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KINGDOM OF BELGIUM

FEDERAL PUBLIC SERVICE FOR THE ECONOMY, S.M.Es, THE MIDDLE CLASSES AND ENERGY AND FEDERAL PUBLIC SERVICE FOR EMPLOYMENT, WORK AND SOCIAL DIALOGUE

Royal Decree amending Articles 98 and 99 of the General Regulations on Electrical Installations

ALBERT II, King of the Belgians,

To all those present and to come, Greetings.

Having regard to the Law of 10 March 1925 on energy distribution, in particular Article 21(1);

Having regard to the Law of 4 August 1996 on the well-being of workers while performing their work, in particular Article 4(1);

Having regard to the Royal Decree of 10 March 1981 rendering obligatory the observance of the General Regulations on Electrical Installations for domestic installations and certain transport and energy distribution lines and the Royal Decree of 2 September 1981 amending the General Regulations on Electrical Installations and rendering their observance obligatory in establishments classed as dangerous, insanitary or in which noisy or noxious trades are carried out as well as those referred to in Article 28 of the General Regulations on Employment Protection, amended by the Royal Decrees of 29 May 1985, 7 April 1986 and 30 March 1993;

Having regard to the General Regulations on Electrical Installations annexed to the Royal Decree of 10 March 1981, in particular Articles 98 and 99;

Having regard to the opinion of the Standing Committee on Electricity of 13 February 2003;

Having regard to the opinion of the Higher Council for prevention and protection in the workplace of 27 June 2003;

Having regard to the fulfilment of the formalities laid down by Directive 98/34/EC of the European Parliament and of the Council laying down a procedure for the provision of information in the field of technical standards and regulations;

Having regard to the laws on the Council of State, consolidated on 12 January 1973, in particular Article 3(1), replaced by the Law of 4 July 1989 and amended by the Law of 4 August 1996;

Having regard to urgency;

Whereas the provisions laid down in this Decree constitute amendments and additions to legislation as far as the prevention of electric shocks by indirect contact at high voltage are concerned, they need to be rendered obligatory without delay in order to guarantee safety;

On the proposal of Our Minister for Work, Our Minister for Energy and Our Secretary of State for the Organisation of Work and of Well-Being at Work,

We have decreed and hereby decree:

Article 1.- For the purposes of this Decree, "Regulations" shall be understood to mean the General Regulations on Electrical Installations, covered by the Royal Decree of 10 March 1981 rendering obligatory the observance of the General Regulations on Electrical Installations for domestic installations and certain transport and energy distribution lines and by the Royal Decree of 2 September 1981 amending the General Regulations on Electrical Installations and rendering their observance obligatory in establishments classed as dangerous, insanitary or in which noisy or noxious trades are carried out as well as those referred to in Article 28 of the General Regulations on Employment Protection, amended by the Royal Decrees of 29 May 1985, 7 April 1986 and 30 March 1993.

Article 2.- Articles 98 and 99 of the Regulations are replaced by the following articles, respectively:

"Article 98.- PREVENTION OF ELECTRIC SHOCKS BY INDIRECT CONTACT AT HIGH VOLTAGE

01.- Definitions

01.1.- Terms relating to protection against electric shocks at high voltage

Contact voltage in relation to earth "U_T": part of the earth potential rise U_E which can be applied to a person, the current passing through the human body between the hands and feet (horizontal distance of 1 m between the feet and the frame earth touched).

Permissible contact voltage "U_{Tp}": permissible limit value of the contact voltage as a function of the fault current time.

These limits are defined by the safety curve in figure 98.2 for electricity transmission or distribution systems or for systems only accessible to people of category BA4 or BA5.

They are defined by the safety curves in Article 31-03 in all other cases.

Step voltage "U_S": part of the earth potential rise U_E which can be applied to a person having a step length of 1 m, when the current passes through the human body from foot to foot.

Dangerous potential differences: dangerous potential differences are those which can cause contact voltages exceeding the permissible value U_{Tp}.

01.2.- Terms relating to high voltage earthing

Local earthing system: system of limited extent, containing one or more interconnected earth connections, the corresponding earth conductors and the protection conductors.

Global earthing: earthing obtained by means of a set of local earthing systems connected to each other by a galvanic connection, possibly including the earthing effect cables.

Earthing effect cable: bare conductor or metal part of the sheath of a cable which, through its contact with the ground, acts as an earth connection.

Earth potential rise "U_E": voltage present between an earthing system and the (reference) neutral earth following an earth fault current.

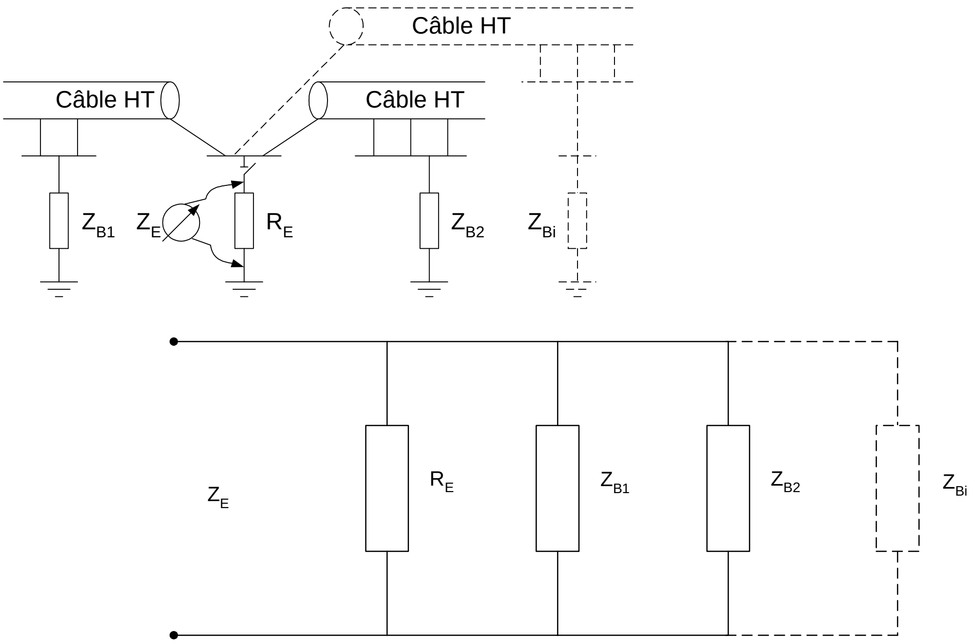
Earth surface potential "$U\varphi$": voltage between a point in the ground and the (reference) neutral earth resulting from a fault current.

