Where the equipment is located in places open to all persons, which can include children, measures of either 6.2.2 with a minimum degree of protection against contact with live parts corresponding to IP4X or IPXXD (see IEC 60529), or 6.2.3 shall be applied.

6.2.2 Protection by enclosures

Live parts shall be located inside enclosures that provide protection against contact with live parts of at least IP2X or IPXXB (see IEC 60529).

Where the top surfaces of the enclosure are readily accessible, the minimum degree of protection against contact with live parts provided by the top surfaces shall be IP4X or IPXXD.

Opening an enclosure (i.e. opening doors, lids, covers, and the like) shall be possible only under one of the following conditions:

a) The use of a key or tool is necessary for access.

NOTE 1 The use of a key or tool is intended to restrict access to skilled or instructed persons (see 17.2 f)).

All live parts, (including those on the inside of doors) that are likely to be touched when resetting or adjusting devices intended for such operations while the equipment is still connected, shall be protected against contact to at least IP2X or IPXXB. Other live parts on the inside of doors shall be protected against unintentional direct contact to at least IP1X or IPXXA.

b) The disconnection of live parts inside the enclosure before the enclosure can be opened.

This may be accomplished by interlocking the door with a disconnecting device (for example, the supply disconnecting device) so that the door can only be opened when the disconnecting device is open and so that the disconnecting device can only be closed when the door is closed.

Exception: a key or tool as prescribed by the supplier can be used to defeat the interlock provided that the following conditions are met:

– it is possible at all times while the interlock is defeated to open the disconnecting device and lock the disconnecting device in the OFF (isolated) position or otherwise prevent unauthorised closure of the disconnecting device;

– upon closing the door, the interlock is automatically restored;

– all live parts, (including those on the inside of doors) that are likely to be touched when resetting or adjusting devices intended for such operations while the equipment is still connected, are protected against unintentional contact with live parts to at least IP2X or IPXXB and other live parts on the inside of doors are protected against unintentional contact to at least IP1X or IPXXA;

– relevant information about the procedures for the defeat of the interlock is provided with the instructions for use of the electrical equipment (see Clause 17).

– means are provided to restrict access to live parts behind doors that are not directly interlocked with the disconnecting means to skilled or instructed persons. (See 17.2 b)).

All parts that are still live after switching off the disconnecting device(s) (see 5.3.5) shall be protected against direct contact to at least IP2X or IPXXB (see IEC 60529). Such parts shall be marked with a warning sign in accordance with 16.2.1 (see also 13.2.4 for identification of conductors by colour), except for:

– parts that can be live only because of connection to interlocking circuits and that are distinguished by colour as potentially live in accordance with 13.2.4;

– the supply terminals of the supply disconnecting device when the latter is mounted alone in a separate enclosure.

c) Opening without the use of a key or a tool and without disconnection of live parts shall be possible only when all live parts are protected against contact to at least IP2X or IPXXB (see IEC 60529). Where barriers provide this protection, either they shall require a tool for

d) conductors of each PELV circuit shall be physically separated from those of any other circuit. When this requirement is impracticable, the insulation provisions of 13.1.3 shall apply;

e) plugs and socket-outlets for a PELV circuit shall conform to the following:

- plugs shall not be able to enter socket-outlets of other voltage systems;
- socket-outlets shall not admit plugs of other voltage systems.

6.4.2 Sources for PELV

The source for PELV shall be one of the following:

– a safety isolating transformer in accordance with IEC 61558-1 and IEC 61558-2-6;

– a source of current providing a degree of safety equivalent to that of the safety isolating transformer (for example a motor generator with winding providing equivalent isolation);

– an electrochemical source (for example a battery) or another source independent of a higher voltage circuit (for example a diesel-driven generator);

– an electronic power supply conforming to appropriate standards specifying measures to be taken to ensure that, even in the case of an internal fault, the voltage at the outgoing terminals cannot exceed the values specified in 6.4.1.

7 Protection of equipment

7.1 General

This Clause 7 details the measures to be taken to protect equipment against the effects of:

– overcurrent arising from a short-circuit;

– overload and/or loss of cooling of motors;

– abnormal temperature;

– loss of or reduction in the supply voltage;

– overspeed of machines/machine elements;

– earth fault/residual current;

– incorrect phase sequence;

– overvoltage due to lightning and switching surges.

7.2 Overcurrent protection

7.2.1 General

Overcurrent protection shall be provided where the current in any circuit can exceed either the rating of any component or the current carrying capacity of the conductors, whichever is the lesser value. The ratings or settings to be selected are detailed in 7.2.10.

