Table 1 – Minimum clearances in air – Voltage range I (1 kV < U_m ≤ 245 kV)

Voltage range	Nominal voltage of system	Highest voltage for equipment	Rated short-duration power-frequency withstand voltage	Rated lightning impulse withstand voltage [a]	Minimum phase-to-earth and phase-to-phase clearance, N [c]	
	U_n r.m.s.	U_m r.m.s.	r.m.s.	1,2/50 µs (peak value)	Indoor installations	Outdoor installations
	kV	kV	kV	kV	mm	mm
I	3	3,6	10	20	60	120
				40	60	120
	6	7,2	20	40	60	120
				60	90	120
	10	12	28	60	90	150
				75	120	150
				95	160	160
	15	17,5	38	75	120	160
				95	160	160
	20	24	50	95	160	
				125	220	
				145	270	
	30	36	70	145	270	
				170	320	
	45	52	95	250	480	
	66	72,5	140	325	630	
	110	123	185 [b]	450	900	
			230	550	1 100	
	132	145	185 [b]	450 [b]	900	
			230	550	1 100	
			275	650	1 300	
	150	170	230 [b]	550 [b]	1 100	
			275	650	1 300	
			325	750	1 500	
	220	245	275 [b]	650 [b]	1 300	
			325 [b]	750 [b]	1 500	
			360	850	1 700	
			395	950	1 900	
			460	1 050	2 100	

[a] The rated lightning impulse is applicable to phase-to-phase and phase-to-earth.

[b] If values are considered insufficient to prove that the required phase-to-phase withstand voltages are met, additional phase-to-phase withstand tests are needed.

[c] For rod-structure.

Table 2 – Minimum clearances in air – Voltage range II (U_m > 245 kV)

Voltage range	Nominal voltage of system	Highest voltage for equip-ment [c]	Rated lightning impulse withstand voltage [a]	Rated switching impulse withstand voltage	Minimum phase-to-earth clearance		Rated switching impulse withstand voltage	Minimum phase-to-phase clearance	
	U_n r.m.s.	U_m r.m.s.	1,2/50 µs (peak value)	Phase-to-earth 250/ 2 500 µs (peak value)	Conductor – structure	Rod – structure *N*	Phase-to-phase 250/ 2 500 µs (peak value)	Conductor – conductor parallel	Rod – conductor
	kV	kV	kV	kV	mm		kV	mm	
II	275	300	850/950	750	1 600 1 700 [b]	1 900	1 125	2 300	2 600
			950/1 050	850	1 800 1 900 [b]	2 400	1 275	2 600	3 100
	330	362	950/1 050	850	1 800 1 900 [b]	2 400	1 275	2 600	3 100
			1 050/1 175	950	2 200	2 900	1 425	3 100	3 600
	380	420	1 050/1 175	850	1 900 2 200 [b]	2 400	1 360	2 900	3 400
			1 175/1 300	950	2 200 2 400 [b]	2 900	1 425	3 100	3 600
			1 300/1 425	1 050	2 600	3 400	1 575	3 600	4 200
	480	525 (550) [c]	1 175/1 300	950	2 200 2 400 [b]	2 900	1 615	3 700	4 300
			1 300/1 425	1 050	2 600	3 400	1 680	3 900	4 600
			1 425/1 550	1 175	3 100	4 100	1 763	4 200	5 000
	700	765 (800) [c]	1 675/1 800	1 300	3 600	4 800	2 210	6 100	7 400
			1 800/1 950	1 425	4 200	5 600	2 423	7 200	9 000
			1 950/2 100	1 550	4 900	6 400	2 480	7 600	9 400

[a] The rated lightning impulse is applicable phase-to-phase and phase-to-earth.

[b] Minimum clearance required for upper value of rated lightning impulse withstand voltage.

[c] The introduction of U_m = 550 kV (instead of 525 kV); 800 kV (instead of 765 kV); 1 200 kV, of a value between 765 kV and 1 200 kV, and of the associated rated withstand voltages, is under consideration.

5.4 Minimum clearances between parts under special conditions

5.4.1 The minimum clearances between parts of an installation which may be subject to phase opposition shall be 20 % higher than the values given in table 1 and table 2 and annex A.

5.4.2 Minimum clearances between parts of an installation, which are assigned to different insulation levels, shall be at least 125 % of the clearances of the higher insulation level.

5.4.3 If conductors swing under the influence of short-circuit forces, 50 % of the minimum clearances of table 1 and table 2 and annex A shall be maintained as a minimum.

5.4.4 If conductors swing under the influence of wind, 75 % of the minimum clearances of table 1 and table 2 and annex A shall be maintained as a minimum.

5.4.5 In case of rupture of one sub-chain in a multiple insulator chain, 75 % of the minimum clearances of table 1 and table 2 and annex A shall be maintained as a minimum.

5.4.6 If neither the neutral point nor a phase conductor is effectively earthed in an installation that is fed via auto transformers, the insulation of the lower voltage side shall be rated according to the highest voltage for equipment on the higher voltage side. Attention should be paid to neutral point insulation according to the method of neutral earthing.

5.5 Tested connection zones

Information on mounting and service conditions supplied by the manufacturer shall be observed on site.

NOTE In tested connection zones, the minimum clearances according to table 1 and table 2 and annex A need not be maintained because the ability to withstand the test voltage is established by a dielectric type test.

6 Equipment

6.1 General requirements

6.1.1 Selection

Equipment shall be selected and installed to satisfy the following requirements:

a) safe construction when properly assembled, installed and connected to supply;

b) safe and proper performance taking into account the external influences that can be expected at the intended location;

c) safe and proper performance during normal operation and in the event of reasonably expected conditions of overload, abnormal operation and fault, without resulting in damage that would render the equipment unsafe;

d) protection of personnel during use and maintenance of the equipment.

6.1.2 Compliance

Equipment shall comply with the relevant IEC standards with particular attention to IEC Guide 107 and ISO/IEC Guide 51.

6.1.3 Personnel safety

Particular attention shall be given to the safety of personnel during the installation, operation and maintenance of equipment.

This may include

a) manuals and instructions for transport, storage, installation, operation and maintenance;

b) special tools required for operation, maintenance and testing;

c) safe working procedures developed for specific locations.

6.2 Specific requirements

6.2.1 Switching devices

6.2.1.1 A facility shall be provided to indicate the contact position of the interrupting or isolating equipment (including earthing switches). The method of indication in accordance with the equipment standard should be specified by the user.

The position indicator shall provide an unambiguous indication of the actual position of the equipment primary contacts.

The device indicating the open/close position shall be easily visible to the operator.

6.2.1.2 Disconnectors and earthing switches shall be installed in such a way that they cannot be inadvertently operated by tension or pressure exerted manually on operating linkages.

6.2.1.3 Where specified by the user, interlocks and/or locking facilities shall be provided to prevent maloperation.

6.2.1.4 If an interlocking system is provided which prevents the earthing switch from carrying the full short-circuit current, it is permissible, by agreement with the user, to specify a reduced rating for the switch which reflects its possible short-circuit-current stress.

6.2.1.5 Equipment shall be installed in such a way that ionized gas released during switching does not result in damage to the equipment or in danger to operating personnel.

NOTE The word 'damage' is considered to be any failure of the equipment which impairs its function.

6.2.2 Power transformers and reactors

6.2.2.1 Unless otherwise stated, this subclause applies both to transformers and reactors even if only transformers are referred to in the text.

The main selection criteria for transformers are given in clauses 4 and 8.

6.2.2.2 The transformers are classified taking into account the dielectric in contact with winding and the type of internal or external cooling as described in clause 3 of IEC 60076-2.

6.2.2.3 When designing the transformer or reactor installation, the possibility of fire propagation (see 8.6) shall be considered. Similarly, means shall be implemented to limit, if necessary, the acoustic noise level (see 4.5.2).

6.2.2.4 For transformers installed indoors, suitable ventilation shall be provided (see 7.5.7).

6.2.2.5 Water (ground water, surface water and waste water) shall not be polluted by transformer installations. This shall be achieved by the choice of the design of transformer type and/or site provisions. For measures see 8.7.

6.2.2.6 If it is necessary to take samples (oil sampling) or to read monitoring devices (such as fluid level, temperature, or pressure), which are important for the operation of the transformer whilst the transformer is energized, it shall be possible to perform this safely and without damage to the equipment.

6.2.2.7 Air-core reactors shall be installed in such a way that the magnetic field of the short-circuit current will not be capable of drawing objects into the coil. Adjacent equipment shall be designed to withstand the resulting electromagnetic forces. Adjacent metal parts such as foundation reinforcements, fences and earthing grids shall not be subject to excessive temperature rise under normal load conditions.

6.2.2.8 The risk of damage to transformers from overstresses resulting from ferroresonance, harmonics and other causes should be minimized by appropriate system studies and measures.

6.2.3 Gas insulated metal-enclosed switchgear (GIS), metal-enclosed switchgear, insulation-enclosed switchgear and other prefabricated type-tested switchgear assemblies

The requirements for installation are given in clause 7. For safety of personnel and gas handling, refer to 8.7.3 and 9.4.

6.2.4 Instrument transformers

The secondary circuits of instrument transformers shall be bonded to earth, or the secondary circuits shall be segregated by earthed metallic screening, in accordance with the recommendations of clause 10.

The earthable point of the secondary circuit shall be determined in such a way that electrical interference is avoided.

Instrument transformers shall be installed in such a way that their secondary terminals are easily accessible when the switchgear assembly has been de-energized.

6.2.4.1 Current transformers

The rated overcurrent factor and the rated burden shall be selected so as to ensure correct functioning of the protective equipment and prevent damage to measuring equipment in the event of a short-circuit.

In high voltage networks where the primary time constant is long and where reclosing is practiced, it is recommended that the transient stress due to the aperiodic portion of the short-circuit current be taken into account: the recommendations of IEC 60044-6 should be considered.

If measuring devices are also connected to protective current transformer cores, the measuring devices shall, if necessary, be protected against the damage resulting from large short-circuit currents by means of suitable auxiliary transformers.

If necessary, an effective screen between the primary and secondary circuit shall be provided for the reduction of the transient overvoltages on secondary circuits arising from the switching operation.

To protect against dangerous overvoltages, provisions shall be made to facilitate shorting the secondary windings of current transformers.

6.2.4.2 Voltage transformers

Voltage transformers shall be selected in such a way that the nominal output and accuracy are adequate for the connected equipment and wiring. The effects of ferroresonance shall be considered.

The secondary side of voltage transformers shall be protected against the effects of short-circuits, and it is recommended that protective devices be monitored.

6.2.5 Surge arresters

6.2.5.1 If monitors are provided in the earth conductor of non-linear resistor type arresters, then the conductor between an arrester and the monitor shall be protected to prevent it being touched. It shall be possible to read the monitors and any counters with the equipment energized.

6.2.5.2 Surge arresters shall be designed or positioned in such a way as to provide personnel safety in case of breaking of the housing or operating of any pressure relief device.