Neutral area or (reference) neutral earth: part of the earth situated outside the area of influence of an earth connection and in which, between any two points, no perceptible potential difference can appear following an earth fault current.

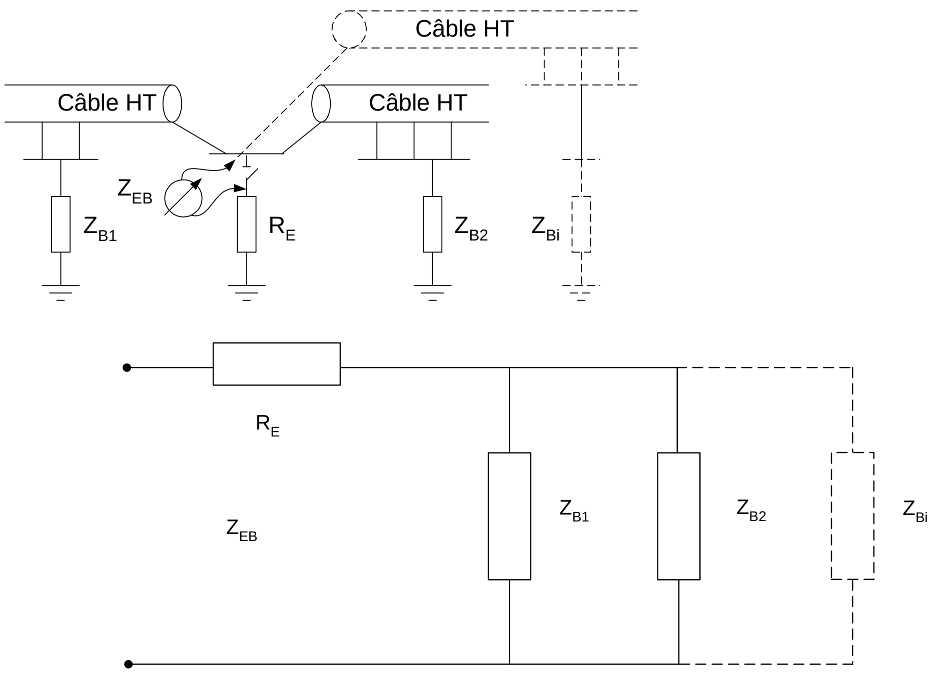
Dispersion area (of an earth connection): area surrounding the earth connection and situated outside the neutral area.

Earth resistance "$\boldsymbol{R_E}$" (dispersion resistance of an earth connection): resistance between the earth connection and the reference earth.

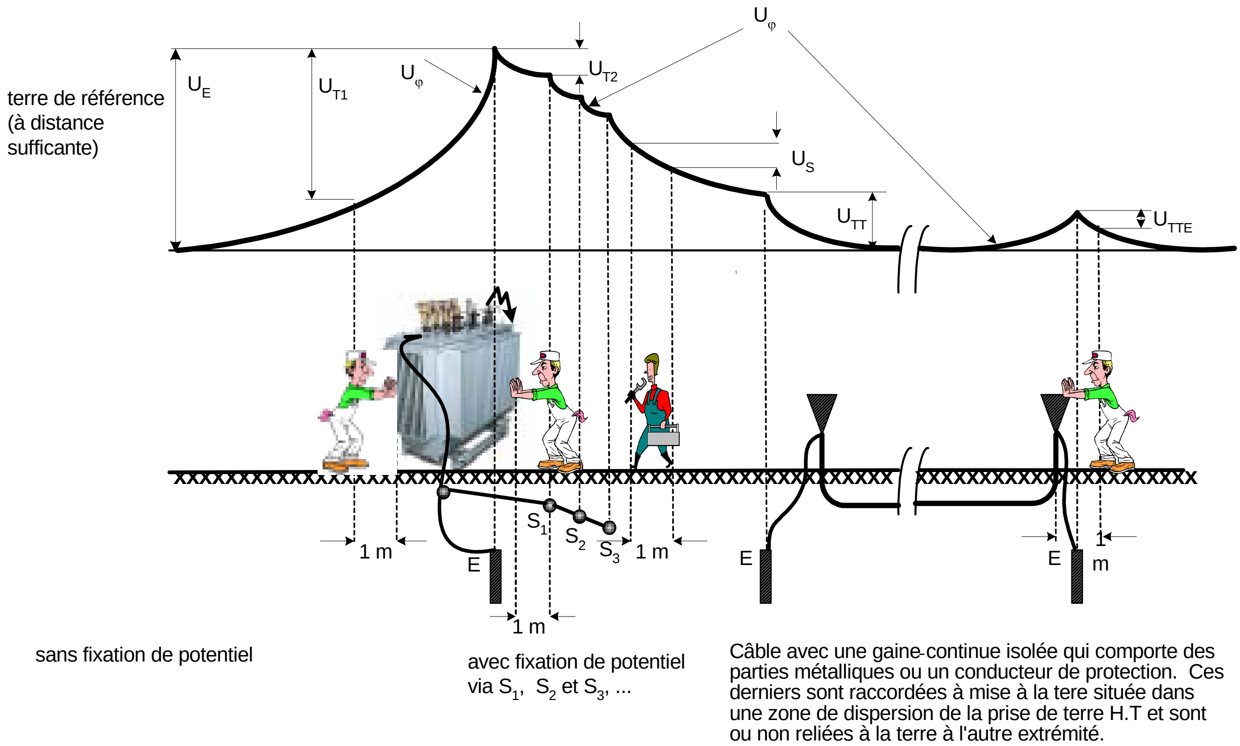
Earth impedance "$\boldsymbol{Z_E}$": impedance between the earthing system, possibly connected to other earthing systems, and the reference earth.



Loop impedance of an earth connection "Z_{EB}": impedance of the circuit made up of the resistance "R_E" of the earth connection in series with the impedance "Z_B" which constitute all the other earth return paths.



