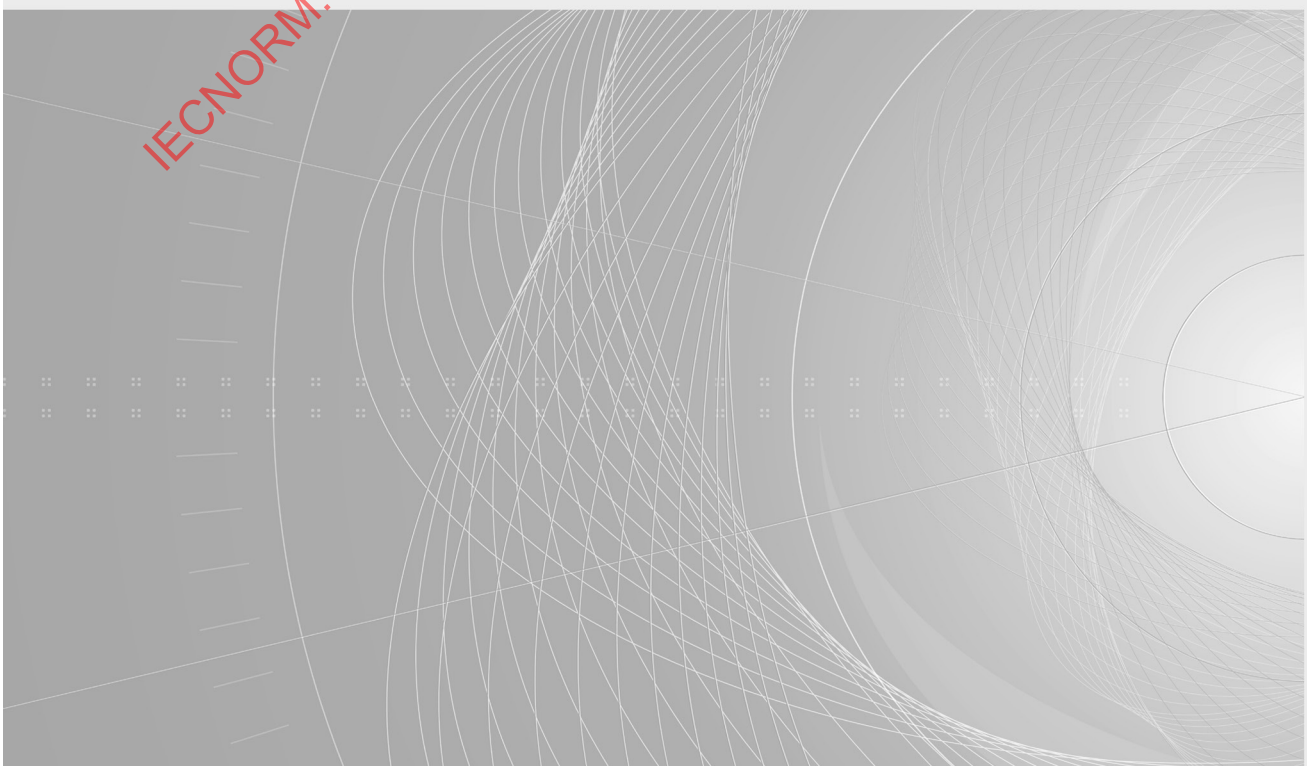
IEC TS 61936-0

Edition 1.0 2023-05

TECHNICAL SPECIFICATION

Power installations exceeding 1 kV AC and 1,5 kV DC –
Part 0: Principles to be observed in the design and erection of high voltage installations – Safety of high voltage installations



IEC TS 61936-0:2023-05(en)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.020; 29.080.01

ISBN 978-2-8322-6946-6

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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POWER INSTALLATIONS EXCEEDING 1 kV AC AND 1,5 kV DC –

Part 0: Principles to be observed in the design and erection of high voltage installations – Safety of high voltage installations

FOREWORD

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IEC TS 61936-0 has been prepared by technical committee 99: Insulation co-ordination and system engineering of high voltage electrical power installations above 1,0 kV AC and 1,5 kV DC. It is a Technical Specification.

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
99/375/DTS	99/404/RVDTS

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Specification is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at https://www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at https://www.iec.ch/standardsdev/publications.

A list of all parts in the IEC 61936 series, published under the general title *Power installations exceeding 1 kV AC and 1,5 kV DC*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

The scope of TC 99 is the standardisation of insulation co-ordination for high voltage systems and common rules and particular requirements for system engineering and erection of high voltage electrical power installations for power generation, transmission, distribution, and consumer premises, in both indoor and outdoor situations, with particular consideration of safety aspects.