6.2.6 Capacitors

The risk of resonance and overvoltages due to harmonics shall be taken into consideration, and appropriate means for limitation of this risk shall be provided.

6.2.6.1 For the selection of the nominal voltage and the current capacity of capacitors, the voltage increase caused by inductive reactances connected in series such as damping reactors and sound frequency or filter circuits shall be considered.

6.2.6.2 Capacitors for coupling, voltage measuring and over-voltage protection shall be selected according to the rated voltage of the switchgear, even if the operating voltage is lower.

6.2.6.3 Safe discharge of power capacitors shall be guaranteed. Discharge units shall be thermally and mechanically capable of carrying out their task.

6.2.6.4 The short-circuiting and earthing facilities provided for a capacitor bank shall take into account the interconnection of units within the bank, the discharge resistors and the type of fusing.

6.2.7 Line traps

The bandwidth should be determined in accordance with the network frequency allocation.

6.2.8 Insulators

6.2.8.1 Unless otherwise specified, the minimum specific creepage distance of insulators shall comply with the recommendations of IEC 60815 for the level of pollution specified by the user.

6.2.8.2 The requirements of the wet test procedure of IEC 60694 shall apply for all external insulation.

Insulator profiles and/or requirements for performance of outdoor insulators in polluted or heavy wetting conditions may be specified by the user.

6.2.9 Insulated cables

6.2.9.1 Temperature rise

Insulated cables shall be selected and laid in such a way that the maximum permitted temperature rise is not exceeded for conductors, their insulation, the connections, the equipment terminals or the surroundings under the following conditions:

a) normal operation;

b) special operating conditions, subject to previous agreement between the supplier and the user;

c) short-circuit.

The connection of a cable to equipment (for example motors, circuit-breakers) shall not result in the cable being subjected to temperatures higher than those admissible for the cable in the foreseeable operating conditions.

6.2.9.2 Stress due to temperature changes

The stress on equipment due to temperature-dependent changes in the length of conductors shall be taken into account. If necessary, the stress shall be relieved by suitable measures (for example flexible connections, expansion terminations or snaking). If these measures are not taken, the additional forces due to temperature changes shall be taken into account during verification of the mechanical strength of the equipment.

6.2.9.3 Flexible reeling and trailing cables

Flexible reeling and trailing cables shall be selected in accordance with the following requirements and conditions:

a) trailing cables or cables having at least equivalent mechanical and electrical characteristics shall be used for supplying power to hoisting, mobile or moveable equipment;

b) in the case of more severe mechanical stress, for example where the cables are subject to abrasion, tension, deflection or winding during operation, double-sheathed trailing cables or cables with at least equivalent mechanical and electrical characteristics shall be used;

c) insulated cables for the power supply of hoisting, mobile or moveable equipment shall contain a protective earth conductor;

d) the design of any connection, be it a joint, termination or other connection arrangement shall be such that in the event of a strain being placed upon the cable the protective conductor shall be the last to part or separate;

e) insulated cables which are to be wound on a drum shall be dimensioned so that when the conductor is fully wound and subject to the normal service loading, the maximum permitted temperature rise is not exceeded.

The terminal ends of flexible and trailing cables shall be free from tension and compression; cable sleeves shall be protected against stripping and cable ends against twisting. The terminals shall also be designed so that the cables will not kink.

6.2.9.4 Crossings and proximities

Where insulated cables cross or are near to gas, water or other pipes, an appropriate clearance shall be maintained between cables and the pipelines. Where this clearance cannot be maintained, contact between the cables and the pipelines shall be prevented, for example, by the insertion of insulating shells or plates. These measures shall be coordinated with the operator of the pipeline. In the case of a long parallel routing, a calculation of the overvoltage induced on the pipeline during a short-circuit shall be effected. It may be necessary to determine appropriate measures (for example, an alternative routing for the cables or pipelines, or a greater clearance between cables and pipelines).

Where insulated cables cross or are near to telecommunication installations, an appropriate clearance shall be maintained between cables and telecommunication installations.

In the case of a long parallel routing, the overvoltage induced on the telecommunication installation during a short-circuit shall be calculated (for guidance refer to ITU directives). It may be necessary to take appropriate measures to reduce this overvoltage (alternative routing for the cables or the telecommunication installations, greater clearance between cables and telecommunication installations).

Where insulated cables cross or are near to other insulated cables, the mutual thermal effects shall be calculated in order to determine the minimum clearance between cables or to determine other appropriate measures (e.g. derating). Cables shall be installed at a sufficient distance from heat sources or shall be separated from such heat sources by means of thermal insulating shields.

NOTE Crossing and proximity of insulated cables, gas and water pipes or other pipes and appropriate clearance should be in compliance with national regulations and standards.

6.2.9.5 Installation of cables

Care should be taken to protect the cable from mechanical damage during and after installation as follows:

a) to avoid any damage to the cable, the laying operations shall be performed at the ambient temperature specified by the equipment standards or the manufacturer;

b) single-core insulated cables shall be laid in such a way as to ensure that the forces resulting from short-circuit currents do not cause damage;

c) the method of laying shall be chosen to ensure that the external effects are limited to acceptable safe values. In addition, when buried in troughs, the cables shall be installed at a specific depth and covered by slabs or a warning grid to prevent any damage being caused by third parties. Underground and submarine cables should be mechanically protected where they emerge from the water or the soil;

d) laying of cables in earth shall be carried out on the bottom of a cable trench free of stones. The bedding shall be in sand or soil, free of stones. Special constructions of cables can be chosen, if necessary, to protect against chemical effects;

e) measures shall be taken to prevent cables in troughs from being damaged by vehicles running over them;

f) ground movements and vibrations shall be taken into account;

g) for vertical installations the cable shall be supported by suitable cleats at interval determined by the cable construction and information provided by the manufacturer.

Cables installed in metallic pipes shall be grouped in such a way that the conductors of all phases (and the neutral, if any) of the same circuit are laid in the same pipe to minimize eddy currents. Consideration should be given to the location of the earthing conductor.

Insulated cables shall be installed so that touch voltages are within the permissible values, or so that accessible parts with impermissible touch voltages are protected against contact by adequate measures.

NOTE There may be a risk of high circulating currents in screens of sheathed single-core cables, especially when laid flat.

Metallic sheaths shall be earthed in accordance with clause 10.

The length of cable connecting transformers and reactors to a circuit should be selected so as to minimize the occurrence of ferroresonance.

Care shall be taken to limit the mechanical stress on equipment when connecting power cables.

6.2.9.6 Bending radius

The minimum values of bend radius during and after installation are dependent on the type of cable and are given in the relevant standards or shall be specified by the manufacturer.

6.2.9.7 Tensile stress

The maximum permissible tensile stress during laying depends on the nature of the conductor and on the type of cable and are given in the relevant standards or shall be specified by the manufacturer.

The continuous static and peak tensile stress applied to the conductors of flexible and trailing cables shall be as small as possible, and shall not exceed the values given by the manufacturer.

6.2.10 Conductors and accessories

This subclause deals with conductors (rigid or flexible) and accessories, which are part of outgoing feeders or busbars in installations.

6.2.10.1 Where conductors and accessories are directly associated with a circuit-breaker, fuse-switch or switch, the value and duration of the rated short-time withstand current of the conductors and accessories shall be not less than the corresponding rating of the equipment to which it is connected, unless safety of personnel and equipment is assured.

6.2.10.2 Provision shall be made to allow for the expansion and contraction of conductors caused by temperature variations. This shall not apply where the stress caused by temperature variations has been allowed for in the conductor system design.

6.2.10.3 Joints between conductors and connections between conductors and equipment shall be without defects and shall not deteriorate while in service. They shall be chemically and mechanically stable. The joint faces shall be suitably prepared and connected as specified for the type of connection. The temperature rise of a connection between conductors and switchgear in service shall not exceed the values specified in IEC 60694.

6.2.11 Rotating electrical machines

6.2.11.1 The risk of personal injury from faults within the terminal boxes of machines shall be minimized. The terminal boxes of motors shall withstand the local short-circuit conditions. Current-limiting devices may be necessary.

6.2.11.2 The degree of protection against the ingress of objects, dust and water shall be chosen in accordance with the special climatic and environmental conditions at the site of installation. Hazardous parts of the machine shall be protected against accidental contact by persons.

The insulation level of the machine shall be selected in accordance with IEC 60034-1.

6.2.11.3 Sufficient cooling shall be provided.

6.2.11.4 Machines should be protected against exceeding the maximum permitted temperature rise by use of suitable electric protective devices. Particularly for large machines or those critical for a production process, protection devices should be installed which indicate an internal fault of the machine or, if necessary, automatically shut it down.

6.2.12 Static converters

6.2.12.1 Accessible parts of converter units that can carry dangerous voltage during normal operation or under fault conditions shall be adequately marked and shall be adequately protected against accidental contact by persons. This may be achieved by providing suitable protective barriers.

6.2.12.2 The cooling and heat transfer mediums shall not contain mechanical pollution or chemically aggressive components which might cause malfunction of the equipment.

When water is used as coolant, the possibility of corrosion caused by leakage currents (currents due to the conductivity of water) shall be considered.

When oil is used as coolant, similar protection against fire and pollution of ground water shall be provided as for oil-filled transformers and reactors.

6.2.12.3 When planning the layout of converter units, the possibility of magnetic interference, caused by high a.c. currents, on other equipment or parts of the installation, especially steel components, shall be considered.

6.2.13 Fuses

6.2.13.1 Clearances

Minimum electrical clearances for fuse assembly installations shall take into consideration all potential position of the live parts before, during and after operation.

Vented fuses shall be provided with adequate clearances or appropriate protective barriers in the direction or directions in which they are vented. Discharges from vented fuses may contain hot gases, arc plasma and molten metal. They may also be conductive.

Facilities should be provided to ensure that personnel is not exposed to discharges of vented fuses either during replacement or when working in the area.

NOTE When this is not possible, the circuit feeding the fusing should be de-energized prior to potential exposures, or the personnel should use protective shielding and clothing.

6.2.13.2 Fuse replacement

Fuses shall be installed in such a way that their replacement can be carried out safely according to manufacturer's instructions.

NOTE All necessary information should be available to the operating and maintenance personnel for the proper selection of replacement fuses.

7 Installations

7.1 General requirements

This clause specifies only general requirements for the installations regarding choice of circuit arrangement, circuit documentation, transport routes, lighting, operational safety and labelling.

Distances, clearances and dimensions specified are the minimum values permitted for safe operation. They are generally based on the minimum values given in the former national standards of the IEC members. A user may specify higher values if necessary.

NOTE For minimum clearances (*N*) of live parts, refer to 5.3 and to tables 1 and 2 and annex A.

National standards and regulations may require the use of higher clearance values.

Where an existing installation is to be extended, the requirements applicable at the time of its design and erection may be specified as an alternative.

The relevant standards for operation of electrical (power) installations shall additionally be taken into account. Operating procedures shall be agreed upon between manufacturer and user (see 7.1.2).