Câble HT = HV cable



reference earth
(at sufficient distance)

without potential attachment

with potential attachment
via S1, S2 and S3

Cable with a continuous insulated sheath having metal parts or a protection conductor. These are connected to an earth located in a dispersion area of the H.V earth connection and are or are not earthed at the other end.

Transferred contact voltage “U_{TT}”: value of the contact voltage transferred by the metal parts of the sheath of a cable or by a protection conductor, if the latter are not earthed at the far end.

Transferred contact voltage “U_{TTE}”: value of the contact voltage transferred by the metal parts of the sheath of a cable or by a protection conductor, if the latter are also earthed at the far end.

E	earth connections.
S_1, S_2, S_3	additional earth connections allowing the potential differences to be limited (for example, earth connections in loop connected to the earth connection E)
U_E	earth potential rise
U_S	step voltage
U_T	contact voltage to earth
U_φ	earth surface potential

Example showing the surface potential variation and the voltages when currents are flowing in the earth connections

02.- General principles

The protection against electric shocks by indirect contact must, in high voltage systems, be provided:

1) by limiting the probability of the appearance of a fault capable of causing dangerous contact voltages.
   In order to do this, it is necessary to ensure that:
   - the electrical equipment has been designed, constructed, chosen and installed so that it can be used in complete safety;
   - the electrical equipment is used in the intended manner;
   - the electrical equipment is properly maintained.

2) by connecting all the frame earths of the high voltage electrical system to an earth connection;

3) by providing any additional protection measures, as the case may be:
   - by the use of passive protection measures, and/or
   - by the use of active protection measures.

   If different protection measures are used simultaneously, they must not cancel each other out or influence each other negatively.

03.- Earthing system

03.1.- Basic requirements

The characteristics of the earthing system are determined in such a way that the following objectives are achieved:

1) to offer resistance to the foreseeable mechanical and chemical influences;
2) to offer resistance to the heating effect of the maximum foreseeable fault current;
3) to prevent the deterioration of goods and equipment;
4) to guarantee personal safety, having regard to the voltage which can appear when the maximum foreseeable fault current is flowing through the earthing system, taking account of the passive and active protection measures.

03.1.1.- Resistance to mechanical and chemical influences

The component parts of an earthing system are manufactured with materials offering sufficient resistance to corrosion phenomena (chemical or biological corrosion, oxidisation, electrolytic corrosion, etc.).
Moreover, they must offer the necessary resistance to the mechanical stresses to which they may be subject both when they are being installed and under their normal operating conditions.

03.1.2.- Resistance to the heating effect of fault currents

The cross-sections to be used for the conductors in the earthing system depend on the maximum foreseeable fault current.
When the fault current is distributed between a number of earthing electrodes, the dimensions of each earthing electrode can be determined taking account of this current distribution.
The calculation of the temperature resistance of the earthing system must take the fault current value and time into account. For this purpose, a distinction is made between a time of 5 seconds or less (adiabatic heating) and a time of over 5 seconds (non-adiabatic heating).

For a time of 5 seconds or less, the minimum section is calculated by the formula:

$$S \geq \frac{I}{k}\sqrt{\frac{t}{\ln\frac{\Theta_f + \beta}{\Theta_i + \beta}}}$$

where:

S : section in mm²

I : r.m.s. value of the phase/earth fault current in A

t : fault current time in seconds

k : constant at 20°Celsius depending on the nature of the material.
The values of this constant corresponding to most of the materials used are given in table 98.2.

β : inverse value of the temperature coefficient (α) of the resistivity of the material as a function of the temperature of the material in degrees Celsius as indicated in table 98.2.

Θ_i : initial temperature in °C under normal ambient conditions.

Θ_f : maximum permissible temperature in °C after the passage of the fault current indicated in table 98.3.

For a time of over 5 seconds, the minimum section is determined with the aid of one of the graphs represented in figures 98.1a and 98.1b. Straight lines 1, 2 and 4 refer to a final temperature of 300°C. Straight line 3 refers to a final temperature of 150°C. When the final temperature to be respected is not equal to 300°C, it is necessary to apply the correction factor defined in table 98.4 to the value read on the graph in figures 98.1a and 98.1b.
The values in figures 98.1a and 98.1b and in table 98.4 are not valid for conductors subject to mechanical stress; for the latter, it is necessary to define these values by calculation.

03.2.- Construction of the earth connections

03.2.1.- General

An earth connection can be provided by burying one or more horizontal, vertical or oblique earth electrodes in the ground.
Horizontally laid earth electrodes are buried at a minimum depth of 0.6 m below ground level.
As far as vertical or oblique earth electrodes are concerned, only the useful part is taken into account. They are placed in relation to each other at a distance of not less than their length.
If different materials capable of forming galvanic couples must be connected to each other, these materials must be protected at their actual point(s) of connection, by durable means, from contact with electrolytes which may be found in their environment.
The earth connection must not be in contact with any metal foreign bodies buried in the ground.

03.2.2.- Characteristics

a. Choice of materials and minimum dimensions

Except in the special cases indicated in b6.1, the earth electrodes will consist of materials mentioned table 98.1.
Their minimum dimensions, depending on the material and the type of electrode, will comply with the values shown in the said table.
b. Execution

The earth connection will be provided by one of the methods or combinations of methods described below:
b.1) Either an earth loop at least 8 m long, in contact with the ground and laid at the bottom of

a trench. If the high voltage system is in a building, the earth loop will preferably be placed under the outside walls of the building.
Both ends of the loop will be connected to an earth disconnection device installed in a safely accessible place;

b.2) At least four earth stakes with a useful length of at least 1.5 m, driven vertically or obliquely (max. 45° to the vertical) towards the outside of the construction and regularly distributed around it. These stakes will be connected to each other by an earth loop of which both ends will be connected to an earth disconnection device installed in a safely accessible place;

b.3) Or a deep earth electrode with a buried length of at least 6 m. This earth electrode will be connected by an earth conductor to an earth disconnection device installed in a safely accessible place;

b.4) Or a horizontal earth electrode with a useful length of at least 8 m. This earth electrode will be connected by an earth conductor to an earth disconnection device installed in a safely accessible place;

b.5) Or a mesh system with an area of more than 200 m^2 and consisting of at least 9 meshes. These meshes, with sides measuring not more than 10 m, will preferably be situated underneath the area occupied by the high voltage system.