With the increasing development of electric power systems and renewable energy devices, there is an increasing demand for Technical Committees to define installations, systems and equipment at voltages above 1,0 kV AC and 1,5 kV DC. This requirement became evident during the activities of TC 99 AhG6's discussions with TC 18 and TC 88 where a review of documents prepared by these TCs showed that there was a need for a document which defines principles to be observed in design and the erection of HV installations.

The objective of this document is to give the principles for TCs in how to define requirements with respect to HV installations to ensure that safety of such systems is maintained and that a consistent approach is taken by all TCs involved with HV installations with respect to design, operation and maintenance of installation at voltages above 1,0 kV AC and 1,5 kV DC.

Figure 1 below describes the relationship of this document to other IEC standards:

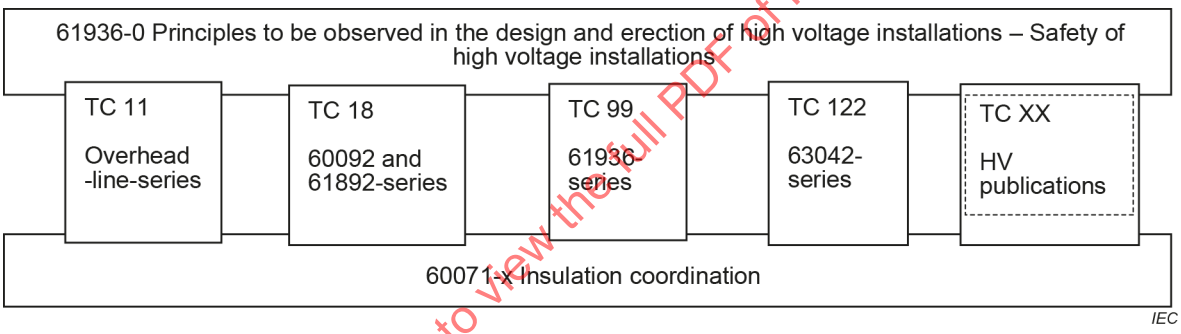

Figure 1 – Relationship of IEC 61936-0 to other IEC standards

POWER INSTALLATIONS EXCEEDING 1 kV AC AND 1,5 kV DC –

Part 0: Principles to be observed in the design and erection of high voltage installations – Safety of high voltage installations

1 Scope

This part of IEC 61936 provides principles to ensure the coherence amongst HV publications to be observed necessary for the coordination of the design, selection of equipment, operation, and maintenance activities for erection of electrical HV installations to ensure the safety of such systems.

In the context of this document, "safety" relates to the safety of persons, domestic animals, livestock and property.

This Technical Specification is intended for use by technical committees in the preparation of standards with safety aspects which can be a part of an electrical high voltage installation.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC Guide 51:2014, *Safety aspects – Guidelines for their inclusion in standards*

IEC 60068 (all parts), *Environmental testing*

IEC 60071 (all parts), *Insulation co-ordination*

IEC 60445, *Basic and safety principles for man-machine interface, marking and identification – Identification of equipment terminals, conductor terminations and conductors*

IEC TR 60479-5, *Effects of current on human beings and livestock – Part 5: Touch voltage threshold values for physiological effects*

IEC 60529, *Degrees of protection provided by enclosure (IP Code)*

IEC 60721 (all parts), *Classification of environmental conditions*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at https://www.iso.org/obp
- IEC Electropedia: available at https://www.electropedia.org/

3.1
arc
arcing
luminous discharge of electricity across an insulating medium, usually accompanied by the partial volatilization of the electrodes

Note 1 to entry: A complete sinusoidal current half-cycle is not considered to be an arcing half-cycle.

[SOURCE: IEC 60050-442:1998/AMD3:2019, 442-05-65]

3.2
arc fault
arcing fault
dangerous unintentional arc

[SOURCE: IEC 60050-442:1998/AMD3:2019, 442-05-66]

3.3
arm's reach
zone of accessibility to touch extending from any point on a surface where persons usually stand or move about to the limits which a person can reach with the hand, in any direction, without assistance

[SOURCE: IEC 60050-195:2021, 195-06-12, modified – The note has been removed.]

3.4
automatic disconnection of supply
interruption of one or more of the line conductors effected by the automatic operation of a protective device in the event of a fault

Note 1 to entry: This does not necessarily mean an interruption in all conductors of the supply system.

[SOURCE: IEC 60050-195:2021, 195-04-10, modified – "in the event of a fault" replaces "in case of a fault" and Note 1 to entry added]

3.5
basic insulation
insulation that provides basic protection

Note 1 to entry: This concept does not apply to insulation used exclusively for functional purposes.

[SOURCE: IEC 60050-195:2021, 195-06-06]

3.6
conditions

3.6.1
normal condition
<protection against electric shock> condition in which all means of protection are intact

[SOURCE: IEC 60050-903:2013, 903-02-07, modified – "<protection against electric shock> has been added.]