7.1.1 Circuit arrangement

7.1.1.1 The circuit arrangement shall be chosen to meet operating requirements and to enable implementation of the safety requirements in accordance with 8.3. The continuity of service under fault and maintenance conditions, taking into account the network configuration, shall also be considered. The circuits shall be arranged so that switching operations can be carried out safely and quickly.

Each electrically separated system shall be provided with an earth fault indicating device which permits detection or disconnection of an earth fault.

It shall be ensured that isolated sections of an installation cannot be inadvertently energized by voltage from parallel connected secondary sources (for example instrument transformers).

7.1.1.2 Installations shall be capable of withstanding the thermal and dynamic stresses resulting from short-circuit current in accordance with clause 4.

The circuit arrangement may, however, be configured in such a way that sections of the installation which are normally operated separately are interconnected for short periods during switching operations, even when, as a result of such connection, the short-circuit current exceeds the design rating for the installation. In such cases, suitable protective measures shall be taken to prevent danger to personnel. Defined operating procedures may be required for this purpose.

NOTE 1 This situation may be unavoidable in operation if, for example, feeders are switched from one busbar to another.

In circuits that have current limiting protective devices, equipment may have ratings that correspond to the cut-off (let through) current of the current limiting device.

NOTE 2 Equipment located between the busbar and the current-limiting devices will have sufficient through-fault current duty only in case of faults on the load side of the current-limiting devices.

7.1.2 Documentation

Where applicable, the documentation shall be provided with each installation to allow erection, commissioning, operation, maintenance and environmental protection.

The extent of the documentation shall be agreed upon between the supplier and the user.

Diagrams, charts and tables, if any, shall be prepared in accordance with IEC 60617 and IEC 61082.

7.1.3 Transport routes

7.1.3.1 Transport routes, their load capacity, height and width shall be adequate for movements of anticipated transport units and shall be agreed upon between the supplier and the user.

7.1.3.2 Within closed electrical operating areas, the passage of vehicles or other mobile equipment beneath or in proximity to live parts (without protective measures) is permitted, provided the following conditions are met (see figure 5):

– the vehicle, with open doors, and its load does not infringe the danger zone: minimum protective clearance for vehicles $T = N + 100$ (minimum 500 mm);

– the minimum height, H, of live parts above accessible areas is maintained (see 7.2.4).

Under these circumstances, personnel may remain in vehicles or mobile equipment only if there are adequate protective measures on the vehicle or mobile equipment, for example the cab roof, to ensure that the danger zone defined above cannot be infringed.

For the lateral clearances between transport units and live parts, similar principles apply.

7.1.4 Aisles and access areas

The width of aisles and access areas shall be adequate for work, operational access, emergency access, emergency evacuation and for transport of equipment.

7.1.5 Lighting

Accessible indoor and outdoor installations shall be provided with suitable lighting for routine operations.

Emergency/auxiliary lighting shall be provided if necessary; this may be a fixed installation or portable equipment.

In some cases, in small distribution substations, a lighting installation may not be required. In such cases, the presence and extent of the lighting shall be agreed upon between the supplier and the user.

Any part of the lighting installation which needs maintenance or replacement, for example lamps, shall be installed so that when the work is carried out correctly, the working clearance to live parts can be maintained.

NOTE Lighting levels should be in accordance with current applicable international and/or national standards and regulations.

7.1.6 Operational safety

Operational safety installations shall be designed so that the escape and rescue paths and the emergency exit can be safely used in the event of a fire, and that protection and environmental compatibility are ensured.

Where necessary, installations themselves shall be protected against fire hazard, flooding and contamination. If required, additional measures shall be taken to protect important installations against the effects of road traffic (salt spray, vehicle accident).

7.1.7 Labelling

Identification and labelling are required to avoid operating errors and accidents.

All important parts of the installation, for example busbar systems, switchgear, bays, conductors, shall be clearly, legibly and durably labelled.

Safety warnings, for example warning notices, safety instruction notices and informative notices shall be provided at suitable points in the installation (see 8.8).

NOTE Local and national regulations should be taken into account.

7.2 Outdoor installations of open design

The layout of open type outdoor installations shall take into account the minimum phase-to-phase and phase-to-earth clearances given in clause 5.

The design of the installation shall be such as to restrict access to danger zones, taking into account the need for operational and maintenance access. External fences shall therefore be provided and, where safety distances cannot be maintained, permanent protective facilities shall be installed.

A separation shall be provided between bays or sections by appropriate distances, protective barriers or protective obstacles.

7.2.1 Protective barrier clearances

Within an installation, the following minimum protective clearances shall be maintained between live parts and the internal surface of any protective barrier (see figure 1):

– for solid walls, without openings, with a minimum height of 1 800 mm, the minimum protective barrier clearance is $B_1 = N$;

– for equipment, where U_m is greater than 52 kV, a wire mesh, screen or solid wall, with openings, with a minimum height of 1 800 mm and a degree of protection of IP1XB (IEC 60529) shall be used. The minimum protective barrier clearance is $B_2 = N + 100$ mm;

– for equipment where U_m is up to 52 kV, a wire mesh, screen or solid wall, with openings, with a minimum height of 1 800 mm and a degree of protection of IP2X (IEC 60529), shall be used. The minimum protective barrier clearance is $B_3 = N + 80$ mm.

For non-rigid protective barriers and wire meshes, the clearance values shall be increased to take into account any possible displacement of the protective barrier or mesh.

7.2.2 Protective obstacle clearances

Within installations the following minimum clearance shall be maintained from live parts to the internal surface of any protective obstacle (see figure 1):

– for solid walls or screens less than 1 800 mm high, and for rails, chains or ropes, the minimum protective obstacle clearance is $O_2 = N + 300$ mm (minimum 600 mm);

– for chains or ropes, the values shall be increased to take into account the sag.

Where appropriate, protective obstacles shall be fitted at a minimum height of 1 200 mm and a maximum height of 1 400 mm.

NOTE Rails, chains and ropes are not acceptable in certain countries.

7.2.3 Boundary clearances

The external fence of outdoor installations of open design shall have the following minimum boundary clearances in accordance with figure 2:

– solid walls (height see 7.2.6) $C = N + 1\,000$ mm;

– wire mesh/screens (height see 7.2.6) $E = N + 1\,500$ mm.

The maximum opening of the wire mesh/screens shall not exceed 50 mm.

7.2.4 Minimum height over access area

The minimum height of live parts above surfaces or platforms where only pedestrian access is permitted shall be as follows:

– for live parts without protective facilities, a minimum height $H = N + 2\,250$ mm (minimum 2 500 mm) shall be maintained (see figure 3). The height H refers to the maximum conductor sag (see clause 4);

– the lowest part of any insulation, for example the upper edge of metallic insulator bases, shall be not less than 2 250 mm above accessible surfaces unless other suitable measures to prevent access are provided.

Where the reduction of safety distances due to the effect of snow on accessible surfaces needs to be considered, the values given above shall be increased.

7.2.5 Clearances to buildings (see figure 4)

Where bare conductors cross buildings which are located within closed electrical operating areas, the following clearances to the roof shall be maintained at maximum sag:

– the clearances specified in 7.2.4 for live parts above accessible surfaces, where the roof is accessible when the conductors are live;

– N + 500 mm where the roof cannot be accessed when the conductors are live;

– O_2 in lateral direction from the end of the roof if the roof is accessible when the conductors are live.

Where bare conductors approach buildings which are located within closed electrical operating areas, the following clearances shall be maintained, allowing for the maximum sag/swing in the case of stranded conductors:

a) outer wall with unscreened windows: minimum clearance given by D_V;

b) outer wall with screened windows (screened in accordance with 7.2.1);

c) protective barrier clearances B_2 in accordance with 7.2.1;

d) outer wall without windows: N.

7.2.6 External fences or walls and access doors

Unauthorized access to outdoor installations shall be prevented. Where this is by means of external fences or walls, the height and construction of the fence/wall shall be adequate to deter climbing.

Additional precautions may be required in some installations to prevent access by excavation beneath the fence.

The external fence/wall shall be at least 1 800 mm high. The lower edge of a fence shall not be more than 50 mm from the ground (for clearances see figure 2).

Access doors to outdoor installations shall be equipped with security locks.

External fences/walls and access doors shall be marked with safety signs in accordance with 8.8.

In some cases, for public security reasons, additional measures may be necessary.

Any adjacent fences, other structures and trees outside the installation should also deter climbing.

7.3 Indoor installations of open design

The layout of open-type indoor installations shall take into account the minimum phase-to-phase and phase-to-earth clearances specified in clause 5 (see tables 1 and 2 and annex A).

The design of the installation shall be such as to prevent access to danger zones taking into account the need of access for operational and maintenance purposes. Therefore, safety distances or permanent protective facilities within the installation shall be provided.

For protective barrier clearances, safety distances and minimum height, see 7.2.

For buildings, corridors, escape routes, doors and windows, see 7.5.

For solid walls or screens less than 1 800 mm high, and for rails, chains or ropes, the protective obstacle clearances are at least

$$O_1 = N + 200 \text{ mm (minimum 500 mm, see figure 1)}$$

For chains or ropes, the values shall be increased taking into account the sag. They shall be fitted at a minimum height of 1 200 mm to a maximum of 1 400 mm, where appropriate.

7.4 Installation of factory-built, type-tested enclosed switchgear

7.4.1 General

This subclause specifies additional requirements for equipment which apply to external connections, erection and operation at the place of installation. The installation shall be dimensioned and designed to avoid danger to persons and damage to property, taking into account the type of installation and local conditions.

Factory-built, type-tested high voltage switchgear shall be manufactured and tested in accordance with relevant IEC standards such as IEC 60298, IEC 60466, IEC 60517 and IEC 60694.

NOTE Normally, switchgear complying with IEC 60466 is considered as an open type indoor installation.

It shall be well adapted to its purpose, clearly arranged and so designed that essential parts are accessible for erection, operation and maintenance. Arrangements and access shall be provided to permit assembly at site. Future possible extensions should be considered.

Appropriate arrangements shall be made for external connections. Conductors and cables shall be selected and arranged in such a way as to ensure safe insulation level between conductors and between each conductor and surrounding earthed metallic structures.

Safety devices that are intended to reduce the internal switchgear pressure resulting from a fault shall be designed and arranged with consideration for their potential hazard to personnel. The accumulation of dangerous concentrations of gas decomposition products in switch rooms shall be prevented.

7.4.2 Additional requirements for gas-insulated metal-enclosed switchgear

7.4.2.1 Design

If platforms and ladders are necessary for operation and maintenance, they shall be designed and arranged to provide safe access for personnel. These elements may be fixed or removable.

Where necessary, arrangements shall be made to protect the switchgear from dangerous vibrations from transformers/reactors with gas-insulated connections. Bellows shall be provided, where necessary, to allow for heat expansion, erection tolerances and settlement of foundations.

For gas-insulated installations with several pressure chambers, clear labels shall be provided indicating the construction of the installation and the position of partitions. Monitoring devices shall be clearly marked and located to permit easy supervision.

Gas pipelines and fittings in areas where mechanical damage is expected shall be protected.