Earth disconnection devices are not required in this case, but measurement of the initial earth resistance value (as specified in c.2) must be possible before the system enters service.

b.6) Special case

1. The earth connection of the electrical installations of railway lines, situated along the tracks and with a rated voltage between live conductors not exceeding 1100 volts on alternating current, can consist of a set of steel posts electrically interconnected and sunk into a concrete foundation directly in contact with the earth, on condition that:

   - the contact area between post and concrete, situated at least 30 cm below ground level, is not less than 5000 cm^2 per post;
   - the number of posts is at least 30;
   - the minimum distance between 2 posts is 10 m.

2. The earth connection of the electrical installations covered in Article 88 of this Regulation can consist of a set of reinforced concrete piles directly in contact with the ground, on condition that:

   - the number of piles is at least 4;
   - the useful length is at least 10 m;
   - the distance between each of the 4 piles is at least 6 m;
   - the diameter of the piles is at least 35 cm;
   - the reinforcements of the different piles are electrically interconnected.

   Earth disconnection devices are not required in this case, but measurement of the initial earth resistance value (as specified in c.2) must be possible before the concrete slab is cast.

c. Earth resistance

c.1) Maximum value

Except for the cases mentioned below, the earth resistance value (R_E) of the earth connection will not exceed 10 Ω.

If the system is connected to a global earth this limit is 15 Ω.
If the soil resistivity is greater than 150 Ωm, these limits are defined by the following formula:

$$15\,\frac{\rho_E\ (\Omega m)}{150\ \ (\Omega m)}\ \Omega$$

where ρ_E is the local soil resistivity at a depth of 1 m.
Special case:
In case b.6.1 in paragraph 3.2.2 these values are not applicable; nevertheless, the earth impedance Z_E must be less than 1 Ω.

c.2) Initial value

The earth resistance value (R_E) is measured before commissioning. It is known as the "initial earth resistance value".

d. Special cases

d.1) The earth connection intended for the earthing of the inaccessible metal parts installed on non-metallic supports of high voltage lines and containing no voltage transformer equipment or isolating equipment, will be provided according to b.2). The requirements relating to the maximum earth resistance value, as defined in c1), are not applicable in this case.

d.2) The provision of an earth isolating switch is not required for the earths of the supports of HV lines on which there is no voltage transformer equipment or isolating equipment installed.

03.2.3.- Global earth

a. General principle

Global earths make it possible to limit the potential rises of the local earths by better dispersion of the fault current into the ground.

Global earthing is obtained by:
- either a sufficient length of cables with earthing effect;
- or a sufficient number of high voltage earthing systems connected to each other by protection conductors;
- or a combination of the above two possibilities.

b. Conditions to be met by a global earth

A global earth must meet one of conditions b.1) or b.2) or b.3) below:

b.1) - the HV local earthing systems are connected to the earthing effect cables;
- the sum of the lengths of these cables is at least 1 km, with the common stretches only counted once;

b.2) at least 20 local HV earthing systems are interconnected;

b.3) a combination of conditions b.1) and b.2), on the understanding that a local earthing system is equivalent to 50 m of cable with earthing effect.
The cables with earthing effect do not necessarily have to be a continuous assembly but can be connected to each other by protection conductors contained in other types of cables or overhead lines. The average length (L) of the protection conductors used to interconnect local earthing systems and/or lengths of cables with earthing effect must comply with the following formula:

$$L \leq 500\frac{S_m}{16mm^2}\quad (m)$$

Sm = average of the sections, weighted according to the length of the protection conductors of the connecting cables and expressed in mm² of equivalent copper section.

If a link consists of various cables in parallel, this should be taken into account when calculating Sm.
The electrical continuity of the metal parts of the sheaths and of the protection conductors must be ensured on the connections, on the isolating switches, on the transformers and on the supports.

c. Use of the global earthing of the public distribution system
At the request of the operator of a high voltage installation which is not part of the high voltage public distribution system, the operator of the high voltage distribution system of this network will confirm in writing whether or not the installation concerned will be included in a system benefiting from a global earth.

03.3.- Checking of the earthing systems
03.3.1.- General
The checking of the earthing systems is intended to inspect:
- the integrity of the local earthing system;
- the continuity of the earths.

The checking is done by measuring one or more of the following parameters:
- the earth resistance R_E
- the loop impedance Z_{EB}
- the earth impedance Z_E

Remarks:

1. The loop impedance Z_{EB} of an earth connection constitutes an estimate of the earth resistance R_E insofar as the impedance of all the other earth connections of the system or network, seen from the point of measurement, shows a considerably lower value.
   The measurement of the loop impedance is also a local continuity test of the interconnection of the earths.
2. The earth impedance Z_E of the system is the main parameter ensuring active protection against electric shocks. It can be measured by the same method as the one used to determine the initial value of R_E.
3. All the impedance values are expressed in modular form.

03.3.2.- Conformity check before commissioning

The checking is carried out by measuring the earth resistance R_E .
The measurement of R_E is not applicable in the case of non-metallic supports of high voltage lines having no voltage transformer or isolating switch equipment.

03.3.3.- Periodic checking
The earth impedance Z_E is measured during the first periodic check. The result of the measurement is satisfactory if Z_E is less than the maximum permitted value of R_E.

If the value of Z_E is less than 1 Ω, and provided there is a connection with other earthing systems, it is useful, during subsequent inspection visits, to measure the loop impedance Z_{EB}. This measurement can be made with or without disconnection from the earth conductor.

The value of Z_{EB} must be higher than Z_E and lower than the larger of the following two limits:
- initial value of $R_E + 1\ \Omega$

or
- initial value of $R_E + 50\ \%$.

If one of these limits is exceeded, R_E must be measured again and the earthing continuity must be checked by measuring Z_{EB}.
If the value of Z_E is equal to or greater than 1 Ω , it is necessary to measure R_E.

The procedure is repeated during subsequent checking visits.

The measurement of R_E and of Z_{EB} is not applicable in the case of overhead line supports. Only Z_E is measured during the periodic checks.

The measurement of R_E, Z_{EB}, Z_E is not applicable in the case of non-metallic supports of high voltage lines having no voltage transformer or isolating switch equipment.