3.6.2
single fault condition
<protection against electric shock> condition in which there is a fault of a single protection (but not a reinforced protection) or of a single component or a device

Note 1 to entry: If a single fault condition results in one or more other fault conditions, all are considered as one single fault condition.

[SOURCE: IEC 60050-903:2013, 903-01-15 modified – "<protection against electric shock>" has been added.]

3.6.3
environmental condition
characteristic of the environment which may affect performance of a component, device or equipment

Note 1 to entry: Examples of environmental conditions are external influences, characteristics of the power supply, duty cycle or duty type.

[SOURCE: IEC 60050-151:2001, 151-16-01 modified – The term "operating conditions" has been replaced by "environmental condition". It has also been replaced by "environmental conditions" in Note 1 to entry.]

3.6.4
normal environmental condition
characteristic of the environment which may affect performance of a device or system, and which is standardized as normal

Note 1 to entry: Examples of environmental conditions are pressure, temperature, humidity, radiation, vibration.

Note 2 to entry: Conditions which are normal as described in IEC Guide 111.

[SOURCE: IEC 60050-151:2001, 151-16-03, modified – The words "and which is standardized as normal" have been added.]

3.6.5
special environmental condition
characteristic of the environment which may affect performance of a device or system, and which is standardized as special

Note 1 to entry: Examples of environmental conditions are pressure, temperature, humidity, radiation, vibration.

Note 2 to entry: Conditions which is special as described in IEC Guide 111.

Note 3 to entry: See 5.3 of IEC Guide 111:2004 for more information on special environmental conditions.

3.6.6
operating condition
state of a component, device, equipment or system characterized by one or more properties

3.6.7
normal operating condition
operating condition representing the range of intended use

[SOURCE: IEC 60050-903:2013/AMD1:2014, 903-01-21 modified – "as closely as possible" has been removed, as well as ""that can reasonably be expected" and "normal use" has been replaced by "intended use".]

3.6.8
abnormal operating condition
operating condition that is not a normal operating condition and is not a single fault condition of the equipment itself

[SOURCE: IEC 60050-903/AMD1:2014:2013, 903-01-22]

3.6.9
intended use
use of a product, process or service in accordance with the information for use

[SOURCE: IEC 60050-903:2014, 903-01-13, modified – The words “provided by the supplier” have been removed.]

3.7
danger zone
in the case of HV, area limited by the minimum clearance around live-parts without complete protection

Note 1 to entry: Entering the danger zone is considered the same as touching live-parts.

[SOURCE: IEC 61140:2016, 3.35, modified – In Note 1 to entry, “hazardous-live-parts” has been replaced by “live-parts”.]

3.8
minimum clearance of danger zone
N
clearance which describes the area of danger zone around live-parts without complete protection

[SOURCE: IEC 61936-1:2021, 3.5.6, modified – “hazardous” and “against direct contact” have been removed, as well as the two notes]

3.9
vicinity zone
limited space outside the live working zone where specific precautions are taken to avoid encroaching into the live working zone

Note 1 to entry: Encroaching into the live working zone will create an electrical hazard.

Note 2 to entry: The outer boundary of the vicinity zone and the specific precautions that apply are generally defined by national or company regulations.

Note 3 to entry: This entry was numbered 651-01-07 in IEC 60050-651:1999. It has been modified as follows: Greater detail is provided regarding the precautions to be taken when in the vicinity zone.

[SOURCE: IEC 60050-651:2014, 651-21-04]

3.10
reference earth
reference ground, US
part of the Earth considered as conductive, the electric potential of which is conventionally taken as zero, being outside the zone of influence of any earthing arrangement

Note 1 to entry: The concept “Earth” means the planet and all its physical matter.

[SOURCE: IEC 60050-195:2021, 195-01-01]

3.11
earth, verb
ground, verb (US)
to make an electrical connection between a conductive part and a local earth

Note 1 to entry: The connection to local earth can be:

– intentional; or

– unintentional or accidental

and can be permanent or temporary.

[SOURCE: IEC 60050-195:2021, 195-01-08]

3.12
local earth
local ground (US)
part of the Earth which is in electric contact with an earth electrode and the electric potential of not necessarily equal to zero

[SOURCE: IEC 60050-195:2021, 195-01-03]

3.13
earthing arrangement
grounding arrangement (US)
all the electrical means involved in the earthing of a system, installation or equipment

Note 1 to entry: Electric connection and devices used for earthing are examples of electrical means.

[SOURCE: IEC 60050-195:2021, 195-02-20]

3.14
earthing conductor
grounding conductor (US)
conductor which forming a conductive path between a conductive part and an earth electrode

EXAMPLE A conductor connected between a main earthing terminal or busbar and an earth electrode.

