insertion, in accordance with law, of a differential circuit breaker upstream of the electrical system which divides into sections the tension in case of leakage currents superior than 30 mA

Classes of electrical insulation

- **Class 2**
  - The devices of class II, also called double insulation devices, are designed so as not to require (and therefore they must not have) grounding connection
  - They are designed so that a single fault will not cause the high voltages by the user
  - This is achieved by making the casing of the container with insulating material, or otherwise making sure that the live parts are surrounded by a double layer of insulating material
  - There are also set stringent limits as regards to the insulation resistance to any external connections
  - In Europe, the devices in this class must be marked "Class II" or by the double insulation symbol (two concentric squares)



Classes of electrical insulation

- **Class 3**
  - Protection against electric shock relies on the fact that there are no voltages exceeding the **Safety Extra Low Voltage** (**SELV**)
  - Such a device is supplied, either from a battery or from a transformer SELV
  - The voltage produced, less than 25V AC or 60V DC, is low enough not to be normally dangerous in case of contact with human body
  - The safety measures provided for classes I and II are not necessary
  - The Class III systems may not be equipped with grounding protection
  - It is interesting to notice that international standards IEC concerning electromedical equipment do not recognize the devices of class III, since the only limitation of the voltage is not considered sufficient to ensure patient safety

The differential switch

- The differential switch (or lifesaving® by a trade name widely used) is an electrotechnical device capable of interrupting a circuit in the event of a ground fault (dispersion)

- It does not offer any protection against overload or short circuit between phases or between phase and neutral, for which it is instead required a magnetothermal circuit breaker.

- Systems that integrate both devices are commercially widespread

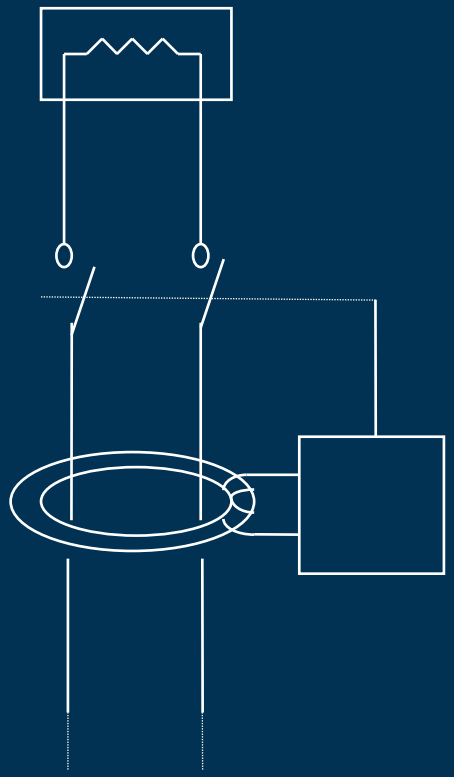
The differential switch

- If a device connected to an electrical system fails, you can have
  - A more or less effective connection between the power line and the metal frame
  - i.e. a direct contact
- The leakage current does not return completely through the differential switch upstream of the system, which reveals that the sum of the node currents is no longer zero and thus it intervenes.
- To avoid that human body achieves the bridge phase-to-ground and to ease the work of the differential switch is necessary that the equipment with metal casing are connected to an appropriate grounding system (indirect contact).

The differential switch

- In case of electrical installations with multiple derivations we can install more differential protection of each branch, so as to achieve a **selective protection**, which can isolate only the branch concerned to the fault, without powering down the other branches.
- If, in addition to the protections of the individual branches, a differential protection generally common to all the branches is also installed, this is usually used at a differential of the delayed type, to prevent that this one, intervening before those located downstream, may power down also undamaged circuits.

The differential switch



Protection from Atmospheric discharges

- Atmospheric discharges are characterized by very high power :
  - current = 100.000 A
  - voltage = 100 ÷ 600 kV
  - height = 15 ÷ 50 m
  - speed = 100 ÷ 300 km/s

- The cloud masses and the ground are the plates of a huge capacitor whose dielectric is represented by the atmosphere

- The effects of Atmospheric discharges are:
  - thermic effects
  - dynamic effects
    - Air ionization produces pressure waves, and then explosions
    - The voltage gradient produces magnetic fields, and then
      - secondary electric shock (side discharge)
      - electromagnetic induction in technological systems

Protection from Atmospheric discharges

- The plant for atmospheric discharges protection is made by:
  - Organs of uptake
    - vertical rod
    - ropes, cables
    - mesh
  - Down conductors
  - Ground electrodes
- The organs of uptake and their enveloped volumes must contain the volume to be protected.
- Natural organs of uptake can be considered the metal parts which already exist.
- The down conductors must be in such a number as to avoid side discharge (dropped no more than 20 m and in a number at least equal to 2).

Protection from Atmospheric discharges

- The protection system is constituted by:
  - Basic system for direct discharges
  - Integrative system for secondary discharges (side)
- The basic system design is subjected to a probabilistic approach:
  - The probability of discharge in the volume to be protected must be less than a threshold value determined by the designer

Protection from Atmospheric discharges

- The volume to be protected must be identified.