04.- Passive protection against electric shocks caused by indirect contact at high voltage

04.1. - General

The passive protection measures are measures which are not based on the interruption of the supply and which are limited to insulated machines and switchgear or to local electrical equipment, in order to make simultaneous access impossible to parts between which, because of a fault in the high voltage system, the contact voltage could reach a dangerous value.

This protection consists of taking the following measures, either separately or in combination:

1) the covering of the frame earths of the low and very low voltage installations and of the conductive foreign elements;
2) the insulation of the frame earths of the low and very low voltage installations and of the conductive foreign elements;
3) the separation of the frame earths of the low and very low voltage installations and of the conductive foreign elements;
4) the screening protection of the frame earths of the low and very low voltage installations and of the conductive foreign elements;
5) the provision of an equipotential earthing area.

Notwithstanding the protection measures mentioned above, the frame earths of the high voltage equipment must be locally earthed.

04.2.- Covering of the frame earths of the low and very low voltage installations and of the conductive foreign elements in relation to the high voltage frame earths.

The covering of the frame earths and of the conductive foreign elements is considered to be effective if, in the volume of accessibility to the touch:

1) the covering of the frame earths and conductive foreign elements is done in such a way that the dielectric strength level corresponds to the foreseeable contact voltage which will not exceed $U_E/2$;
2) the covering is suitably fixed and will withstand the forces to which it can be exposed.

04.3.- Insulation of the frame earths of the low and very low voltage installations and of the conductive foreign elements in relation to the high voltage frame earths or vice-versa

The insulation of the frame earths and of the conductive foreign elements is considered to be effective if, in the volume of accessibility to the touch:

1) the insulation of the frame earths, and of the conductive foreign elements, or the insulated positioning of the conductive foreign elements, is done in such a way that the level of insulation corresponds to the foreseeable contact voltage which will not exceed $U_E/2$;

2) the means of insulation used are suitably fixed and will withstand the forces to which they can be exposed.

04.4.- Separation of the frame earths of the low and very low voltage installations and of the conductive foreign elements in relation to the high voltage frame earths

The separation of the frame earths of the low and very low voltage installations and of the conductive foreign elements in relation to the high voltage frame earths is considered to be effective when it is impossible for anyone to be able, under normal operating circumstances, to have simultaneous access to a high voltage frame earth on the one hand, and to a frame earth of an installation at another voltage and/or to a conductive foreign element on the other hand.

This separation is considered to be sufficient if the horizontal and vertical distance is not less than 2.5 m.

In electrical service areas, the horizontal distance can be reduced to 1.25 m.

0.45. - Protection by obstacles of the frame earths of low and very low voltage installations and of the conductive foreign elements in relation to the high voltage frame earths

The obstacles used as protective screens for the frame earths of low and very low voltage installations and of conductive foreign elements in relation to the high voltage frame earths are considered to be effective if, in the volume of accessibility to the touch:

1) the distance between the high voltage frame earths on the one hand and the frame earths of the low and very low voltage installations and the conductive foreign elements on the other hand, is not less than 2.5 m

and

2) the top edge of the obstacle is at a height of not less than 1.25 m.

In electrical service areas, the horizontal distance can be reduced to 1.25 m.

The obstacles must consist of securely fixed non-conductive materials and must withstand the forces to which they can be exposed.

04.6.- Provision of an equipotential earthing area

All the simultaneously accessible frame earths and conductive foreign elements must be galvanically connected to a local earthing system, in such a way that in case of a fault in the high voltage the appearance of differences in potential greater than those defined by the safety curve shown in figure 98.2 is prevented. Conductive elements which cannot cause dangerous differences in potential should not be earthed (doors or metal ventilation gratings incorporated in the brickwork, etc.)

The following measures should be taken for this purpose:

1) provision of an equipotential earthing area, by means of a mesh system placed underneath the installation.

   This mesh system, whose dimensions will be not less than those of the installation, will consist:

   - either of the reinforcement of the foundation slab, on condition that the reinforcement wire-meshes are connected to the neighbouring wire-meshes in at least two places and that the whole assembly is linked to the local earthing system by at least two connections, possibly disconnectable;

- or of a metal wire-mesh with mesh sides of not more than 10 m.

2) control of the potential gradient on the edge of the area. This can be done in particular by burying one or more earth loops around the area. These earth loops can be complemented by earth stakes sunk obliquely into the ground. If the control of the potential gradient cannot be guaranteed, additional passive measures should be taken, such as for example by covering the ground by a non-conductive material or by the installation of insulated fences.

05.- Active protection against electric shocks caused by indirect contact at high voltage with automatic interruption of the power supply

05.1.- General

This protection measure is intended to limit in time, by disconnection of the power supply, the contact voltages which can be dangerous in case of a fault in the high voltage system.

The application of this measure requires:

1) the local earthing of the frame earths of the high voltage equipment

2) the use of circuit breaker devices having an operating characteristic such that there are no dangerous potential differences, taking account of the value of the fault loop impedances and of the characteristics of the system.

This protection measure is considered to be fulfilled if one of the following conditions is satisfied:

a) for electricity transmission and distribution systems and for systems accessible only to category BA4 or BA5 persons, the HV frame earths benefit from a global earth and the fault time does not exceed 5 seconds.

   or

b) the rise in the earth potential U_E (calculated or measured) is limited to the admissible contact voltage U_{Tp} .

$$U_E \leq U_{Tp}$$

   When the high voltage frame earths are in the immediate vicinity (horizontal distance < 5 m) of their earth connection, the rise in the earth potential can reach a maximum of twice the admissible contact voltage.

To determine the rise in the earth potential and the contact voltage of a system, all of the earth connections which are part of the earthing system can be taken into account.

The voltage U_E can be approximately worked out by the formula $U_E < I_f.Z_E$

in which:

I_f: phase-earth fault current (A) foreseeable at the place of the installation
Z_E: earth impedance (Ω)

For the determination of the admissible contact voltage, additional resistances (footwear or floor surface having a high resistance to the passage of electric current) can be taken into account.