[SOURCE: IEC 60050-195:2021, 195-02-03]

3.15
earth electrode
ground electrode (US)
conductive part that is in electric contact with local earth, directly or through an intermediate conductive medium

[SOURCE: IEC 60050-195:2021, 195-02-01]

3.16
earthed protective-equipotential-bonding
protective-equipotential-bonding connected to local earth

3.17
equipotential bonding
set of electric connections intended to achieve equipotentiality between conductive parts

Note 1 to entry: The effectiveness of the equipotential bonding may depend on the frequency of the current in the bonding.

[SOURCE: IEC 60050-195:2021, 195-01-10, modified – Note 1 to entry added]

3.18
exposed-conductive-part
conductive part of equipment that can be touched and which is not live under normal conditions, but that can become live when basic insulation fails

Note 1 to entry: A conductive part of electrical equipment which can become live only through contact with an exposed-conductive-part which has become live, is not considered to be an exposed-conductive-part itself.

[SOURCE: IEC 60050-195:2021, 195-06-10 modified – Note 1 to entry added]

3.19
extraneous-conductive-part
conductive part not forming part of the electrical installation and that is likely to introduce an electric potential, generally the electric potential of a local earth

[SOURCE: IEC 60050-195:2021, 195-06-11

3.20
instructed person
electrically instructed person
person adequately advised or supervised by electrically skilled persons to enable him or her to perceive risks and to avoid hazards which electricity can create

[SOURCE: IEC 60050-195:2021, 195-04-02]

3.21
insulation
set of properties which characterize the ability of an insulation to provide its function

Note 1 to entry: Examples of relevant properties are: resistance, breakdown voltage.

Note 2 to entry: Insulation can be a solid, a liquid or a gas (e.g. air), or any combination.

[SOURCE: IEC 60050-151:2001, 151-15-42, modified – Note 2 to entry has been added]

3.22
insulation coordination
selection of the dielectric strength of equipment in relation to the operating voltages and overvoltages which can appear on the system for which the equipment is intended, and taking into account the service environment and the characteristics of the available preventing and protective devices

[SOURCE: IEC 60050-614:2016, 614-03-08]

3.23
live part
conductive part intended to be energized in normal operating conditions, including a neutral conductor or mid-point conductor

Note 1 to entry: This concept does not necessarily imply a risk of electric shock.

[SOURCE: IEC 60050-195:2021, 195-02-19, modified – “under normal operating conditions, including the neutral conductor and mid-point conductor, but excluding the PEN conductor, PEM conductor and PEL conductor” has been replaced with “normal operating conditions, including a neutral conductor or mid-point conductor”. Note 1 to entry has been added.]”

3.24
main contact
contact included in the main circuit of a mechanical switching device, intended to carry, in the closed position, the current of the main circuit

[SOURCE: IEC 60050-441:1984, 441-15-07]

3.25
manual disconnection of supply
interruption of one or more of the line conductors effected by the manual operation of an operating person in the event of a fault

3.26
ordinary person
person who is neither a skilled person nor an instructed person

[SOURCE: IEC 60050-195:2021, 195-04-03]

3.27
overvoltage
voltage:

– between one phase conductor and earth or across a longitudinal insulation having a peak value exceeding the peak of the highest voltage of the AC-system divided by $\sqrt{3}$ or;
– between phase conductors having a peak value exceeding the amplitude of the highest voltage of the AC-system
– voltage having a value exceeding the corresponding highest steady state voltage of the DC-system

[SOURCE: IEC 60050-614:2016, 614-03-10, modified – The specific use <in an electric power system> has been removed. In the first dash, “line” has been replaced with “phase” and “of the AC-system” has been added; in the second dash: “of the AC-system” has been added and the last dash has been added.]

3.28
potential grading
<for HV installations> control of the local earth potential, especially the earth surface potential, by means of earth electrodes

3.29
protective barrier
<electrically> part providing protection against contact by a human being or livestock with a live part from any usual direction of access

[SOURCE: IEC 60050-195:2021, 195-06-15, modified – "human being or livestock with hazardous-live-parts" has been replaced with "human or livestock with a live part"]

3.30
protective-equipotential-bonding
equipotential bonding for the purposes of electrical safety

[SOURCE: IEC 60050-195:2021, 195-01-15]

3.31
protective obstacle
<electrically> part preventing unintentional contact by a human or livestock with a live part, but not preventing such contact by deliberate action

[SOURCE: IEC 60050-195:2021, 195-06-16, modified – “with hazardous-live-parts” has been replaced by “with a live part”.]