- The number of lightnings that can affect the volume to be protected in a year can be calculated (N_f)

$$N_f = N_t * A_{eq}$$

  - N_t, number of lightnings to the ground a year per square kilometer
  - $A_{eq} = f (a, b, H, h, c)$

Protection from Atmospheric discharges

- a, b: plan dimensions of the volume to be protected
- h: average height of the volume to be protected
- H: heignt difference between the portion where there is the volume to be protected and the average land 1 km away
- c:
  - = 0 in plain
  - = 0,1 by the sea
  - = 0,2 in the hills
  - = 0,3 in mountain

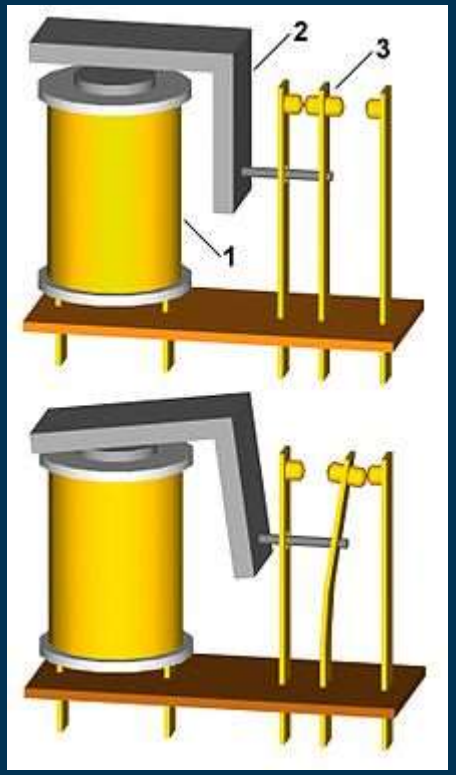
Static Electricity

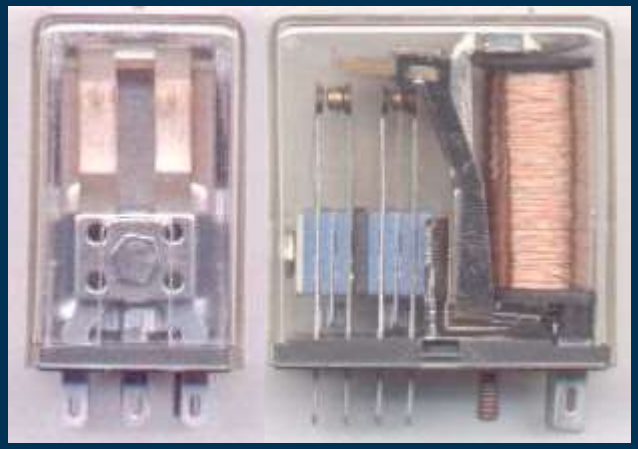
- Static electricity is produced by:
  - Mechanical actions between solids
  - Mechanical actions solids-liquids
  - Mechanical actions gas / vapor-solid
  - Thermal actions on change of status
- Static electricity is not dangerous for people
  - Very high potentials
  - Very weak currents

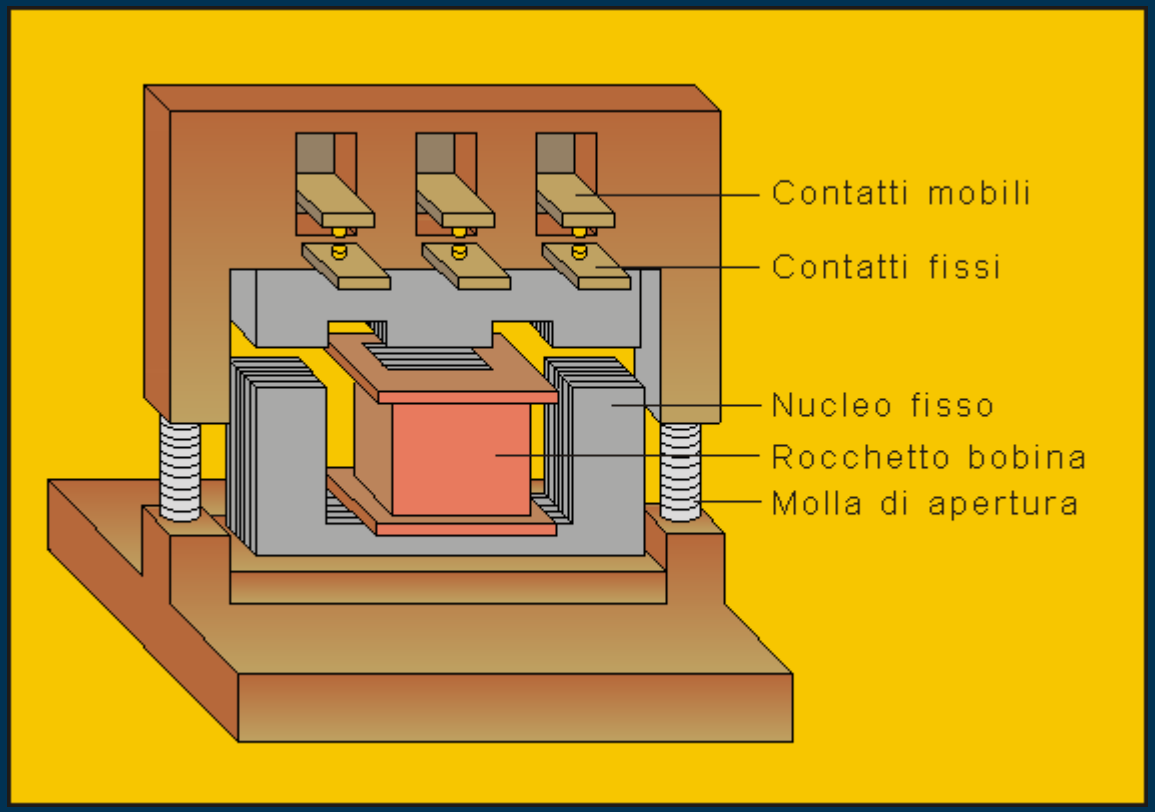
Static Electricity

- Protection measures:
  - Electrical grounding system
  - Natural Electrical grounding system
    - Ionization of the atmosphere
    - Humidification of the environment