7.2.2 Supply conductors

Unless otherwise specified by the user, the supplier of the electrical equipment is not responsible for providing the supply conductors and the overcurrent protective device for the supply conductors to the electrical equipment.

The supplier of the electrical equipment shall state in the installation documents the data necessary for conductor dimensioning (including the maximum cross-sectional area of the supply conductor that can be connected to the terminals of the electrical equipment) and for selecting the overcurrent protective device (see 7.2.10 and 17).

7.2.3 Power circuits

Devices for detection and interruption of overcurrent, selected in accordance with 7.2.10, shall be applied to each live conductor including circuits supplying control circuit transformers.

The following conductors, as applicable, shall not be disconnected without disconnecting all associated live conductors:

– the neutral conductor of AC power circuits;

– the earthed conductor of DC power circuits;

– DC power conductors bonded to exposed conductive parts of mobile machines.

Where the cross-sectional area of the neutral conductor is at least equal to or equivalent to that of the line conductors, it is not necessary to provide overcurrent detection for the neutral conductor nor a disconnecting device for that conductor. For a neutral conductor with a cross-sectional area smaller than that of the associated line conductors, the measures detailed in 524 of IEC 60364-5-52:2009 shall apply.

In IT systems, it is recommended that the neutral conductor is not used. However, where a neutral conductor is used, the measures detailed in 431.2.2 of IEC 60364-4-43:2008 shall apply.

7.2.4 Control circuits

Conductors of control circuits directly connected to the supply voltage shall be protected against overcurrent in accordance with 7.2.3.

Conductors of control circuits supplied by a transformer or DC supply shall be protected against overcurrent (see also 9.4.3.1.1):

– in control circuits connected to the protective bonding circuit, by inserting an overcurrent protective device into the switched conductor;

– in control circuits not connected to the protective bonding circuit;

  - where all control circuits of the equipment have the same current carrying capacity, by inserting an overcurrent protective device into the switched conductor, or;
  - where different control circuits of the equipment have different current carrying capacity, by inserting an overcurrent protective device into both switched and common conductors of each control circuit.

Exception: Where the supply unit provides current limiting below the current carrying capacity of the conductors in a circuit and below the current rating of connected components, no separate overcurrent protective device is required.

7.2.5 Socket outlets and their associated conductors

Overcurrent protection shall be provided for the circuits feeding the general purpose socket outlets intended primarily for supplying power to maintenance equipment. Overcurrent protective devices shall be provided in the unearthed live conductors of each circuit feeding such socket outlets. See also 15.1.

7.2.6 Lighting circuits

All unearthed conductors of circuits supplying lighting shall be protected against the effects of short-circuits by the provision of overcurrent devices separate from those protecting other circuits.

7.2.7 Transformers

Transformers shall be protected by an overcurrent protective device having a type and setting in accordance with the transformer manufacturer's instructions. Such protection shall (see also 7.2.10):

– avoid nuisance tripping due to transformer magnetizing inrush currents;
– avoid a winding temperature rise in excess of the permitted value for the insulation class of transformer when it is subjected to the effects of a short-circuit at its secondary terminals.

7.2.8 Location of overcurrent protective devices

An overcurrent protective device shall be located at the point where a reduction in the cross-sectional area of the conductors or another change reduces the current-carrying capacity of the conductors, except where all the following conditions are satisfied:

– the current carrying capacity of the conductors is at least equal to that of the load;
– the part of the conductor(s) between the point of reduction of current-carrying capacity and the position of the overcurrent protective device is no longer than 3 m;
– the conductors are installed in such a manner as to reduce the possibility of a short-circuit, for example, protected by an enclosure or duct.

7.2.9 Overcurrent protective devices

The rated short-circuit breaking capacity shall be at least equal to the prospective fault current at the point of installation. Where the short-circuit current to an overcurrent protective device can include additional currents other than from the supply (for example from motors, from power factor correction capacitors), those currents shall be taken into consideration.

NOTE Information on co-ordination under short-circuit conditions between a circuit-breaker and another short-circuit protective device is provided in Annex A of IEC 60947-2:2006, IEC 60947-2:2006/AMD1:2009 and IEC 60947-2:2006/AMD2:2013.

Where fuses are provided as overcurrent protective devices, a type readily available in the country of use shall be selected, or arrangements shall be made for the supply of spare parts.

7.2.10 Rating and setting of overcurrent protective devices

The rated current of fuses or the setting current of other overcurrent protective devices shall be selected as low as possible but adequate for the anticipated overcurrents (for example during starting of motors or energizing of transformers). When selecting those protective devices, consideration shall be given to the protection of switching devices against damage due to overcurrents.