3.32
protective measure
<protection against electric shock>appropriate combination of protective provisions

[SOURCE: IEC 60050-195:2021, 195-06-26]

3.33
protective provision
independent provision intended to protect against electric shock under specified conditions

Note 1 to entry: The provision may be a means or technique or device or process.

[SOURCE: IEC 60050-195:2021, 195-06-25, modified – Note 1 to entry has been added.]

3.34
short-circuit current
current flowing at a given point of a network resulting from a short circuit at another point of this network

[SOURCE: IEC 60050-603:1986, 603-02-26]

3.35
skilled person
electrically skilled person
person with relevant education and experience to enable him or her to perceive risks and to avoid hazards which electricity can create

[SOURCE: IEC 60050-195:2021, 195-04-01]

3.36
step voltage
voltage between two points on the Earth's surface

Note 1 to entry: Typically, a distance of 1 m between the two points is considered to be the stride length of a person.

[SOURCE: IEC 60050-195:2021, 195-05-12, modified – The term “human being” has been replaced by “person”.]

3.37
thermal hazard
harm caused by high or low temperatures in, near or on electrical equipment

3.38
touch voltage
<effective> voltage between conductive parts when touched simultaneously by a human being or livestock

Note 1 to entry: The value of the effective touch voltage is influenced by the impedance of the human being or the livestock in electric contact with these conductive parts.

[SOURCE: IEC 60050-195:2021, 195-05-11]

3.39
undervoltage
voltage between phase conductors having a value below the lowest voltage of the installation for correct operation or preventing damage to equipment

4 General requirements for design, construction, operation and maintenance

4.1 General

Electrical HV installations shall be designed, constructed and be able to be operated and maintained such that they fulfil their intended function with necessary protection against electric shock, burns and thermal effects of persons, livestock and property when used according to the intended use and for reasonably foreseeable misuse.

Installations shall be constructed and secured such that operations and maintenance can be performed in a manner that do not cause harm to persons, the public and the surroundings. Necessary safety equipment should be accessible.

Installations and their equipment shall be suitable for the stresses to which they may be exposed and for the surrounding in which they shall operate.

The requirements regarding risk management in ISO/IEC Guide 51 shall be met in the process for establishing the requirements in HV-standards.

NOTE The ISO/IEC 31000 series and the ISO/IEC 31010 series give guidelines for risk management for the user of the standards.

Clause 5 to Clause 10 of this document give principles to be adopted for the safe design of HV installations.

4.2 Basic requirements during faults

Electrical installations shall be designed, constructed such that protection against hazards is ensured under normal conditions and under credible single fault conditions or a single erroneous operation. Faults shall be managed or corrected.

4.3 Danger signs and labelling

Installations shall have danger signs, labelling and identification, such that erroneous operation and accidents are prevented. Danger signs, labelling and identification shall be durable, clear, readily visible.

4.4 Protection, automation, and auxiliary systems

Installations should have the auxiliary systems and equipment for monitoring, automation and protection which are necessary for carrying out operations and maintenance.

4.5 Considerations of design to ensure maintainability, constructability, and operability

The design of electrical power installations should take into account the work activities that may be undertaken to ensure maintainability in addition to constructability and operability of electrical power installations.

The methods of working in the live working zone, in the vicinity zone or dead working shall be able to be performed in a proper manner.

The values for the minimum clearance of danger zone in AC installations are given in Tables 2 and 3 (N) in IEC 61936-1:2021. These values can be used to define clearances in the design of installations and for working. It describes the area of danger zone around live parts without complete protection against direct contact.

Working distances may be determined based upon minimum clearance of danger zone, taking into consideration overvoltage conditions and ergonomic factors (e.g. considerations of inadvertent movements (full or expected reach) of persons, tools, equipment, vehicles and conductors).

NOTE Requirements for DC installations are under consideration.

5 Protection against electric shock[1]

5.1 General

This Clause 5 is limited to installations up 1 000 Hz.

Electric shock is defined as the physiological effect resulting from an electric current passing through a human body or livestock. The physiological effect can be harmful (such as ventricular fibrillation, burns, asphyxiation), or non-harmful (such as muscular reaction, perception).

Live-parts shall not be accessible and accessible conductive parts shall not become hazardous, either:

– under normal conditions (under intended use, see 3.6 of ISO/IEC Guide 51:2014, and absence of a fault); or
– under single-fault conditions.

NOTE The accessibility rules for ordinary persons can differ from those for skilled or instructed persons and can also vary for different products and locations.

Protection under normal conditions is provided by basic protection.

Protection under single-fault conditions is provided by fault protection.

5.2 Normal conditions

To meet the fundamental rule for protection against electric shock under normal conditions, basic protection, as specified in this document, is necessary.

The requirements for provisions for basic protection are given in 5.4.2.