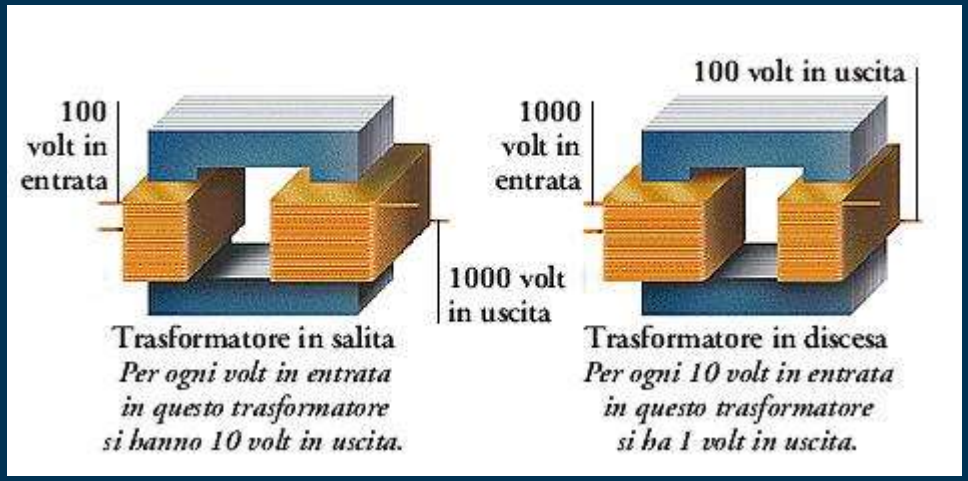
Electronic board

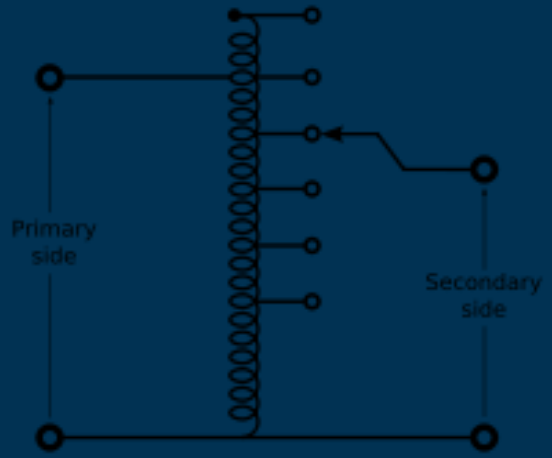

2
3
1

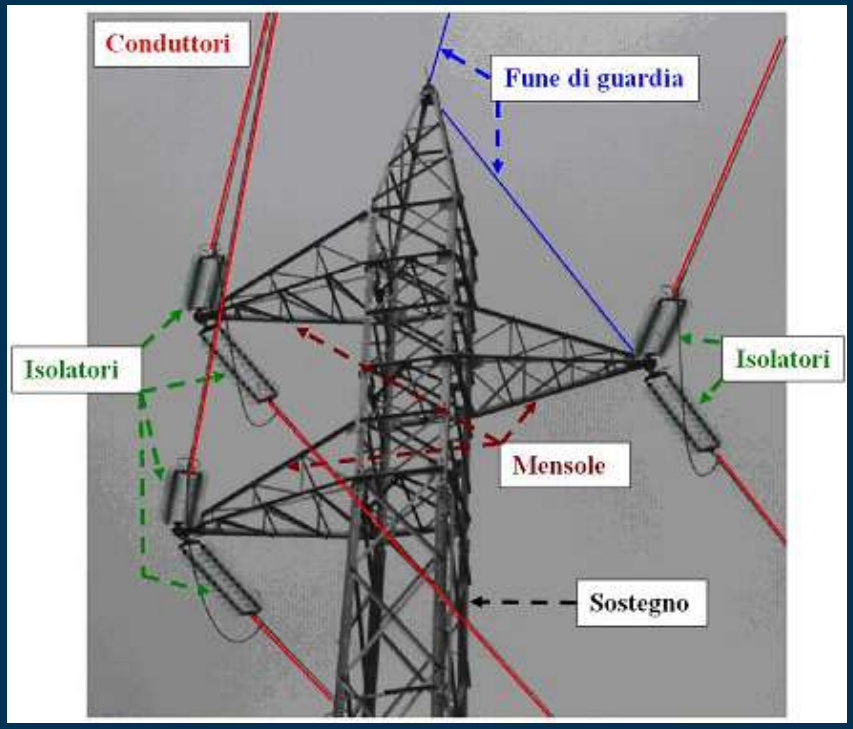


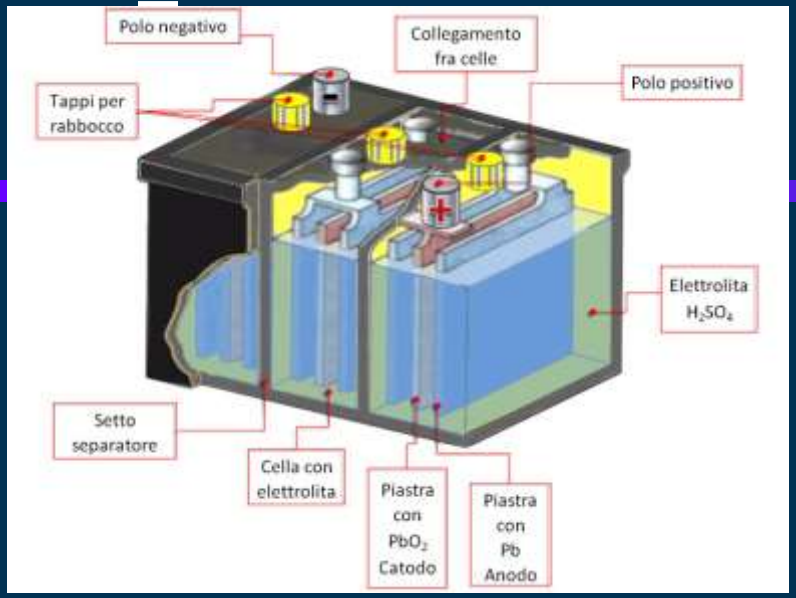

Contatti mobili
Contatti fissi
Nucleo fisso
Rocchetto bobina
Molla di apertura

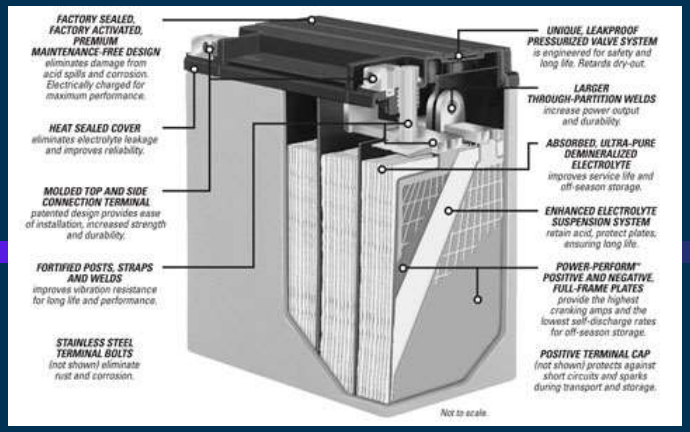
Disconnector


100
volt in
entrata
1000 volt
in uscita
Trasformatore in salita
Per ogni volt in entrata
in questo trasformatore
si hanno 10 volt in uscita.