SF_6 gas pipelines shall be marked where there is a possibility of confusion with other pipelines.

7.4.2.2 Erection on site

Erection of GIS shall be carried out in a clean environment.

For outdoor installations, it may be necessary to provide a suitable temporary enclosure over the work area to protect the equipment from the environmental conditions whilst installation and/or maintenance is taking place.

For SF_6 gas handling, see 9.4.

For SF_6 leakage, see 8.7.2 and 8.7.3.

7.4.2.3 Protection against overvoltages

Protection of the GIS against overvoltages should normally be provided by the surge arresters installed on the feeders. In some cases, the protection given by this equipment may be inadequate. This situation arises mainly in the following configurations:

– large distance between the GIS and transformers;
– transformers connected to the GIS by means of cables;
– long busbars open at their ends;
– connection to overhead lines by means of insulated cables;
– locations with high probability of lightning strikes.

For these configurations, the installation of additional surge arresters may be required. Their location should be based on experience with similar situations or on calculations.

7.4.2.4 Earthing

The enclosure of a GIS should be connected to the earthing system at least at the following points:

a) inside the bays:
   - close to the circuit-breaker;
   - close to the cable sealing end;
   - close to the SF_6/air bushing;
   - close to the instrument transformer.

b) on the busbars:
   - at both ends and at intermediate points, depending on the length of the busbars.

The three enclosures of a single-phase type GIS shall be bonded together before earthing. The bonding conductor shall either be rated to carry the nominal current of the bays and busbars, or if a lower rated bonding conductor is used, then it shall be proved by tests that no danger will arise during operation.

Additional bonding straps are not required at flange joints if it can be ensured that the contact pressure of the flange provides adequate contact connection for high frequencies.

Earthing conductors of surge arresters for the protection of gas-insulated installations shall be connected by as short a connection as possible to the enclosure.

Metallic sheaths (for example metal enclosures, armoured coverings, screens) of cables with nominal voltages above 1 kV should be connected directly to the GIS enclosure.

In some special cases, e.g. cathodic protection of cables, it may be necessary to separate the earth connection of the cables from the GIS enclosure. In this case, the installation of a voltage surge protection device is recommended between the sealing end and enclosure.

7.5 Requirements for buildings

7.5.1 Introduction

Buildings shall comply with national building codes and fire regulations. Where such national standards do not exist, the following may be used as a guide.

This subclause indicates the requirements that have to be satisfied in areas or locations where electrical equipment for high voltage installations is installed. For the purpose of this standard, prefabricated substations covered by IEC 61330 are not considered as buildings.

7.5.2 Structural provisions

7.5.2.1 General

Load-carrying structural members, partition walls, claddings, enclosures, etc. shall be selected to withstand the expected combustible load.

Electrical operating areas shall be designed to prevent ingress of water and to minimize condensation.

Materials used for walls, ceilings and floors on the ground shall, where possible, not be damaged by water penetration or leakage. If this requirement cannot be met, precautions shall be taken to prevent the consequences of a leak or of condensation affecting the operating safety.

The building design shall take into account the expected mechanical loading and internal pressure caused by an arc fault.

Pipelines and other equipment, if allowed in substations, shall be designed so that the electrical installation is not affected, even in the event of damage.

7.5.2.2 Specifications for walls

The external walls of the building shall have sufficient mechanical strength for the environmental conditions.

The mechanical strength of the buildings shall be sufficient to withstand all static and dynamic loads due to normal operation of the installation.

The passage of pipes or wiring systems shall not affect the structural integrity of the walls.

Metal parts that pass through walls shall meet the requirements of clause 10.

Panels of the exterior surface of buildings that are accessible to the general public shall not be removable from the outside. The constituent materials of the external enclosures shall be capable of withstanding the attacks of atmospheric elements (rain, sun, aggressive wind, etc.).

7.5.2.3 Windows

Windows shall be designed so that entry is difficult. This requirement is considered fulfilled if one or more of the following measures are applied:

– the window is made of unbreakable material;
– the window is screened;
– the lower edge of the window is at least 1,8 m above the access level;
– the building is surrounded by an external fence at least 1,8 m high.

7.5.2.4 Roofs

The roof of the building shall have sufficient mechanical strength to withstand the environmental conditions.

If the ceiling of the switchgear room is also the roof of the building, the anchoring of the roof to the walls shall be adequate in terms of pressure relief.

7.5.2.5 Floors

The floors shall be flat and stable and shall be able to support the static and dynamic loads.

Raised floors shall be arranged so that the spread of fire is prevented.

7.5.3 Rooms for switchgear

The dimensions of the room and of required pressure relief openings depend on the type of switchgear and the short-circuit current.

If pressure relief openings are necessary, they shall be arranged and situated in such a way that when they operate (blow out due to an arc fault) the danger to people or property is minimized.

7.5.4 Service areas

Service areas comprise aisles, access areas, handling passages and escape routes.

Aisles and access areas shall be adequately dimensioned for carrying out work, operating switchgear and transporting equipment.

Aisles shall be at least 800 mm wide.

The width of the aisles shall not be reduced even where equipment projects into the aisles, for example permanently installed operating mechanisms or switchgear trucks in isolated positions.

Space for evacuation shall always be at least 500 mm, even when removable parts or open doors, which are blocked in the direction of escape, intrude into the escape routes.

For erection or service access ways behind closed installations (solid walls), a width of 500 mm is sufficient.

Clear and safe access for personnel shall be provided at all times.

The doors of switchgear cubicles or bays should close in the direction of escape.

Below ceilings, covers or enclosures, except cable accesses, a minimum height of 2 000 mm is required.

Exits shall be arranged so that the length of the escape route within the room does not exceed 40 m for rated voltages U_m greater than 52 kV, and 20 m for rated voltages up to U_m = 52 kV. This does not apply to accessible bus ducts or cable ducts.

If an operating aisle does not exceed 10 m, one exit is enough. An exit or emergency possibilities shall be provided at both ends of the escape route if its length exceeds 10 m.

Permanently installed ladders or similar are permissible as emergency exits in escape routes.

7.5.5 Doors

Access doors shall be equipped with security locks.

Access doors shall open outwards and be provided with safety signs in accordance with 8.8.

Doors which lead to the outside shall be of low flammability material, except where the building is surrounded by an external fence at least 1,8 m high.

Doors between various rooms within a closed electrical operating area are not required to have locks.

It shall be possible to open emergency doors from the inside without a key by using a latch or other simple means, even when they are locked from the outside. This requirement need not be complied with for small installations where the door has to be kept open during operating or servicing.

The minimum height of an emergency door shall be 2 000 mm and the minimum clear opening 750 mm.

7.5.6 Draining of insulating liquids

Protective measures shall be taken when insulating liquids are used (see also 8.7).

7.5.7 Air conditioning and ventilation

Indoor climate conditions shall be established e.g. by adequate cooling, heating, dehumidifying, ventilation or by adequate design of the building.

It is preferable to use natural ventilation for transformer rooms.

Forced ventilation systems (permanent or mobile) shall be designed to take into consideration smoke removal from the building.

Monitoring of the operation of a permanent fan is recommended.

Ventilation openings shall be designed so as to prevent any dangerous proximity to live parts and any dangerous ingress of foreign bodies.

Coolants and heat transfer media shall not contain mechanical impurities or chemically aggressive substances in quantities or qualities which may be hazardous to the correct function of the equipment in the installation.

Filters or heat exchangers shall be provided, if necessary.

Mechanical ventilation systems shall be so arranged and placed that inspection and maintenance can be carried out even when the switchgear is in operation.

7.5.8 Buildings which require special consideration

For high voltage installations located in public or residential buildings, special conditions shall be imposed, in accordance with existing standards or national regulations.

7.6 High voltage/low voltage prefabricated substations

For the rules governing manufacture and testing, see IEC 61330.

Compact substations shall be situated so that they are unlikely to be damaged by road vehicles. Adequate space for operating and maintenance purposes shall also be provided.

7.7 Electrical installations on mast, pole and tower

The minimum height H' of live parts above surfaces accessible to the general public shall be

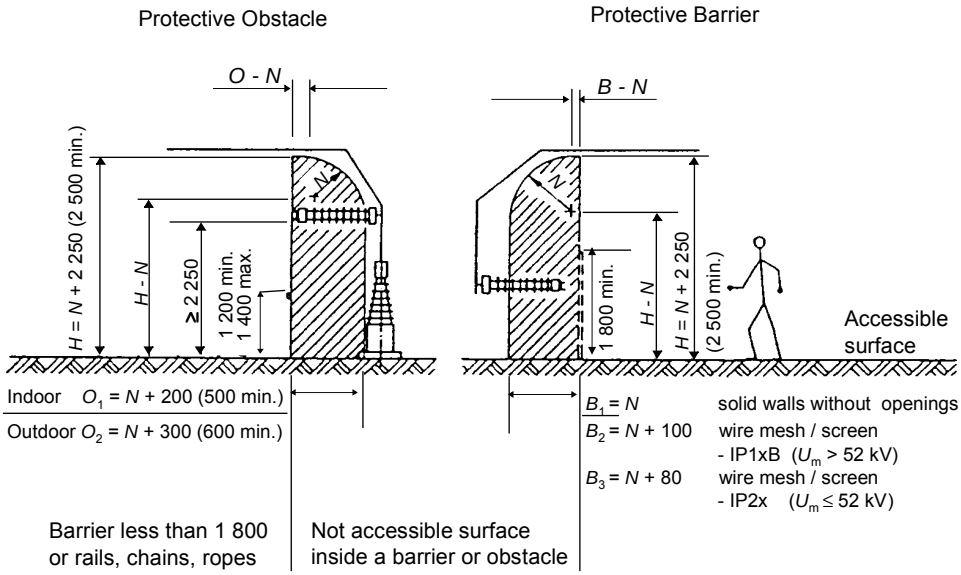
- H' = 4 300 mm for rated voltages U_m up to 52 kV;
- $H' = N$ + 4 500 mm (minimum 6 000 mm) for rated voltages U_m above 52 kV;

where N is the minimum clearance.

Where the reduction of safety distances due to the effect of snow on accessible surfaces needs to be considered, the values given above shall be increased.

Isolating equipment and fuses shall be arranged so that they can be operated without danger. If necessary, isolating equipment shall be capable of being locked. The operating rods shall be compliant with the relevant standard.

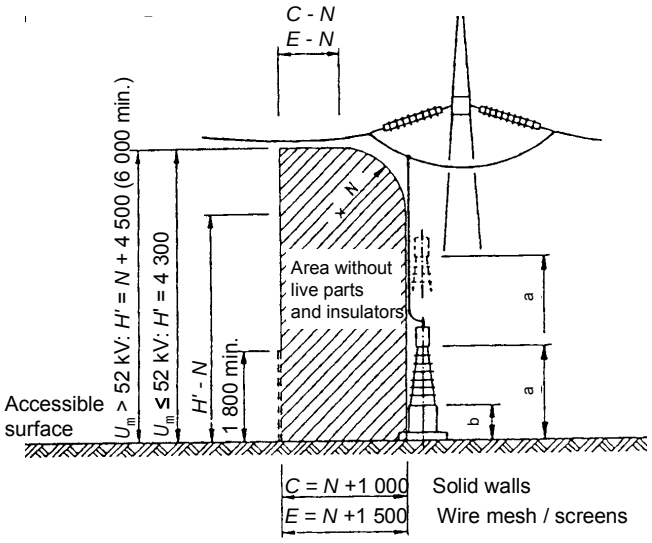
Safe phase-to-phase connection and earthing of the overhead line shall be possible.