5.3 Single-fault conditions

5.3.1 General

Single faults shall be considered, if they would:

– cause an accessible conductive part which is not energized under normal conditions to become energized (e.g. due to failure of basic insulation to exposed-conductive-parts or extraneous-conductive-parts).

To meet the fundamental rule under single-fault conditions, fault protection is necessary. This protection shall be achieved by a further protective provision, independent of that for basic protection.

[1] This Clause 5 is based on the horizontal standard IEC 61140:2016.

5.3.2 Protection by independent protective provisions

Each of the independent protective provisions shall be designed so that a failure is unlikely under conditions specified by the relevant technical committee.

The independent protective provisions shall have no influence on each other such that a failure of one of the protective provisions could impair another.

Simultaneous failure of independent protective provisions is unlikely and need not normally be taken into consideration. Reliance is placed on the unaffected protective provisions remaining effective.

5.4 Protective provisions (elements of protective measures)

5.4.1 General

Subclauses 5.4.1 to 5.4.2.9 give an overview of the different protective provisions. Protective measures result from a suitable combination of them. The structure of typical protective measures is described in 5.5.

All protective provisions shall be designed and constructed to be effective during the anticipated lifetime of the installation, of the system or of the equipment when used as intended and properly maintained.

The environment shall be taken into account by use of the classification of external influences as described in the IEC 60721 series and for testing in the IEC 60068 series. Attention is particularly drawn to the ambient temperature, climatic conditions, presence of water, mechanical stresses, capability of persons and area of contact of persons or livestock with local earth potential.

Technical committees shall take account of the requirements for insulation coordination. For high-voltage installations, systems and equipment, the requirements are found in the IEC 60071 series.

5.4.2 Basic protection (protection against direct contact)

5.4.2.1 General

Installations shall be such that they prevent unintentional infringement of the danger zone and prevent structures/accessible parts to be energized due to capacitive or inductive coupling, or high earth currents under normal conditions.

The following provisions for basic protection are recognized:

– protection by basic insulation;
– protection by enclosure;
– protection by barrier;
– protection by obstacle;
– protection by placing out of arms reach;
– bonding extraneous-conductive-parts to each other, and/or to the earthing arrangement (capacitive or inductive coupling); or
– potential grading.

5.4.2.2 Basic insulation

Where solid basic insulation is used, it shall prevent contact with live parts.

In case of high-voltage installations and equipment, further precautions shall be considered to avoid voltage to be present on the surface of solid insulation.

Where basic insulation is provided by air, access to live parts or entering the danger zone shall be prevented by obstacles, protective barriers or enclosures as specified in 5.4.2.3 and 5.4.2.4 or by placing out of arm's reach as specified in 5.4.2.5.

5.4.2.3 Protective barriers or enclosures

Protective barriers or enclosures shall prevent entering the danger zone by providing a degree of protection according to the principles of IEC 60529. The requirements shall give distances which are related to danger zone and additional distances. These additional distances shall be defined in the applicable standards. Special considerations shall be given to providing a degree of protection for readily accessible horizontal top surfaces of protective barriers or enclosures.

NOTE The IP code applies to the enclosures of electrical equipment of rated voltage not exceeding 72,5 kV.

Protective barriers or enclosures shall have sufficient mechanical strength, stability and durability to maintain the specified degree of protection, taking account of all relevant influences from the environment and from inside the enclosure. They shall be firmly secured in place.

Where the design or construction allows for the removal of protective barriers, the opening of enclosures or the removal of parts of enclosures, access to live parts or entering the danger zone shall be possible only:

– by the use of a key or tool, or
– after isolation of live parts from the supply circuit, and if necessary, earthing. Restoration of the supply shall become possible only after replacement of protective barriers or parts of enclosures or after the closing of doors.

NOTE See also Clause 8.

5.4.2.4 Obstacles

Obstacles are intended to protect skilled or instructed persons but their use is not permitted for the protection of ordinary persons.

During the operation of the installation, system or equipment under special operating and servicing conditions, obstacles shall prevent unintentional entering the danger zone.

Obstacles may be removable without using a key or tool but shall be so secured as to make unintentional removal unlikely.

Where a conductive obstacle is separated from live parts by basic insulation only, it is considered to be an exposed-conductive-part, and measures for fault protection (see 5.4.3) shall also be applied.

5.4.2.5 Placing out of arm's reach

Where provisions specified in the previous paragraphs are found to be not applicable, placing out of arm's reach may be appropriate to prevent unintentional entering into the danger zone.

Details shall be specified by technical committees.

For high-voltage installations, parts that are separated by a distance of more than 2,5 m are normally considered not to be simultaneously accessible. Where access is restricted to skilled or instructed persons, reduced distances may be specified.