100 volt in uscita
1000
volt in
entrata
Trasformatore in discesa
Per ogni 10 volt in entrata
in questo trasformatore
si ha 1 volt in uscita.

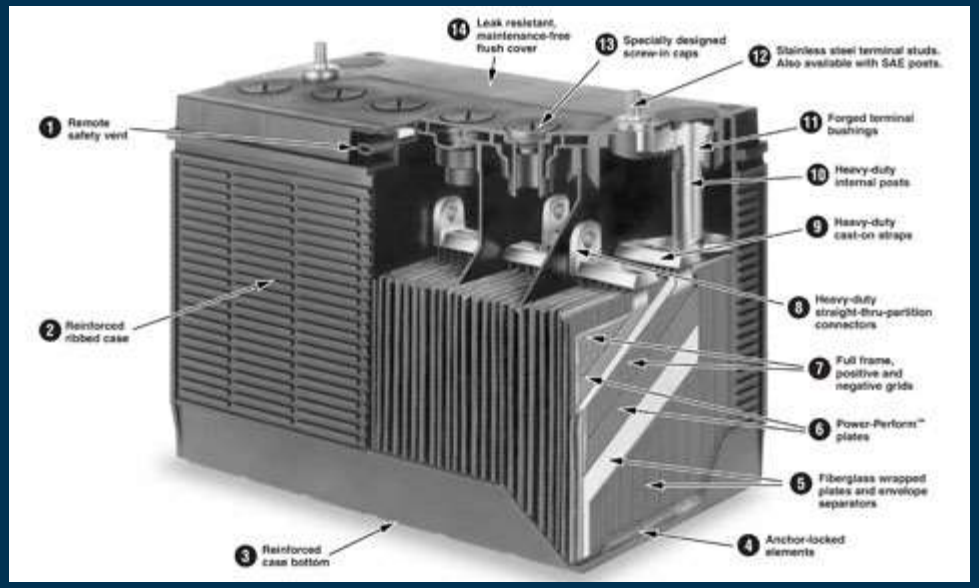

Primary
side
Secondary
side


Conduttori
Fune di guardia
Isolatori
Isolatori
Mensole
Sostegno


Polo negativo
Collegamento fra celle
Polo positivo
Tappi per rabbocco
Elettrolita H_2SO_4
Setto separatore
Cella con elettrolita
Piastra con PbO_2 Catodo
Piastra con Pb Anodo