In this case the value of the admissible contact voltage is defined by the following formula:

$$U_{STP} = U_{Tp} + (R_{a1} + R_{a2}) \times I_B$$

with $I_B = \frac{U_{TP}}{Z_B}$

where:

U_{STp}: admissible contact voltage (V) between the hands and earth, taking account of the resistance of the footwear and of the floor covering
Z_B : impedance of the human body (Ω)
I_B : current through the body (A)
R_{a1} : footwear resistance (Ω)
R_{a2} : floor surface resistance (Ω)

05.2.- Characteristics of the system
The protection equipment indicated requires co-ordination between:

1) the characteristics of the system
and
2) the operating characteristics of the circuit breaker devices.

The high voltage system operator determines the standard arrangement of his system. At the request of the installer, the operator of the high voltage supply system provides him with the characteristics of the system.

06 - Application of the protection measures against electric shocks by indirect contact at high voltage
When the conditions in point 5 are not met, additional passive protection measures should be provided.
If suitable measures have been taken to ensure protection against the contact voltages, it is assumed that protection against step voltages has also been provided.

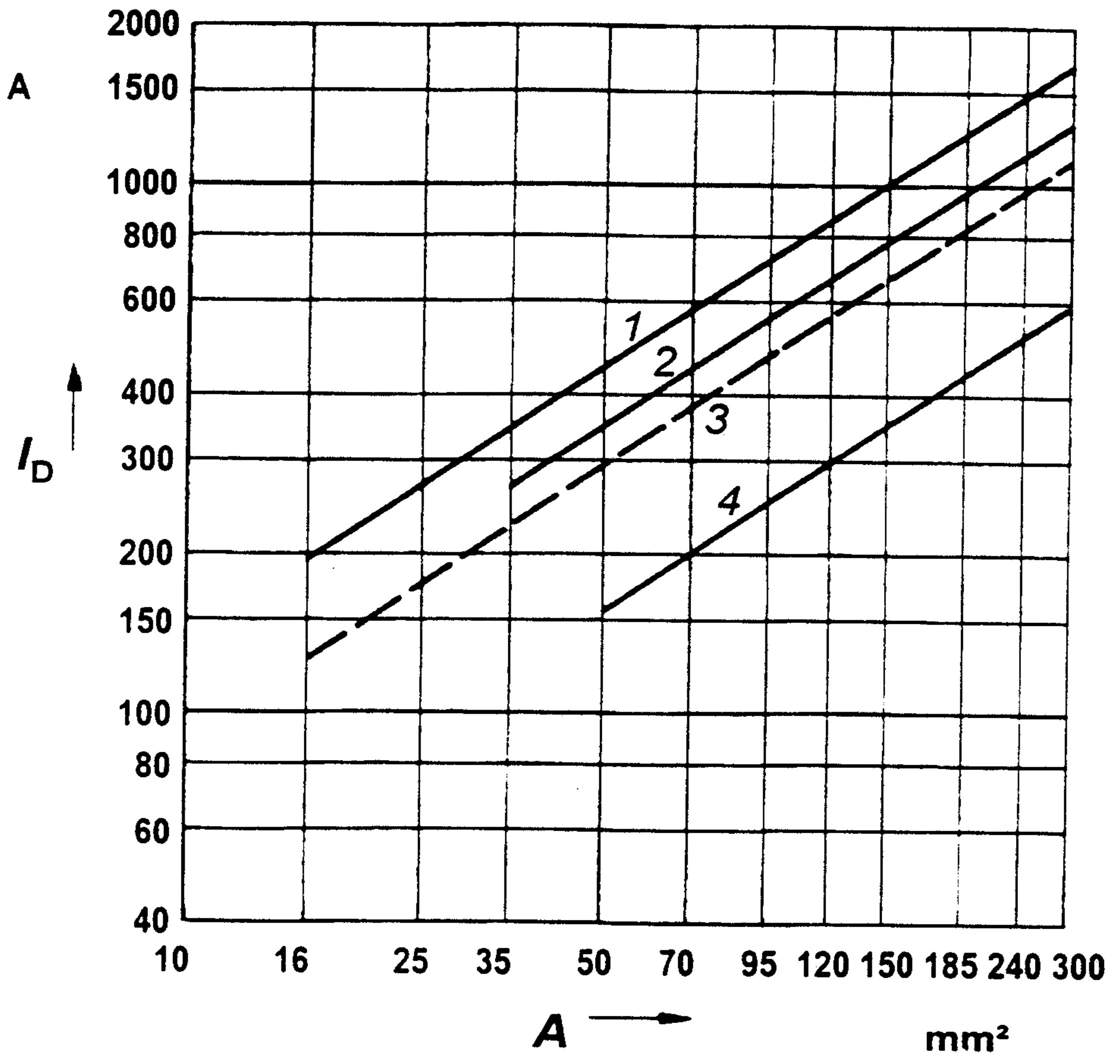


Figure 98.1a

Currant I_D for earth conductors of circular section as a function of their section (A in mm²)

Straight lines 1, 2 and 4 apply to a final temperature of 300 °C; straight line 3 is for a final temperature of 150 °C.

Line 1: copper, bare or with zinc coating
Line 2: aluminium
Line 3: copper, tinned or with lead sheath
Line 4: galvanised steel