The rated current or setting of an overcurrent protective device for conductors is determined by the current carrying capacity of the conductors to be protected in accordance with 12.4, Clause D.3 and the maximum allowable interrupting time t in accordance with Clause D.4, taking into account the needs of co-ordination with other electrical devices in the protected circuit.

7.3 Protection of motors against overheating

7.3.1 General

Protection of motors against overheating shall be provided for each motor rated at more than 0,5 kW.

Exception: In applications where an automatic interruption of the motor operation is unacceptable (for example fire pumps), the means of detection shall give a warning signal to which the operator can respond.

Table 10 – Examples of maximum cable lengths from protective devices to their loads for TN-systems

1 Maximum source impedance of the supply to the protective device	2 Minimum cross-sectional area	3 Maximum nominal rating or setting of the protective device I_N	4 Fuse disconnect time 5 s	5 Fuse disconnect time 0,4 s	6 Miniature circuit-breaker char.B $I_a = 5 \times I_N$	7 Miniature circuit-breaker char.C $I_a = 10 \times I_N$	8 Miniature circuit-breaker char.D $I_a = 20 \times I_N$	9 Adjustable circuit-breaker $I_a = 8 \times I_N$
mΩ	mm^2	A	Maximum cable length in m from each protective device to its load					
500	1,5	16	97	53	76	30	7	31
500	2,5	20	115	57	94	34	3	36
500	4,0	25	135	66	114	35		38
400	6,0	32	145	59	133	40		42
300	10	50	125	41	132	33		37
200	16	63	175	73	179	55		61
200	25 (line)/16 (PE)	80	133					38
100	35 (line)/16 (PE)	100	136					73
100	50 (line)/25 (PE)	125	141					66
100	70 (line)/35 (PE)	160	138					46
50	95 (line)/50 (PE)	200	152					98
50	120 (line)/70 (PE)	250	157					79
	The values of the maximum cable length in Table 10 are based on the following assumptions: • PVC cable with copper conductors, conductor temperature under short-circuit conditions 160 °C (see Table D.5); • cables with line conductors up to 16 mm^2 provide a protective conductor of equal cross sectional area to that of the line conductors; • cables above 16 mm^2 provide a reduced size protective conductor as shown; • 3-phase system, nominal voltage of the power supply 400 V (U_0 = 230 V); • column 3 values are correlated with Table 6 (see 12.4). • disconnection time for circuit-breakers is ≤ 0,4 s (columns 6 – 9) A deviation from these assumptions can require a complete calculation or measurement of the fault loop impedance. Further information is available from IEC 60228 and IEC TR 61200-53.							

18.3 Insulation resistance tests

When insulation resistance tests are performed, the insulation resistance measured at 500 V DC between the power circuit conductors and the protective bonding circuit shall be not less than 1 MΩ. The test may be made on individual sections of the complete electrical installation.

Exception: for certain parts of electrical equipment, incorporating for example busbars, conductor wire or conductor bar systems or slip-ring assemblies, a lower minimum value is permitted, but that value shall not be less than 50 kΩ.

If the electrical equipment of the machine contains surge protection devices which are likely to operate during the test, it is permitted to either:

– disconnect these devices, or

– reduce the test voltage to a value lower than the voltage protection level of the surge protection devices, but not lower than the peak value of the upper limit of the supply (phase to neutral) voltage.

18.4 Voltage tests

When voltage tests are performed, test equipment in accordance with IEC 61180-2 should be used.

The test voltage shall be at a nominal frequency of 50 Hz or 60 Hz.

The maximum test voltage shall have a value of twice the rated supply voltage of the equipment or 1 000 V, whichever is the greater. The maximum test voltage shall be applied between the power circuit conductors and the protective bonding circuit for at least 1 s. The requirements are satisfied if no disruptive discharge occurs.

Components and devices that are not rated to withstand the test voltage and surge protection devices which are likely to operate during the test shall be disconnected during testing.

Components and devices that have been voltage tested in accordance with their product standards may be disconnected during testing.

18.5 Protection against residual voltages

Where appropriate, tests shall be performed to ensure compliance with 6.2.4.

18.6 Functional tests

The functions of electrical equipment shall be tested.

18.7 Retesting

Where a portion of the machine or its associated equipment is changed or modified, the need for re-verification and testing of the electrical equipment shall be considered.

Particular attention should be given to the possible adverse effects that retesting can have on the equipment (for example overstressing of insulation, disconnection/reconnection of devices).