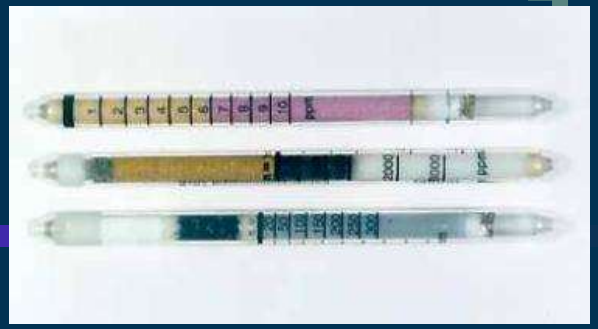

FACTORY SEALED, FACTORY ACTIVATED, PREMIUM MAINTENANCE-FREE DESIGN
eliminates damage from acid spills and corrosion. Electrically charged for maximum performance.
HEAT SEALED COVER
eliminates electrolyte leakage and improves reliability.
MOLDED TOP AND SIDE CONNECTION TERMINAL
patented design provides ease of installation, increased strength and durability.
FORTIFIED POSTS, STRAPS AND WELDS
improves vibration resistance for long life and performance.
STAINLESS STEEL TERMINAL BOLTS
(not shown) eliminate rust and corrosion.
UNIQUE, LEAKPROOF PRESSURIZED VALVE SYSTEM
is engineered for safety and long life. Retards dry-out.
LARGER THROUGH-PARTITION WELDS
increase power output and durability.
ABSORBED, ULTRA-PURE DEMINERALIZED ELECTROLYTE
improves service life and off-season storage.
ENHANCED ELECTROLYTE SUSPENSION SYSTEM
retain acid, protect plates, ensuring long life.
POWER-PERFORM™ POSITIVE AND NEGATIVE, FULL-FRAME PLATES
provide the highest cranking amps and the lowest self-discharge rates for off-season storage.
POSITIVE TERMINAL CAP
(not shown) protects against short circuits and sparks during transport and storage.
Not to scale.

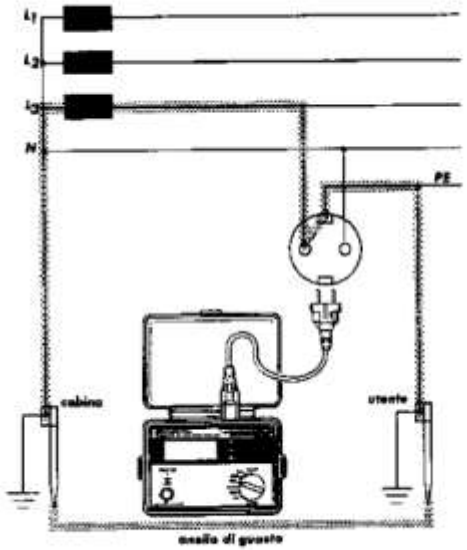

BIGBAT
MAINTENANCE FREE
SEALED LEAD - ACID
RECHARGEABLE BATTERY
12V. 7Ah.

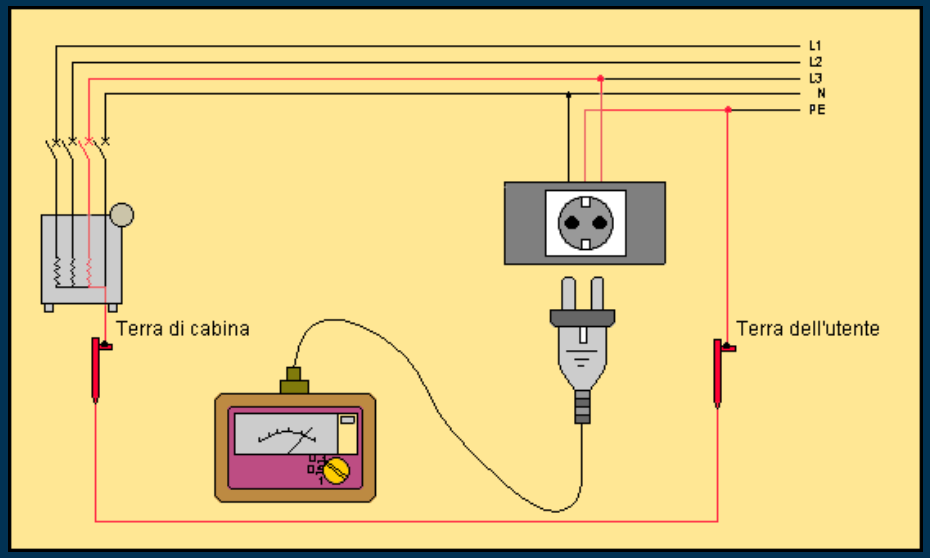

14 Leak resistant, maintenance-free flush cover
13 Specially designed screw-in caps
12 Stainless steel terminal studs. Also available with SAE posts.
1 Remote safety vent
11 Forged terminal bushings
10 Heavy-duty internal posts
9 Heavy-duty cast-on straps
8 Heavy-duty straight-thru-partition connectors
2 Reinforced ribbed case
7 Full frame, positive and negative grids
6 Power-Perform™ plates
5 Fiberglass wrapped plates and envelope separators
3 Reinforced case bottom
4 Anchor-locked elements