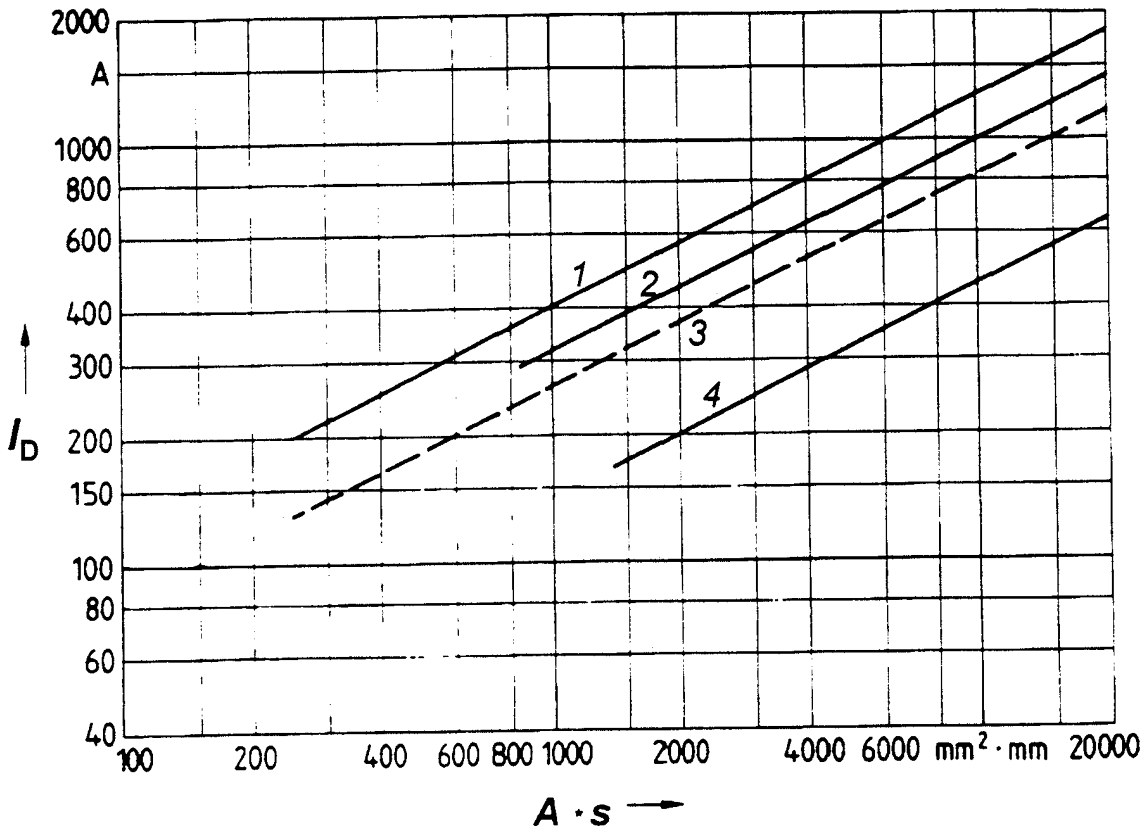
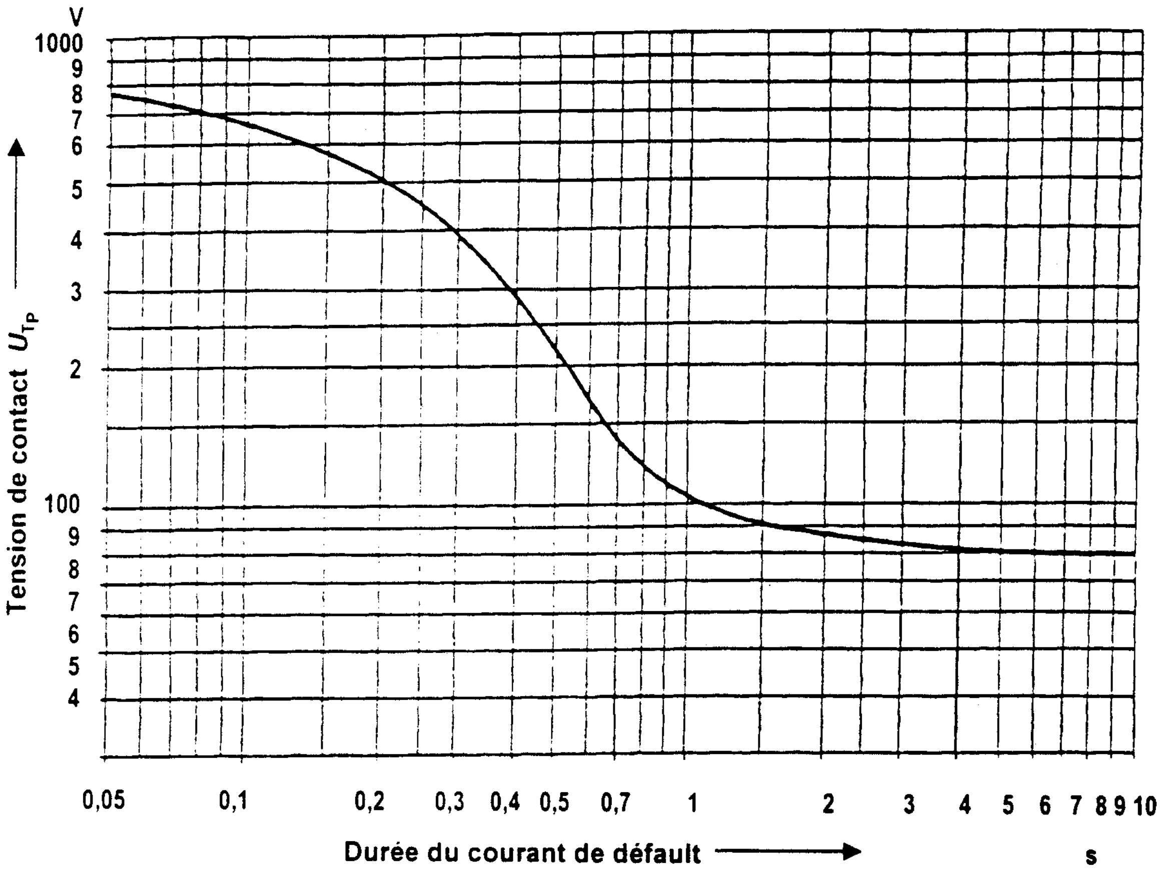


Figure 98.1b

Current I_D for earth conductors of rectangular section as a function of the result of the section multiplied by the perimeter (A x s)

Straight lines 1, 2 and 4 apply to a final temperature of 300 °C; straight line 3 is for a final temperature of 150 °C.

Line 1: copper, bare or with zinc coating
Line 2: aluminium
Line 3: copper, tinned or with lead sheath
Line 4: galvanised steel



Tension de contact = Contact voltage
Durée du courant de défault = Fault current time

Figure 98.2

Admissible contact voltage U_{Tp} as a function of the fault current time

Note 1: this curve refers to earth faults in high voltage systems

Note 2: if the current passage time is longer than 10 seconds, a value of 75 V can be used for U_{Tp}

TABLE 98.1

Minimum dimensions of the earth electrodes as a function of the materials used relating to their resistance to mechanical and corrosive influences.