N = Minimum clearance
O = Obstacle clearance
B = Barrier clearance

Dimensions in millimetres

Figure 1 – Protection against direct contact by protective barriers/protective obstacles within closed electrical operating areas



H' = Minimum clearance of live parts above accessible surface at the external fence

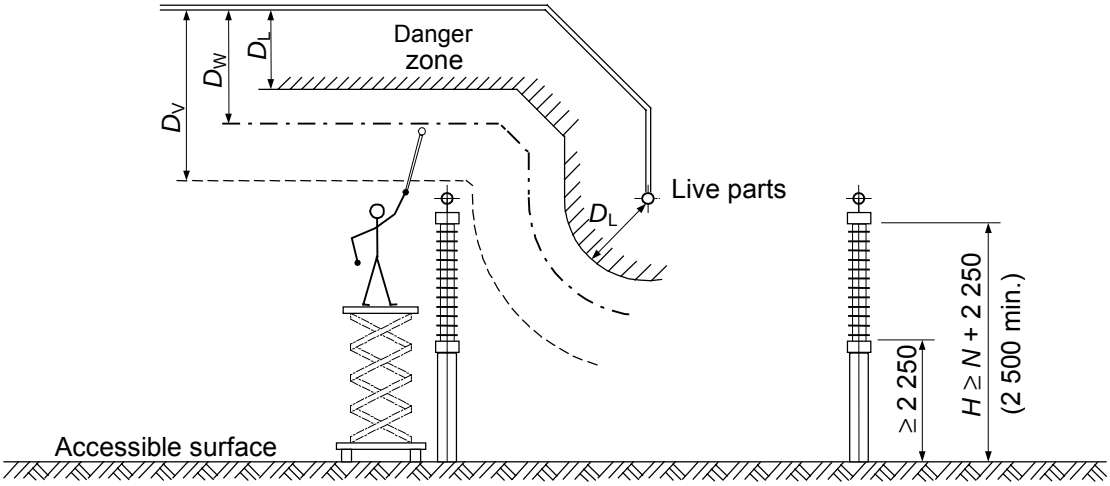
N = Minimum clearance

[a] If this distance to live parts is less than *H*, protection by barriers or obstacles shall be provided

[b] If this distance is smaller than 2 250 mm, protection by barriers or obstacles shall be provided

Dimensions in millimetres

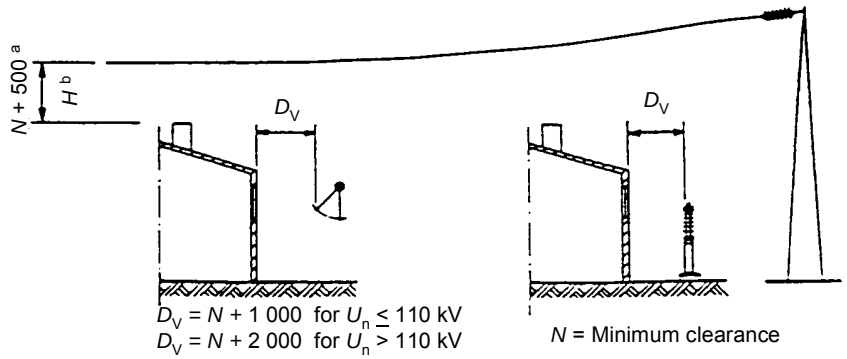
Figure 2 – Boundary distances and minimum height at the external fence/wall



D_L = N
D_V = N + 1 000 for $U_n \leq 110$ kV
D_V = N + 2 000 for $U_n > 110$ kV
D_W = according to national standards or regulations
N = minimum clearance

Dimensions in millimetres

Figure 3 – Minimum heights and minimum working clearances within closed electrical operating areas



[a] The roof cannot be accessed when the conductors are live.
[b] The roof can be accessed when the conductors are live.

Figure 4a - Outer wall with unscreened windows

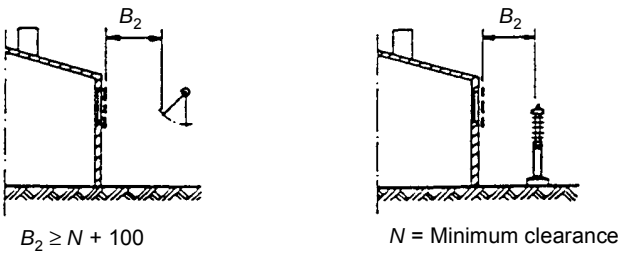
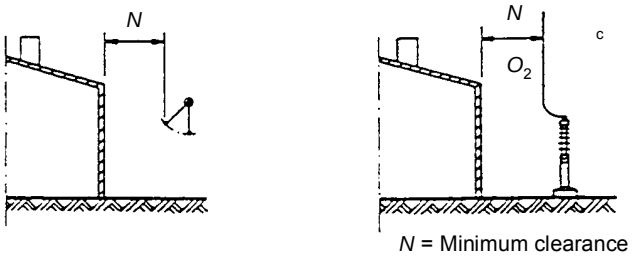


Figure 4b - Outer wall with screened windows

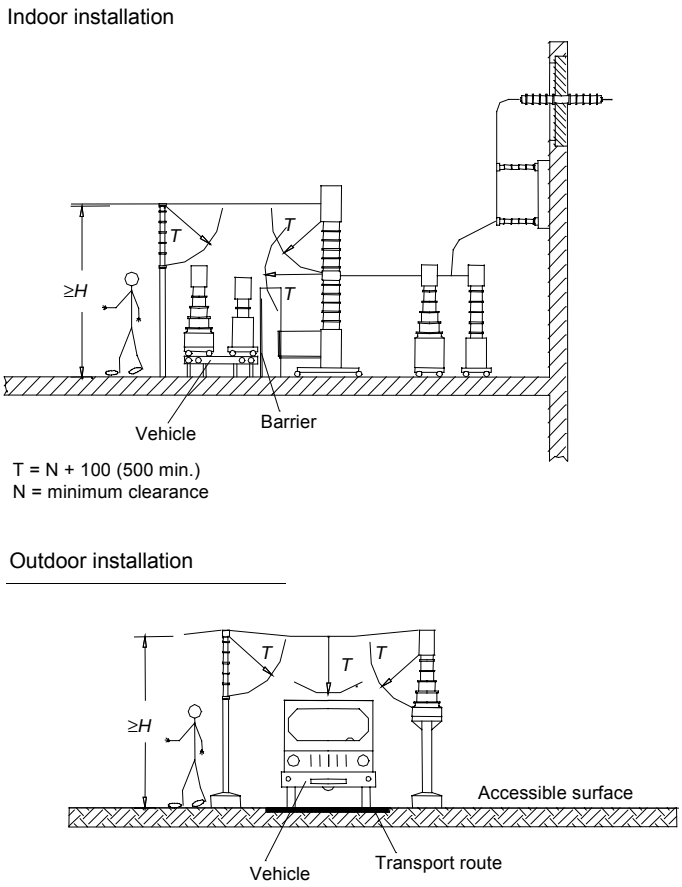


[c] $O_2 \geq N + 300$ (Min. 600) if the roof is accessible when the conductors are live.

Figure 4c - Outer wall without windows

Dimensions in millimetres

Figure 4 – Approaches with buildings (within closed electrical operating areas)



Dimensions in millimetres

Figure 5 – Minimum approach distance for transport

8 Safety measures

Installations shall be constructed in such a way as to enable the operating and maintenance personnel to circulate and intervene within the framework of their duties and authorizations, according to circumstances, at any point of the installation.

Specific maintenance work, preparation and repair work, which involve working in the vicinity of live parts or actual work on live parts, are carried out observing the rules, procedures and work distances as defined in national standards and regulations.

8.1 Protection against direct contact

8.1.1 General

Installations shall be constructed so that unintentional touching of live parts or unintentional reaching into a dangerous zone near live parts is prevented.

Protection shall be provided for live parts, parts with functional insulation only and parts which can be considered to carry a dangerous potential.

Examples of such parts are as follows:

– exposed live parts;
– parts of installations where earthed metallic sheaths or conducting screens of cables have been removed;
– cables and accessories without earthed metallic sheaths or earthed conducting elastomeric screens, as well as flexible cables without conducting elastomeric screens;
– terminations and conducting sheathing of cables, if they can carry a dangerous voltage;
– insulating bodies of insulators and other such parts, for example electrical equipment insulated by cast resin, if a dangerous touch voltage can occur;
– frames or cases of capacitors, converters and converter transformers, which can carry a dangerous voltage during normal operation.
– windings of electrical machines, transformers and air-cored reactors.

Protection may be achieved by different means, depending on whether the installation is located in a closed electrical operating area or not.

Information on protection against electric shock is given in IEC 61140.

8.1.2 Measures for protection against direct contact

8.1.2.1 The following types of protection are recognized.

– Protection by enclosure.
– Protection by barrier.
– Protection by obstacle.
– Protection by placing out of reach.

8.1.2.2 Design of protective measures

Protective barriers can be solid walls, doors or screens (wire mesh) with a minimum height of 1 800 mm to ensure that no part of the body of a person can reach the dangerous zone near live parts.

Protective obstacles can, for example, be covers, rails, chains and ropes as well as walls, doors and screens which are less than 1 800 mm high and therefore cannot be considered as protective barriers.

Protection by placing out of reach is achieved by placing live parts outside a zone extending from any surface where persons can usually stand or move about, to the limits which a person can reach with a hand in any direction (see clause 7).

Protective facilities used as a protective measure against direct contact, such as walls, covers, protective obstacles, etc., shall be mechanically robust and securely mounted.

Doors of switchgear rooms or bays used as a part of an enclosure shall be designed so that they can be opened only by using a tool or a key. In areas outside closed electrical operating areas, these doors shall be provided with safety locks.

Movable, conductive protective facilities shall be secured so that when correctly used the relevant protective barrier or protective obstacle clearance is maintained; otherwise they shall be made of insulating material or dry wood. It is permitted that a rail may be removed without the use of a tool. Protective rails shall be rigid.

In areas or rooms accessible to the public, protective facilities shall not be easily removable from outside with normal tools.

8.1.3 Protection requirements

8.1.3.1 Protection outside of closed electrical operating areas

Outside the closed electrical operating areas, only protection by enclosure or protection by placing out of reach is allowed.

When protection by enclosure is used, the minimum degree of protection shall be IP2XC.

NOTE As an exception, ventilation openings may be such that a straight wire cannot intrude into the equipment in such a way that it causes danger by approaching parts needing to be protected from direct contact.