Where a distance is expected to be reduced by objects which a person uses or holds in the hand, such as a tool or a ladder, technical committees shall specify relevant restrictions, or an appropriate distance between conductive parts between which a hazardous voltage can exist.

5.4.2.6 Metal structures bonded to each other, and/or to the earthing arrangement

Where capacitive or inductive coupling can make metal structures have a potential, they shall be bonded to each other, and/or to the earthing arrangement.

5.4.2.7 Potential grading

Where surrounding local earth can have a potential because of voltage gradients, potential grading shall be applied to minimalize step voltage. Potential grading shall prevent persons or livestock from hazardous step and touch voltages under normal conditions by providing a potential grading earth electrode.

NOTE Potential grading is typically used for electrical railway systems and substations, where high earth currents occur e.g. due to unbalance or transition.

5.4.2.8 Protection outside of closed electrical operating areas

Accepted provisions for basic protection outside the closed electrical operating areas, are protection by enclosure, protection by placing out of reach or potential grading.

5.4.2.9 Protection inside closed electrical operating areas

Accepted provisions for basic protection inside closed electrical operating areas are protection by enclosure, protective barrier, protective obstacle, placing out of arm's reach or potential grading.

5.4.3 Provisions for fault protection (protection against indirect contact)

5.4.3.1 General

Fault protection shall consist of one or more provisions independent of and additional to provisions for basic protection for protection against electric shock during single fault conditions for an electrical HV installation with its electrical equipment, extraneous conductive parts, and its surroundings.

The main lethal hazard to human beings is that a current will flow through the region of the heart which is sufficient to cause ventricular fibrillation. The current limit, for power-frequency purposes is derived from the appropriate curve in IEC 60479-1. This body current limit is translated into voltage limits for comparison with the calculated step and touch voltages taking into account the following factors:

– proportion of current flowing through the region of the heart;
– body impedance along the current path;
– resistance between the body contact points and e.g. metal structure to hand including glove, feet to reference earth including shoes or gravel;
– fault duration.

As a general rule, meeting the touch voltage requirements satisfies the step voltage requirements, because the tolerable step voltage limits are much higher than touch voltage limits due to the different current path through the body.

The following provisions for fault protection are accepted:

– protective potential grading;
– earthed protective-equipotential-bonding;
– disconnection of supply automatically or manually.

5.4.3.2 Earthed protective-equipotential-bonding

Protective-equipotential-bonding is a provision whereby items are bonded together to avoid hazardous touch voltages.

The equipotential bonding system of a high-voltage installation or system shall be connected to local earth because of the risks, which can be present, such as e.g., the danger of high touch and step voltage and of exposed-conductive-parts becoming live due to electrical discharge. The impedance to reference earth of the earthing arrangement shall be rated so that no hazardous touch voltage can occur. Exposed-conductive-parts, which can become live under fault conditions, shall be connected to the earthing arrangement.

The protective-equipotential-bonding system shall consist of one or a suitable combination of two or more of the elements below:

– earthed protective-equipotential-bonding in the installation;
– earthed protective-equipotential-bonding in equipment;
– protective screen;
– earthed point of the source or artificial neutral point;
– earth electrode (including earth electrodes for potential grading);
– earthing conductor.

Accessible conductive parts which could acquire a hazardous effective touch voltage in the event of a failure of basic protection, i.e. exposed-conductive-parts and any protective screen, shall be connected to the earthed protective-equipotential-bonding system.

The earthed protective-equipotential-bonding system shall be of sufficiently low impedance to avoid hazardous potential difference between conductive parts in case of an insulation failure. Where necessary, the earthed protective-equipotential-bonding system shall be used in association with a protective device operated by the fault current (see 5.4.3.4.3). The maximum difference in potential and its duration shall be based on IEC TR 60479-5.

All parts of the earthed protective-equipotential-bonding system shall be so dimensioned that thermal and dynamic stresses which are likely to occur do not impair the characteristics of the earthed protective-equipotential-bonding system, e.g. as a consequence of a failure or bridging of basic insulation.

All parts of the earthed protective-equipotential-bonding system shall be capable of withstanding all internal and external influences (including mechanical, thermal and corrosive) which can be expected.

Where a component of an installation, system or equipment is intended to be removed, the protective-equipotential-bonding for any other part of the installation, system or equipment shall not be interrupted when removing the component unless the electrical supply to the other part is first disconnected.

No element of the earthed protective-equipotential-bonding system shall contain any device which can reasonably be expected to break the electrical continuity or introduce significant impedance. This requirement may be dispensed with by technical committees for the verification of the continuity of protective conductors or for measuring of the current of the protective conductor.