Materials	**Type of earth electrodes**	**Minimum dimensions**				
		Core			**Coating/sheath**	
		Diameter [mm]	Section [mm^2]	Thickness [mm]	Individual value [µm]	Average value [µm]
STEEL						
Thermal galvanisation	Strips (2)		90	3	63	70
	Sections		90	3	63	70
	Tubes	25		2	47	55
	Round bars	16			63	70
	Round wires	10				50
Lead sheath	Round wires	8			1000	
Extruded copper sheath	Round bars	15			2000	
Electrolytic covering	Round bars	14.2			90	100
COPPER						
Refined	Strips (2)		50	2		
	Round wires		25			
	Twisted cables	1.8 (1)	25			
	Tubes	20		2		
Tinned	Twisted cables	1.8 (1)	25		1	5
Galvanised	Strips		50	2	20	40
Lead sheath	Twisted cables	1.8 (1)	25		1000	
	Round wires		25		2000	

(1) Value for each wire
(2) Strips, rolled or cut, with rounded edges

TABLE 98.2

Materials	β [°C]	**k** [$A\sqrt{s}/mm^2$]
Copper	234.5	226
Aluminium	228	148
Steel	202	78
Aluminium alloy	258	149

TABLE 98.3

Materials		**Initial temperature Θ_i [°C]**	**Final temperature Θ_f [°C]**
Wires not under mechanical load	Refined copper	20	300
	Galvanised refined copper	20	300
	Refined aluminium	20	300
	Galvanised refined steel	20	300
Overhead lines	Refined copper	20	170
	Aluminium alloy	20	170
	Aluminium - steel	20	150
	Aluminium alloy - steel	20	150
Tinned refined copper		20	150
Copper with lead sheath		20	150
<u>The said materials with sheath made of:</u>			
Polyvinyl chloride (PVC)		20	160
Rubber		20	220
Reticulated polyethylene (PRC)		20	250
Ethylene - propylene (EPR)		20	250
Silicone rubber (SIR)		20	350

TABLE 98.4

Final temperature Θ_f [°C]	**Correction factor**
400	1.2
350	1.1
300	1
250	0.9
200	0.8
150	0.7
100	0.6

ARTICLE 99 PREVENTION OF ELECTRIC SHOCKS BY INDIRECT CONTACT FOLLOWING PROPAGATION OF POTENTIAL

01.- General

Measures must be taken in order to prevent, following an insulation fault in a high voltage system, the propagation of the potential via the live conductors, via the earthing system or via conductive parts foreign to the system from being able to cause dangerous contact voltages.
In this respect, the continuity of the foreign conductive elements which pass between the dispersion zone of the high voltage earth connection and a neutral earth potential zone must be interrupted by a suitable insulating material.

02.- Measures to be taken

0*2.1.- General measures*

The earth of the neutral point of a low voltage system, the conductive elements foreign to the system, and the earths of low or very low voltage systems will be installed outside the dispersion area of the high voltage earth connection.

02.2.- Exceptions to the general measures

02.2.1. - The frame earths of the low voltage equipment of a TT or IT type system situated in the same building as that of the high voltage system can be connected to the high voltage earth on condition that the requirements given in table 99.1 are met or that the high voltage system is provided with a global earth.
02.2.2. - The frame earths of the LV equipment and the foreign conductors situated in the same building as the HV frame earths can be connected to the HV earth on condition that an effective equipotential connection is provided.
In the case of a global earth, the cross-sections required for the equipotential conductors are those indicated in Article 73.

02.2.3. - The neutral point of a low voltage system can be connected to a high voltage earthing system on condition that:

- in the case of a **TN type low voltage system**, there is no risk of dangerous contact voltages due to the propagation of potential via the neutral conductor and the protection conductor outside the equipotential area;
- in the case of a **TT type low voltage system**, there is no risk of exceeding the withstand voltage of the insulation of the low voltage equipment..

These conditions are considered to be met if:

- either the low voltage system is of the TN type and the LV frame earths and foreign conductors situated in the same building are connected together by an effective equipotential link;
- or the low voltage system is of the TN type and the rise in the earth potential U_E of the LV frame earths and of the foreign conductors does not exceed the values indicated in table 99.1, in which the admissible contact voltage U_{Tp} is taken as equal to the relative conventional limit voltage U_L (t) of Article 31. The voltage U_E can be approximately worked out by the formula $U_E < I_f.Z_E$, on the understanding that Z_E is measured by temporarily connecting the low voltage earth to the high voltage earth;
- the low voltage system is of the TT type and the high voltage system is provided with a global earth.

02.3.- Special measures

If it is not possible to avoid dangerous contact voltages within the dispersion area of an HV earthing system, following the propagation of potential, it is necessary to ensure that the frame earths of the low or very low voltage systems and/or the elements foreign to the system which are found in this dispersion area and which are galvanically connected to the neutral earth, are made inaccessible.

This inaccessibility can be obtained:
- either by obstacles;
- or by insulation;
- or by moving them outside the volume of accessibility of the maintenance and service locations.

TABLE 99.1

Type of arrangement of the L.V. system	Fault time	The earths of the low voltage and high voltage systems are common	
		Maximum earth potential rise requirements	
		(As far as the transferred contact voltage is concerned)	(As far as the withstand voltage of the low voltage equipment's insulation is concerned)
TT	$t \leq 5$ s $t > 5$ s	Not applicable	$U_E \leq 1200V$ $U_E \leq 250V$
TN		$U_E \leq U_{Tp}$ (1) $U_E \leq 2.U_{Tp}$(2)	Not applicable

(1) The PE(N) conductor of the low voltage system is earthed only by connection to the high voltage earthing system.
(2) The PE(N) conductor of the low voltage system is earthed at a number of points, distributed as regularly as possible, in order to ensure that the potential of the protection conductor remains, in case of a fault, as close as possible to that of the earth.
(3)

Article 3. - This Decree applies to electrical installations and important alterations or extensions to be carried out on site that have not already been started three months after the date of publication of this Decree.

Article 4. - Our Minister for Work, Our Minister for Energy and Our Secretary of State for the Organisation of Work and Well-Being at Work are responsible, each for their own part, for the implementation of this Decree.

Done at

By the King:

The Minister for Work,

F. VANDENBROUCKE.

The Minister for Energy,

F. MOERMAN.

The Secretary of State for the Organisation of Work and Well-Being at Work.

A. TEMSAMANI.