When protection by placing out of reach is used, the vertical clearances between accessible surfaces and the parts to be protected from direct contact shall be in accordance with 7.2.6 or figure 2.

8.1.3.2 Protection inside closed electrical operating areas

Inside closed electrical operating areas, protection by enclosure, protective barrier, protective obstacle or placing out of reach is allowed.

When protection by enclosure is used, the degree of protection shall meet the requirements of IP2X in minimum. However, special protection measures to meet danger resulting from arc faults may be necessary.

When protection by protective barrier is used, see 7.2.1.

When protection by protective obstacle is used, see 7.2.2 and 7.3.

When protection by placing out of reach is used, see 7.2.4 and 7.2.5.

NOTE For more detailed requirements on external fences, transport routes, crossings and access to buildings, etc., see clause 7.

8.1.3.3 Protection during normal operation

NOTE The relevant standards for operation of electrical installations should be taken into account.

Protection measures in an installation shall take into account the need for access for purposes of operation and control and maintenance, e.g.:

– control of a circuit-breaker or a disconnector;
– changing a fuse or a lamp;
– adjusting a setting value of a device;
– resetting a relay or an indicator;
– earthing for work;
– erection of a temporary insulating shutter;
– reading the temperature or oil level of a transformer.

In installations with $U_m \leq 52$ kV, where doors or covers have to be opened in order to carry out normal operation or maintenance, it may be necessary to provide fixed non-conductive rails as a warning.

8.2 Means to protect persons in case of indirect contact

Measures to be taken in order to protect people in case of indirect contact are given in clause 10.

Information on protection against electric shock is given in IEC 61140.

8.3 Means to protect persons working on electrical installations

Electrical installations shall be constructed and installed to ensure that the measures necessary for the protection of persons working in or on electrical installations can be employed. The relevant standards for operation and maintenance of electrical power installations shall also be taken into account. The working procedures shall be agreed upon between the manufacturer and the user.

NOTE Whilst individual functions are considered in separate subclauses, these functions may be combined in a single item of equipment.

8.3.1 Equipment for isolating installations or apparatus

Equipment shall be provided by means of which the complete installation or sections thereof can be isolated, depending on operating requirements.

This may be achieved by disconnectors or switch disconnectors (see 6.2.1) or by disconnecting part of the installation, for example by removing links or cable loops. In the latter case, see 5.4.1.

Installations or parts of installations which can be energized from several sources shall be arranged so that all sources can be isolated.

If the neutral points of several pieces of equipment are arranged in parallel, it shall be possible to isolate them individually. This also applies to associated earth fault coils and resistors. The overvoltage protection shall be maintained.

Where equipment may still carry voltage after complete disconnection from the installation, for example capacitors, devices shall be provided to discharge them.

Isolating gaps may only be bridged by insulators if leakage currents from the terminal on one side to the terminal on the other side are prevented.

8.3.2 Devices to prevent reclosing of isolating devices

Suitable devices shall be provided to render inoperative the actuating force (that is spring force, air pressure, electrical energy) or the control of power mechanisms used for the operation of switchgear employed for isolating purposes. Users may require that these devices shall be able to be locked.

Where removable parts such as fuses or screw-in circuit breakers are used for complete disconnection and are replaced by screw caps or blank inserts, these caps or inserts shall be such that they can only be removed using an appropriate tool such as a key.

Manually operated switches shall permit the use of mechanical locking devices to prevent reconnection.

8.3.3 Devices for determining the de-energized state

Devices for determining that the equipment is no longer energized, shall be provided, where required, with due consideration for operational requirements. The extent of such provision shall be agreed upon between the supplier and the user.

All devices supplied shall permit the de-energized state to be checked at all points where the work is to be done and on all parts which have previously been live, without danger for the person performing the task.

Either fixed equipment or portable devices (see IEC 61243) can be used to meet this requirement.

8.3.4 Devices for earthing and short-circuiting

Each part of an installation which can be isolated from the other parts of the system shall be arranged to enable it to be earthed and short-circuited.

Equipment (for example transformers or capacitors) shall be provided with a means of earthing and short-circuiting at the point of installation, except where it is located in the immediate vicinity of the associated switchgear. This requirement shall not apply to parts of a system where this is not practicable or is unsuitable (for example transformers or electrical machines with flange-mounted cable sealing ends or with cable connection boxes). In these cases, earthing and short-circuiting shall be effected in the associated switchgear cubicles or bays on the primary and secondary sides. Normally it should be possible to earth and short-circuit both sides of a transformer.

The following shall be provided for or supplied as earthing and short-circuiting devices, the system chosen being agreed upon between the supplier and the user:

– earthing switches (preferably fault-making and/or interlocked);
– earthing switch trucks;
– free earthing rods and short-circuiting equipment (see IEC 61230);
– guided earthing rods and short-circuiting equipment (see IEC 61219).

For each part of an installation, suitably dimensioned and easily accessible connection points shall be provided on the earthing system and on the live parts for connection of earthing and short-circuiting equipment. Switchgear cubicles or bays shall be designed so that connection of the earthing and short-circuiting equipment by hand to the earth terminal point can be carried out in accordance with the rules for carrying out work in the vicinity of live parts.

When earthing and short-circuiting is achieved by remotely controlled earthing switches, the switch position shall be reliably transmitted to the remote control point.

8.3.5 Equipment acting as protective barriers against adjacent live parts

All boundary elements such as walls, floors, etc. shall be constructed according to 7.2 or 7.3.

If walls or protective facilities do not exist, the separation to neighbouring bays or sections shall respect the appropriate distances.

If working clearances cannot be maintained, live parts in the vicinity of the working area shall be capable of being covered by insertable insulated partitions or walls in such a way that accidental proximity to these parts by body parts, tools, equipment and materials is prevented.

8.3.5.1 Mobile screens and insertable insulated partitions shall meet the following requirements:

a) the edges of insulating shutters shall not be located within the danger zone;
b) gaps are permissible outside the danger zone:
   – up to 10 mm wide without limitation,
   – up to 40 mm wide provided the distance from the edge of the shutter to the danger zone is at least 100 mm,
   – up to 100 mm wide in the vicinity of disconnector bases.

Insertable insulated partitions used as protective barriers against live parts shall be part of the equipment or provided separately in accordance with operational requirements by agreement between the supplier and the user.

Insertable insulated partitions shall be capable of being secured so that their position cannot be accidentally altered where this would lead to a hazardous condition.

Insertable insulated partitions used as protective barriers against live parts shall not touch or be in contact with live parts.

It shall be possible to install and remove insertable insulated partitions without persons being required to enter the danger zone.

NOTE This can be achieved by the type of insulating shutters (for example angled plate, associated insulating rods, suitable operating rods) or by the installation (for example guide rails).

8.3.5.2 For installations without permanently installed partition walls, suitable insertable partition walls should be provided to isolate adjacent live cubicles or bays in accordance with the operational requirements. When required, the extent shall be agreed upon between the supplier and the user.

Partition walls which enter the danger zone during installation or removal, or which lie within the danger zone when fitted, shall meet the requirement for mobile insulating plates.

Insertable insulated partitions used as protective barriers against live parts shall not touch or be in contact with live parts.

8.3.6 Storage of accident prevention equipment

If accident prevention equipment is to be stored in the installation, a place shall be provided for this purpose where the equipment is protected from humidity, dirt and damage whilst remaining readily accessible.

8.4 Protection from danger resulting from arc fault

Electrical installations shall be designed and installed so that personnel are protected as far as practical from arc faults during operation.

The following list of measures to protect against dangers resulting from arc fault shall serve as a guide in the design and construction of electrical installations. The degree of importance of these measures shall be agreed upon between the supplier and user.

a) Protection against operating error, established, for example, by means of the following:
   - load break switches instead of disconnectors,
   - short-circuit rated fault-making switches,
   - interlocks,
   - non-interchangeable key locks.

b) Operating aisles as short, high and wide as possible (see 7.5).

c) Solid covers as an enclosure or protective barrier instead of perforated covers or wire mesh.

d) Equipment tested to withstand internal arc fault instead of open-type equipment (e.g. IEC 60298, IEC 60517).

e) Arc products to be directed away from operating personnel, and vented outside the building, if necessary.

f) Use of current-limiting devices.

g) Very short tripping time; achievable by instantaneous relays or by devices sensitive to pressure, light or heat.

h) Operation of the plant from a safe distance.

8.5 Protection against direct lightning strokes

Different methods of analysis are available. The method to be used shall be agreed upon between the supplier and user.

The user shall select the level of protection to be achieved, depending on the reliability level required, and the protection method to be used.

NOTE 1 For calculation methods, see for example either annex H of CENELEC HD 637 S1 or IEEE Guide 998.

Lightning rods and shield wires shall be earthed.

It is not necessary to equip a steel structure with a separate earthing conductor where it provides a suitable path for the lightning current itself.

Shield wires shall be connected to the steel structure or earthing conductor to ensure that the lightning current flows to earth. For buildings and similar structures, see IEC 61024.

NOTE 2 For technical and economic reasons, damage resulting from lightning strokes cannot be fully prevented.

8.6 Protection against fire

8.6.1 General

Relevant national, provincial and local fire protection regulations shall be taken into account in the design of the installation.

NOTE Fire hazard and fire risk of electrical equipment is separated into two categories: fire victim and fire origin. Precautions for each category should be taken into account in the installation requirements.

a) Precautions to fire victim:
   i) space separation from origin of fire;
   ii) flame propagation prevention:
      – grading,
      – liquid containment,
      – fire barriers (e.g. REI fire-resistant materials 60/90),
      – extinguishing system;
b) Precautions to fire origin:
   i) electrical protection;
   ii) thermal protection;
   iii) pressure protection;
   iv) fire resistant materials.

Care shall be taken that, in the event of fire, the escape and rescue paths and the emergency exits can be used (see 7.1.6).

The user or owner of the installation shall specify any requirement for fire extinguishing equipment.

Automatic devices to protect against equipment burning due to severe overheating, overloading and faults (internal/external) shall be provided, depending on the size and significance of the installation.

Equipment in which there is a potential for sparks, arcing, explosion or high temperature, for example electrical machines, transformers, resistors, switches and fuses, shall not be used in operating areas subject to fire hazard unless the construction of this equipment is such that flammable materials cannot be ignited by them.

If this cannot be ensured, special precautions, for example fire walls, fire-resistant separations, vaults, enclosures and containment, are necessary.

8.6.2 Transformers, reactors

In the following subclauses, the word 'transformer' represents 'transformers and reactors'.

For the identification of coolant types, see 6.2.2.2.

IEC 61100 classifies insulating liquids according to fire point and net caloric value (heat of combustion). IEC 60726 classifies dry-type transformers in terms of their behaviour when exposed to fire.

The fire hazard associated with transformers of outdoor and indoor installations is dependent on the rating of the equipment, the volume and type of insulating mediums, the type and proximity and exposure of nearby equipment and structures. The use of one or more recognized safeguard measures shall be used in accordance with the evaluation of the risk.