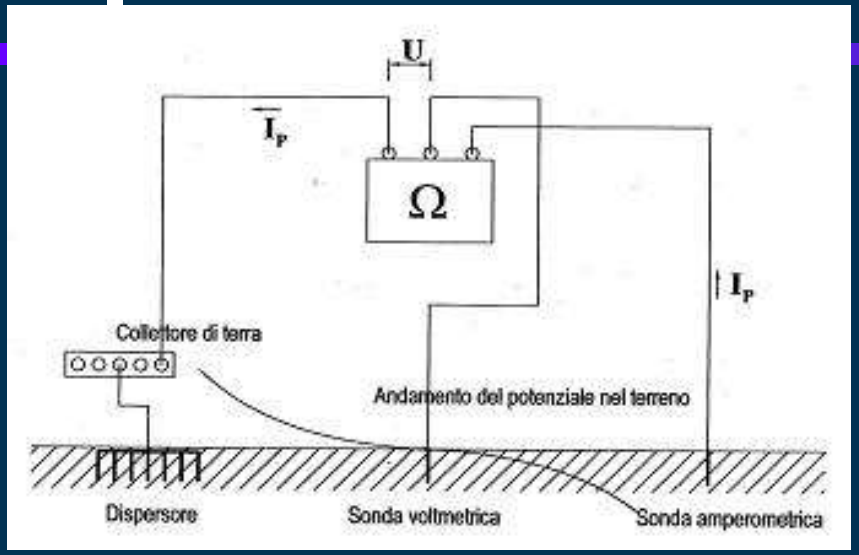

Delco
1000

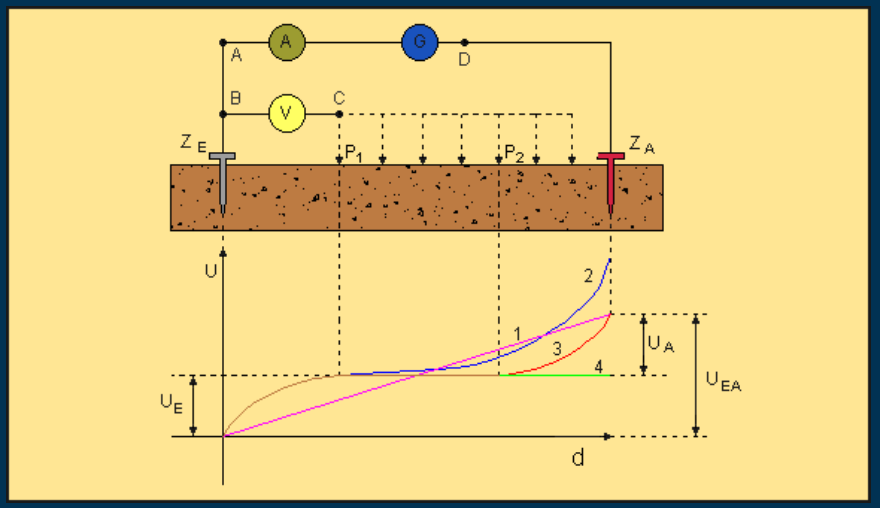
SAPIENZA
UNIVERSITÀ DI ROMA

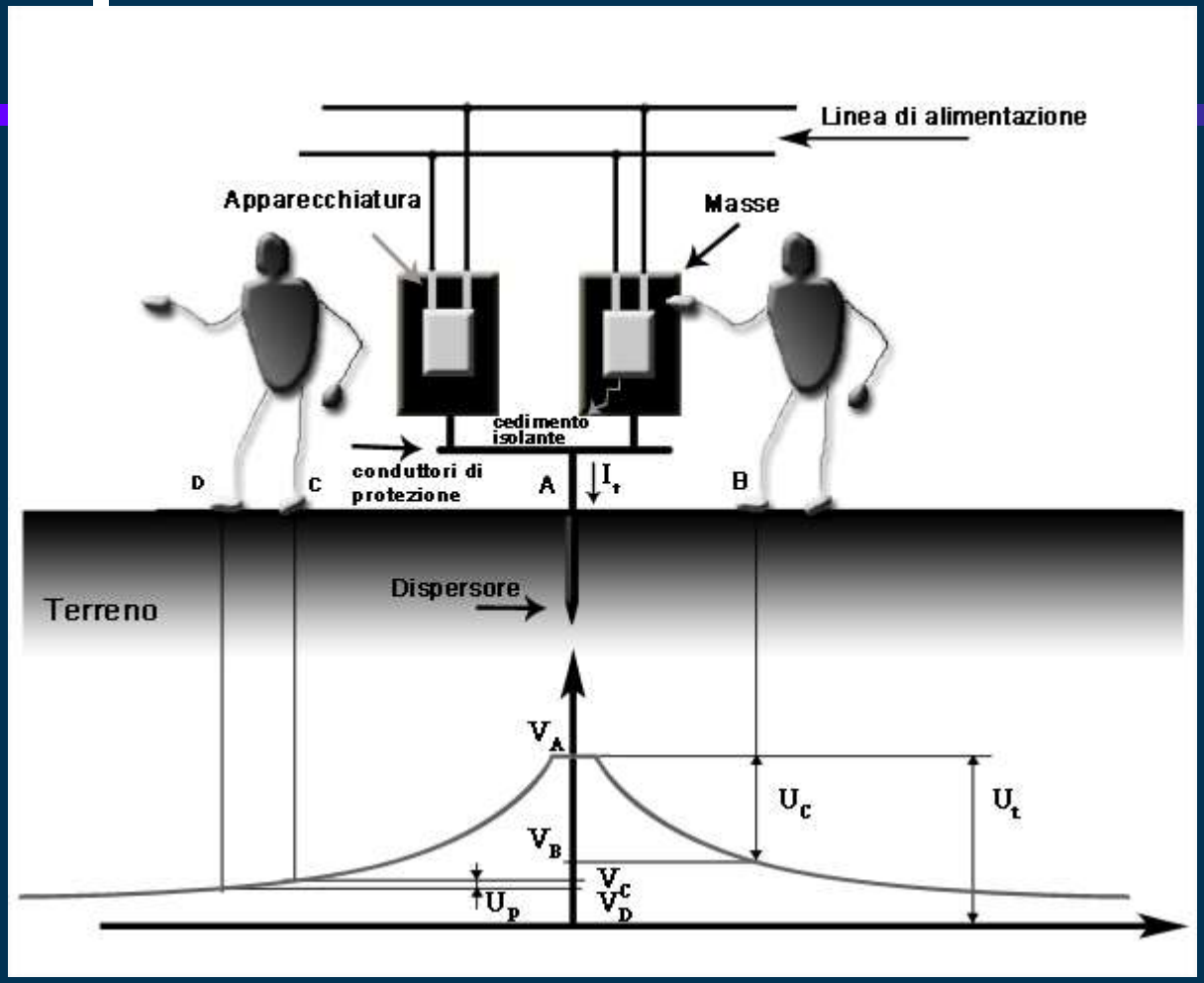


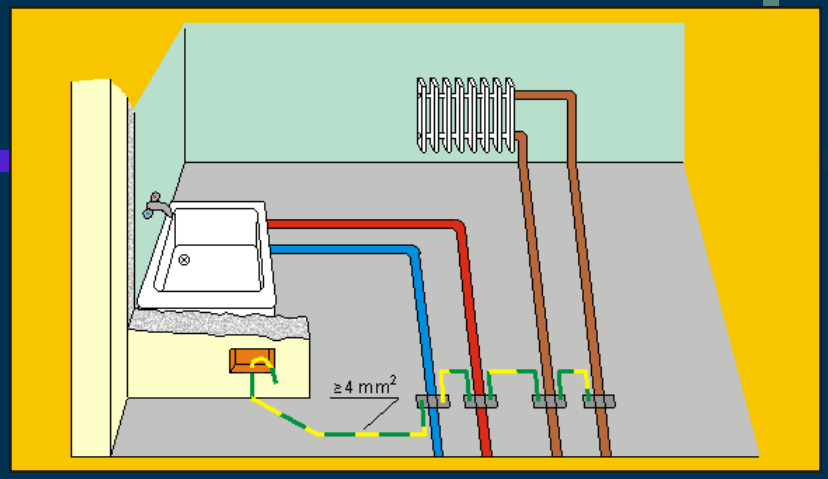

L1
L2
L3
N
PE
cabina
utente