NOTE For definition of risk, see ISO/IEC Guide 51.

Common sumps or catchment tanks, if required, for several transformers shall be arranged so that a fire in one transformer cannot spread to another.

The same applies to individual sumps which are connected to the catchment tanks of other transformers; gravel layers or pipes filled with fluid can, for example, be used for this purpose. Arrangements which tend to minimize the fire hazard of the escaped fluid are preferred.

8.6.2.1 Outdoor installations

The layout of an outdoor installation shall be such that burning of a transformer with a liquid volume of more than 1 000 l will not cause a fire hazard to other transformers or objects. For this purpose adequate clearances, *G*, shall be necessary. Guide values are given in table 3. Where transformers with a liquid volume below 1 000 l are installed near combustible walls, special fire precautions may be necessary depending on the nature and the use of the building.

If it is not possible to allow for adequate clearance as indicated in table 3, fire-resistant separating walls with the following dimensions shall be provided:

a) between transformers (see figure 6) separating walls. For example EI 60 in accordance with the *Official Journal of the European Community*, No. C 62/23:
   - height: top of the expansion chamber (if any), otherwise the top of the transformer tank;
   - length: width or length of the sump (in the case of a dry-type transformer, the width or length of the transformer, depending upon the direction of the transformer);

b) between transformers and buildings (see figure 7) separating walls. For example EI 60; if additional fire separating wall is not provided, fire rating of the building wall should be increased, for example REI 90 in accordance with the *Official Journal of the European Community* C 62/23.

8.6.2.2 Indoor installations in electrical power systems

Minimum requirements for the installation of indoor transformers are given in table 4.

Table 3 – Guide values for outdoor transformer clearances

<table>
<tr><th rowspan="3">Transformer type</th><th rowspan="3">Liquid volume

l</th><th colspan="2">Clearance G to</th></tr>
<tr><th>other transformers or non-combustible building surface
m</th><th>combustible building surface
m</th></tr>
<tr><td rowspan="4">Oil insulated transformers (O)</td><td>1 000
<....<
2 000</td><td>3</td><td>7,6</td></tr>
<tr><td>2 000
<u>≤</u>....<
20 000</td><td>5</td><td>10</td></tr>
<tr><td>20 000
<u>≤</u>....<
45 000</td><td>10</td><td>20</td></tr>
<tr><td>≥ 45 000</td><td>15,2</td><td>30,5</td></tr>
<tr><td rowspan="2">Less flammable liquid insulated transformers (K) without enhanced protection</td><td>1 000
<...<
3 800</td><td>1,5</td><td>7,6</td></tr>
<tr><td>≥ 3 800</td><td>4,6</td><td>15,2</td></tr>
<tr><td rowspan="3">Less flammable liquid insulated transformers (K) with enhanced protection</td><td colspan="3">Clearance G to building surface or adjacent transformers</td></tr>
<tr><td colspan="2">Horizontal
m</td><td>Vertical
m</td></tr>
<tr><td colspan="2">0,9</td><td>1,5</td></tr>
<tr><td rowspan="3">Dry-type transformers (A)</td><td rowspan="2">Fire behaviour class</td><td colspan="2">Clearance G to building surface or adjacent transformers</td></tr>
<tr><td>Horizontal
m</td><td>Vertical
m</td></tr>
<tr><td>F0</td><td>1,5</td><td>3,0</td></tr>
<tr><td>F1 / F2</td><td>None</td><td>None</td></tr>
<tr><td colspan="4">NOTE Enhanced protection means
– tank rupture strength;
– tank pressure relief;
– low current fault protection;
– high current fault protection.
For an example of enhanced protection, see Factory Mutual Global standard 3990, or equivalent.</td></tr>
</table>

If automatically activated fire extinguishing equipment is installed, the clearance *G* can be reduced.

Table 4 – Minimum requirements for the installation of indoor transformers

Transformer type	Liquid volume l	Safeguards
Oil insulated transformers (O)	≤ 1 000	EI 60 respectively REI 60
	> 1 000	EI 90 respectively REI 90 **or** EI 60 respectively REI 60 and automatic sprinkler protection
Less flammable liquid insulated transformers (K) without enhanced protection		EI 60 respectively REI 60 **or** automatic sprinkler protection
Less flammable liquid insulated transformers (K) with enhanced protection	≤ 10 MVA and U_m ≤ 38 kV	EI 60 respectively REI 60 **or** separation distances 1,5 m horizontally and 3,0 m vertically
Dry-type transformer (A)	Fire behaviour class	
	F0	EI 60 respectively REI 60 **or** separation distances 0,9 m horizontally and 1,5 m vertically
	F1 / F2	Non combustible walls
NOTE 1 REI represents bearing system (wall) whereas EI represents non-load bearing system (wall) where R is the load bearing capacity, E is the fire integrity, I is the thermal insulation and 60/90 refers to time in minutes. NOTE 2 Enhanced protection means – tank rupture strength; – tank pressure relief; – low current fault protection; – high current fault protection. For an example of enhanced protection, see Factory Mutual Global standard 3990 or equivalent.		

Doors shall have a fire resistance of at least 60 min. Doors which open to the outside are adequate if they are of fire-retardant material and construction. Ventilation openings necessary for the operation of the transformers are permitted. When designing the openings, the possible escape of hot gases shall be considered.

8.6.2.3 Indoor installations in industrial buildings

For all transformers in industrial buildings, fast-acting protective devices which provide immediate automatic interruption in the event of failure are necessary.

Transformers with coolant type O require the same provisions as in 8.6.2.2.

For all other liquid-immersed transformers no special arrangements in respect of fire protection are required, except for the provisions for liquid retention in case of leakage and the provision of portable fire extinguishing apparatus suitable for electrical equipment.

Dry-type transformers (A) require the selection of the correct fire behaviour class depending on the activity of the industry and on the material present in the surroundings. Fire extinguishing provisions are advisable, particularly for class F0.

NOTE For all transformers in industrial buildings, additional fire precautions may be necessary, depending on the nature and use of the building.

8.6.2.4 Indoor installations in buildings which are permanently occupied by persons

In high voltage installations, located in public or residential buildings, special conditions shall be observed in accordance with existing standards or national regulations.

8.6.2.5 Fire in the vicinity of transformers

If there is an exceptional risk of the transformer being exposed to external fire, consideration shall be given to

– fire-resistant separating walls;
– gas-tight vessels capable of withstanding the internal pressure generated;
– controlled release of the hot liquid;
– fire extinguishing systems.

8.6.3 Cables

The danger of the spread of fire and its consequences shall be reduced, as far as possible, by selecting suitable cables and by the method of installation.

The cables may be assessed by reference to the following categories:

– cables without particular fire performance characteristics;
– cables (single) with resistance to flame propagation;
– cables (bunched) with resistance to flame propagation;
– cables with low emission of smoke;
– cables with low emission of acidic and corrosive gases (IEC 60754-1);
– cables with fire-resisting characteristics (IEC 60331-11 or IEC 60331-21).

Cables in trenches and buildings shall be laid in such a way that the regulations regarding fire safety of the building are not adversely affected. For example, to avoid fire propagation, holes through which the cables go from one room to another shall be sealed with suitable material.

A physical separation or different routing of power circuits from the control circuits for high voltage equipment is recommended if it is necessary to preserve the integrity of the latter as long as possible following damage to the power circuits.

Where necessary, fire alarm and fire extinguishing systems shall be installed in cable tunnels and in cable racks in the basement of control buildings.

8.6.4 Other equipment with flammable liquid

For all equipment (except instrument transformers), such as switchgear which contains more than 100 l of flammable liquid in each separate compartment, special fire precautions as specified for transformers may be necessary, depending on the nature and use of the installation and its location.

8.7 Protection against leakage of insulating liquid and SF_6

8.7.1 Insulating liquid leakage and subsoil water protection

8.7.1.1 General

Measures shall be taken to contain any leakage from liquid immersed equipment to prevent environmental damage. National and/or local regulations may specify the minimum quantity of liquid contained in an equipment for which containment is required. As a guideline, where no national and/or local regulations exist, containment should be provided around liquid immersed equipment containing more than 1 000 l or 2 500 l (refer to IEEE 980).

NOTE In all cases, local regulations should be taken into account and approvals obtained when required.

8.7.1.2 Containment for indoor equipment

In indoor installations, spills of insulating liquid may be contained by providing impermeable floors with thresholds around the area where the equipment is located or by collecting the spilled liquid in a designated holding area in the building (see figure 11).

The volume of the insulating liquid in the equipment as well as any volume of water discharges from a fire protection system shall be considered when selecting height of threshold or volume of the holding area.

8.7.1.3 Containment for outdoor equipment

The quantity of insulating liquid in equipment, the volume of water from rain and fire protection systems, the proximity to water courses and soil conditions shall be considered in the selection of a containment system.

NOTE 1 Containments (sumps) around liquid immersed equipment and/or holding tanks (catchment tanks) are extensively used to prevent escape into the environment of insulating liquid from equipment.

Containments and holding-tanks, where provided, may be designed and arranged as follows:

– tanks;

– sump with integrated catchment tank for the entire quantity of fluid (figure 8);

– sump with separate catchment tank. Where there are several sumps, the drain pipes may lead to a common catchment tank; this common catchment tank should then be capable of holding the fluids of the largest transformer (figure 9);

– sump with integrated common catchment tank for several transformers, capable of holding the fluids of the largest transformer (figure 10).

The walls and the associated pipings of sumps and catchment tanks shall be impermeable to liquid.

The capacity of the sumps/catchment tanks for insulating and cooling fluids shall not be unduly reduced by water flowing in. It shall be possible to drain or to draw off the water.

A simple device indicating the level of liquid is recommended.

Attention shall be paid to the danger of frost.

The following additional measures shall be taken for protection of waterways and of ground water:

– the egress of insulating and cooling fluid from the sump/tank/floor arrangement shall be prevented (for exceptions, see 8.7.1.1);
– drained water should pass through devices for separating the fluids; for this purpose, their specific weights shall be taken into account.

NOTE 2 For outdoor installations, CIGRÉ Report 23-07 recommends that the length and width of the sump is equal to the length and the width of the transformers plus 20 % of the transformer's height on each side. IEEE Guide 980 recommends that spill containment extends a minimum 1 500 mm beyond any liquid-filled part of the equipment.

NOTE 3 Examples for the automatic draining of water and separating of liquids is given in CIGRÉ Report 23-07 and IEEE 980.

State and regional laws and regulations shall be taken into account.

8.7.2 SF_6-leakage

Recommendations for use and handling of SF_6 gas are given in IEC 61634.

In rooms with SF_6 installations, which are above ground, natural cross-venting is sufficient. In this case, approximately half of the cross-section of the ventilation openings required shall be close to the ground. This measure depends on the size of the room and the gas quantity. In cases of malfunction, mechanical ventilation may be required.

NOTE 1 Permanent ventilation may be omitted for chambers in installations which are not accessible. For small installations (total quantity of SF_6 ≤ 1 000 l under atmospheric pressure), ventilation on one side of the room is sufficient.