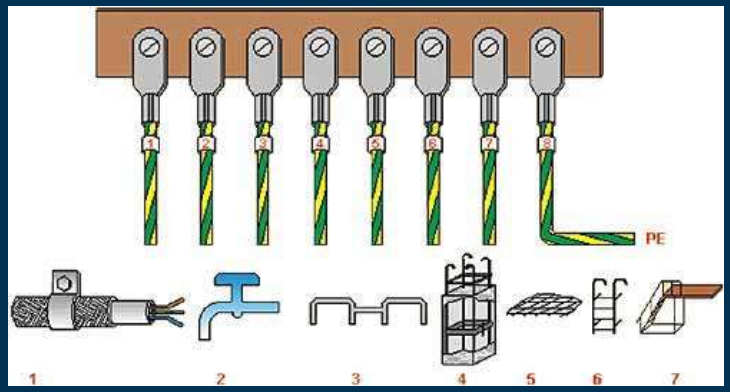

L1
L2
L3
N
PE
Terra di cabina
Terra dell'utente

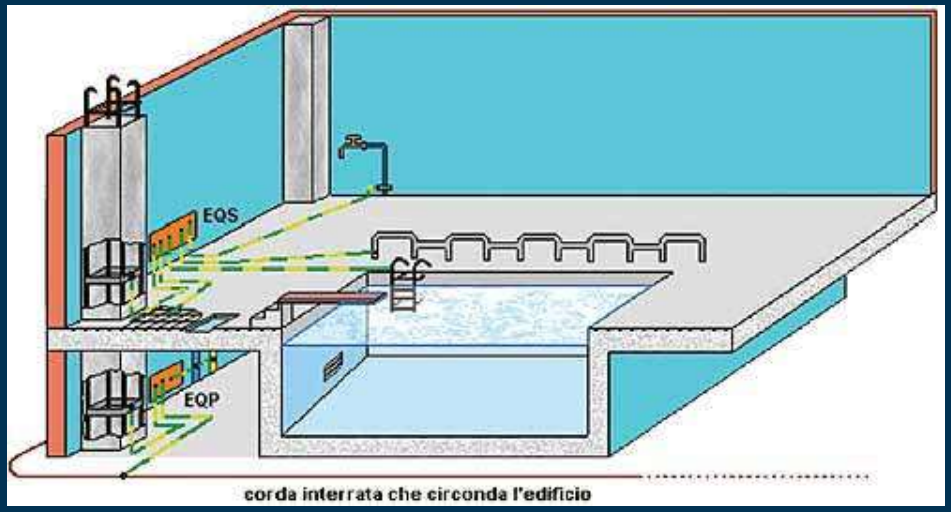

U
I_P
Ω
I_P
Collettore di terra
Andamento del potenziale nel terreno
Dispersore
Sonda voltmetrica
Sonda amperometrica

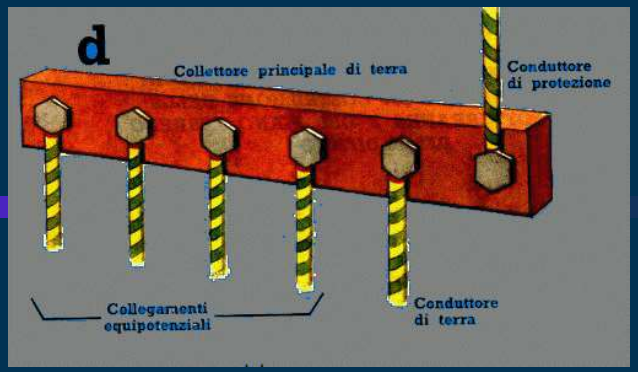

A
G
D
B
V
C
Z_E
P_1
P_2
Z_A
U
2
1
3
4
U_A
U_{EA}
U_E
d

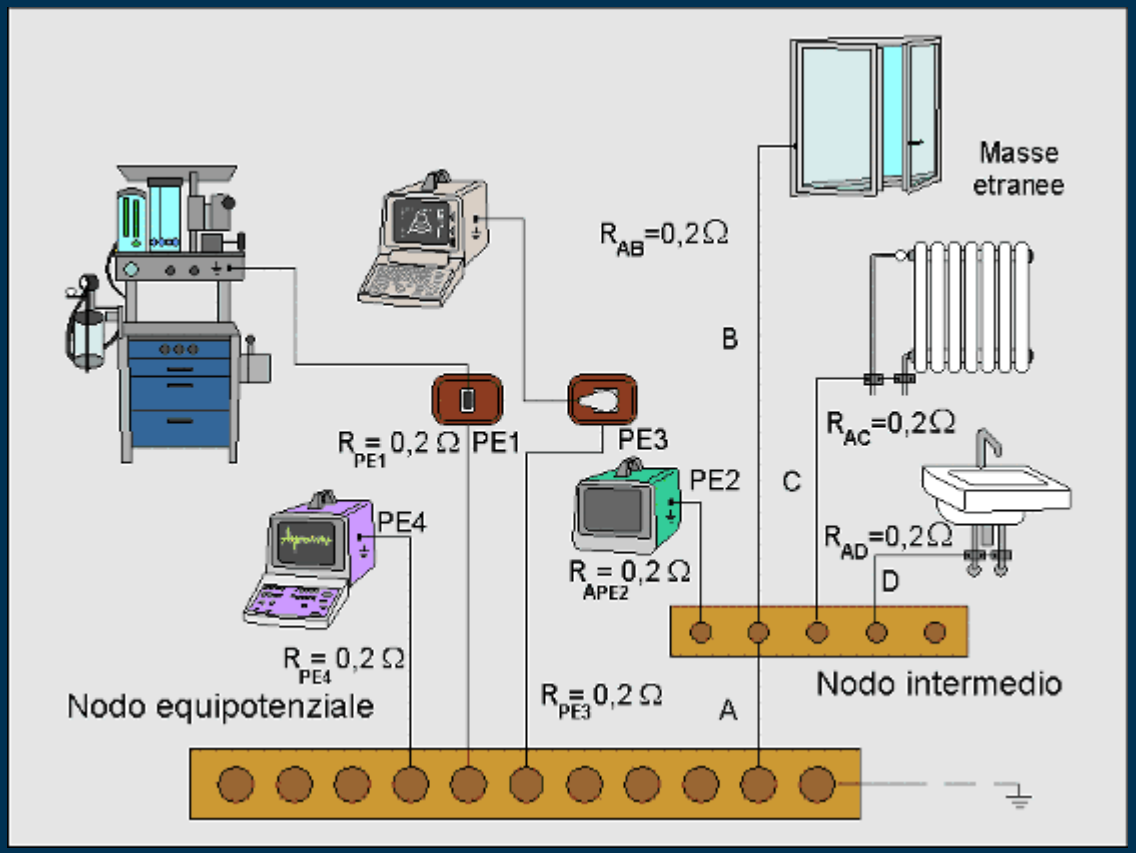

Linea di alimentazione
Apparecchiatura
Masse
cedimento isolante
conduttori di protezione
D
C
A
B
I_t
Terreno
Dispersore
V_A
V_B
V_C
V_D
U_p
U_c
U_t


≥4 mm²


PE
1
2
3
4
5
6
7


EQS
EQP
corda interrata che circonda l'edificio


d
Collettore principale di terra
Conduttore di protezione
Collegamenti equipotenziali
Conduttore di terra


Masse estranee
R_{AB}=0,2Ω
B
R_{AC}=0,2Ω
C
R_{AD}=0,2Ω
D
R_{PE1} = 0,2 Ω PE1
PE3
PE2
R_{APE2} = 0,2 Ω
PE4
R_{PE4} = 0,2 Ω
R_{PE3} = 0,2 Ω
A
Nodo equipotenziale
Nodo intermedio

Blind