In rooms with SF_6 installations, which are below ground on all sides, mechanical ventilation shall be provided if gas quantities which pose an intolerable risk to the health and safety of personnel (see note 2 below) are capable of collecting due to the gas quantity and the size of the room.

Chambers, ducts, pits, shafts, etc., situated below SF_6 installation rooms and connected to them, shall be able to be ventilated.

Mechanical ventilation may be omitted provided the gas volume of the largest gas compartment at atmospheric pressure does not exceed 10 % of the volume of the room. In this case the total volume (calculated at the normal temperature and pressure) of SF_6 gas in the cylinders connected to the SF_6 installations shall be taken into account for the purposes of calculation.

No part of equipment in contact with air may exceed a temperature of 200 °C.

NOTE 2 For maximum SF_6 concentration, national regulations should be considered.

8.7.3 Failure with loss of SF_6 and its decomposition products

Recommendations for use and handling of SF_6 gas are given in IEC 61634.

NOTE Guidance has been issued by CIGRÉ 23-04.

8.8 Identification and marking

8.8.1 General

Clear identification and unambiguous marking are required to avoid incorrect operation, human error, accidents, etc. while operation and maintenance are carried out (see also 7.1.7).

Signs, boards and notices shall be made of durable and non-corrosive material and printed with indelible characters.

The operational state of switchgear and controlgear shall be clearly shown by indicators except when the main contacts can clearly be viewed by the operator.

Cable terminations and components shall be identified. Relevant details making identification possible in accordance with a wiring list or diagram shall be provided.

8.8.2 Information plates and warning plates

In closed electrical operating areas and in industrial buildings, all electrical equipment rooms shall be provided, on the outside of the room and on each access door, with necessary information identifying the room and pointing out any hazards.

The colours and contrasting colours shall comply with IEC standards or national regulations.

8.8.3 Electrical hazard warning

All access doors to closed electrical operating areas and all sides of outer perimeter fences shall be provided with a warning sign.

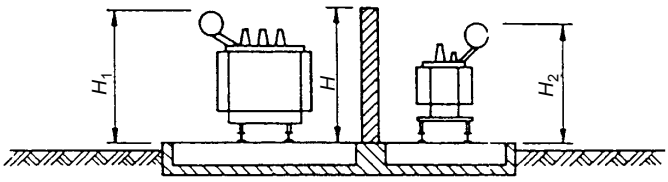
The signs shall comply with IEC standards or national regulations.

8.8.4 Installations with incorporated capacitors

The capacitors shall be provided with a warning label indicating the discharge time.

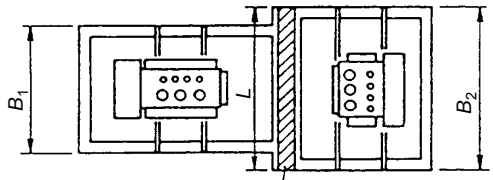
8.8.5 Emergency signs for emergency exits

Emergency exits shall be indicated by the appropriate safety warning sign. The signs shall comply with IEC standards or national regulations.



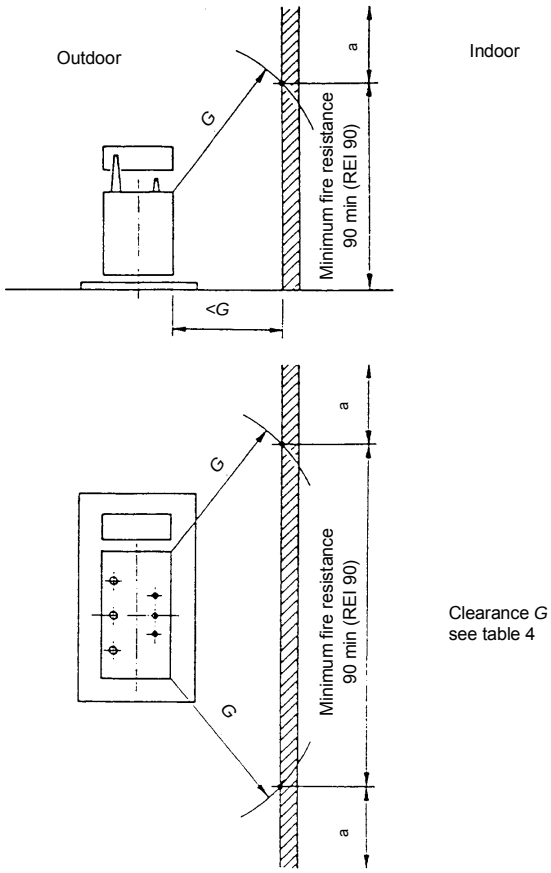
$H \geq H_1$ (with $H_1 > H_2$)

$L \geq B_2$ (with $B_2 > B_1$)



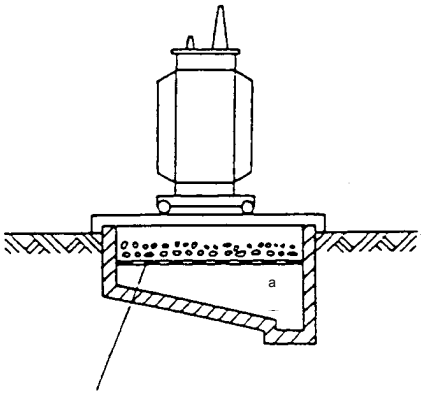
Minimum fire resistance 60 min for the separating wall (EI 60)

Figure 6 – Separating walls between transformers



[a] The wall in this area shall be designed to avoid a spread of fire.

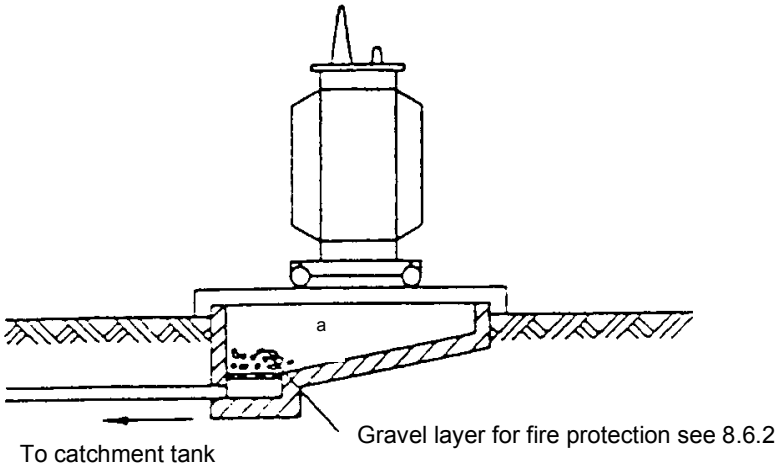
Figure 7 – Fire protection between transformer and building



NOTE In addition, the water from the fire extinguishing installation (if any) should be considered.

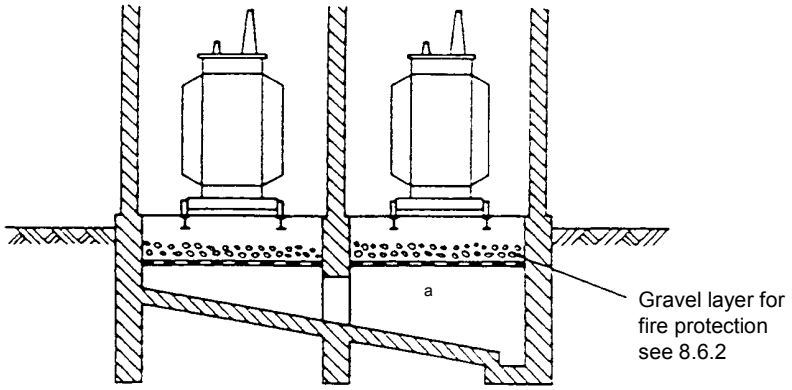
[a] Containment: the entire quantity of fluid of the transformer plus rain water.

Figure 8 – Sump with integrated catchment tank



[a] Containment: minimum 20 % of the fluid from the transformer.

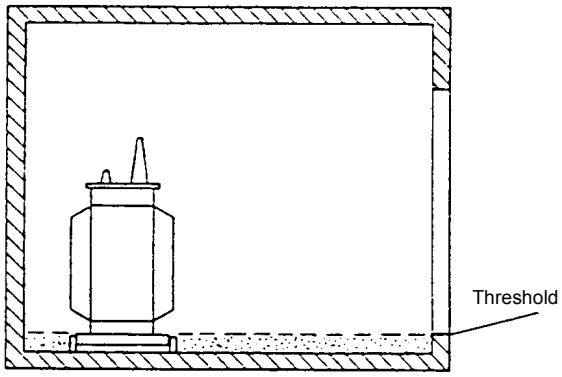
Figure 9 – Sump with separate catchment tank



NOTE In addition, the water from the fire extinguishing installation (if any) should be considered.

[a] Containment outdoor: the entire quantity of fluid of the largest transformer plus rain.
Containment indoor: the entire quantity of fluid of the largest transformer.

Figure 10 – Sump with integrated common catchment tank



NOTE The dotted area denotes the volume of the entire quantity of insulating fluid of the transformer spilled on the floor.

Figure 11 – Example for small transformers without gravel layer and catchment tank

9 Protection, control and auxiliary systems

9.1 Monitoring and control systems

9.1.1 Monitoring, protection, regulating and control devices shall be provided, as necessary, for the correct and safe functioning of the equipment.

9.1.2 Automatic devices, designed to offer selectivity and quick operation, shall provide protection against the effects of unacceptable overload and internal and external faults appropriate to the size and significance of installation.

9.1.3 Equipment shall comply with the severity class (see IEC 60255) corresponding to the part of the installation in which it is located.

9.1.4 Facilities shall be provided for isolating the control circuit of each primary switching equipment or each switchgear bay in order to allow maintenance of high voltage equipment to be performed safely.

9.1.5 Provision shall be made to allow for repair, maintenance, and/or testing to be carried out on protection and control devices without any danger to personnel or the equipment.

9.1.6 Control circuits and signalling circuits shall, preferably, be functionally separated. Tripping signals shall be displayed on the protection panel if it exists.

9.1.7 Alarm and fault-indicating equipment shall clearly indicate danger and fault conditions; several signals can be combined as a common signal to be transmitted to a remote control point.

9.1.8 The control equipment and system, including cables and cords, shall be designed and installed to minimize the possibility of damage to the connected equipment due to electro-magnetic interference. Basic rules are given in 9.5.

9.1.9 The control equipment and system, including cables and cords, shall be designed and installed in such a way that they minimize the danger from operating failure, inadvertent operation or incorrect information. In meeting this requirement, influences such as voltage dips, supply failure, insulation faults and electromagnetic interference effects shall be taken into account.

9.1.10 The actuating elements for the control of a switchgear shall be designed and installed in such a way that accidental actuation is avoided.

9.1.11 Where a remote control is available, local/remote control selection shall be provided at the local operating position (i.e. at or in the close vicinity of the switches) and at any different location from which the equipment can be operated.