In high-voltage installations, systems and equipment, the earthed protective-equipotential-bonding system shall not be interrupted before the main contact has reached an isolating distance which can withstand the equipment rated impulse withstand voltage.

Conductors of the earthed protective-equipotential-bonding system, whether insulated or bare, shall be readily distinguishable by shape, location, marking or colour, except those conductors which cannot be disconnected without destruction, e.g. in wire-wrap and similar wiring in electronic equipment and tracks on printed wiring boards. If identification by colour is used, it shall be in accordance with IEC 60445.

5.4.3.3 Potential grading

Potential grading may be used by installation of additional earth electrodes to reduce the touch voltage and step voltage which appear in the case of a fault.

NOTE Earth electrodes are usually buried at a horizontal distance of 1 m from the equipment or any conductive part, at a depth of 0,5 m below ground level and are connected to the earthing arrangement.

5.4.3.4 Disconnection of supply

A device shall be provided which indicates a fault. Depending on the method of neutral earthing, the fault current shall be disconnected either manually or automatically. The permissible value of the touch voltage depending on the fault duration shall be specified by technical committees based on IEC 60479-1, see also 5.5.

For manual disconnection of supply:

– an earthed protective-equipotential-bonding system shall be provided, and
– a device shall be provided which indicates the fault; and
– a device operated by operating person shall disconnect the line conductor(s) supplying the equipment, system or installation, in the event of a fault of negligible impedance between a line conductor and an exposed-conductive-part or a protective conductor in the circuit or equipment.

For automatic disconnection of supply:

– an earthed protective-equipotential-bonding system shall be provided, and
– a protective device operated by the fault current shall automatically disconnect the line conductor(s) supplying the equipment, system or installation, in the event of a fault of negligible impedance between a line conductor and an exposed-conductive-part or a protective conductor in the circuit or equipment.

The protective device shall interrupt the fault current within a time specified by technical committees based on the IEC 60479 series.

The protective device may be provided in any suitable upstream part of the installation, system or equipment, preferably at the origin of the circuit to be protected and shall be selected taking into account the characteristics of the supply and the load.

5.5 Protective measures

5.5.1 General

Subclause 5.5 describes the structure of typical protective measures, indicating in some cases which protective provision(s) are for basic protection, for fault protection and for additional protection.

More than one of the following protective measures may be used within the same installation, system or equipment both under normal conditions and under single fault conditions.

A protective measure is a measure intended to achieve adequate risk reduction, implemented:

- by the designer:
  - inherent design;
  - safeguarding;
  - complementary protective measures, information for use;

and

- by the user:
  - organization: safe working procedures, supervision, training;
  - permit-to-work systems;
  - provision and use of additional safeguards;
  - use of personal protective equipment.

5.5.2 Protection by manual disconnection of supply

Manual disconnection of supply shall consist of a combination of the following protective provisions:

– basic protection is provided by basic insulation, or protective barriers or enclosures between live parts and exposed-conductive-parts; and

– fault protection is provided by manual disconnection of supply; and

– earthed protective-equipotential-bonding system.

5.5.3 Protection by automatic disconnection of supply

Automatic disconnection of supply shall consist of a combination of the following protective provisions:

– basic protection is provided by basic insulation, or protective barriers or enclosures between live parts and exposed-conductive-parts; and

– fault protection is provided by automatic disconnection of supply; and

– earthed protective-equipotential-bonding system.

The relevant maximum disconnection times can be derived from touch voltage in Figure 4 of IEC 60479-1:2018.

5.5.4 Protection by earthed protective equipotential bonding

Protective measure in which

– basic protection is provided by basic insulation between live parts and exposed-conductive-parts, and

– fault protection is provided by an earthed protective equipotential bonding system preventing hazardous voltages between simultaneously accessible exposed and extraneous-conductive-parts.

Protection by earthed protective equipotential bonding shall be used together with manual or automatic disconnection.

5.5.5 Protection by limiting touch voltage

Protective measure in which

– basic protection is provided by basic insulation between live parts and exposed-conductive-parts, and
– earthed protective equipotential bonding; and
– touch voltages are limited to safe levels by low impedance to reference earth and/or short disconnection times.

6 Protection against thermal hazards

6.1 General

Installations shall be constructed in such a way that they limit the harms that can arise from high temperature, flame or arc, both in normal conditions and in single fault conditions.

Every part of an installation shall be designed and constructed to prevent the occurrence of a single fault as far as possible.

Protection shall be coordinated between installation and equipment withstand levels to provide safety in the final installation.

Equipment manufacturers shall define the equipment withstand levels.

NOTE Examples on thermal hazards are:

– burning;
– fire;
– combustion;
– explosion;
– degradation of materials;
– risk for burns for persons/skin;
– arc flash.

6.2 Normal conditions

6.2.1 General

Every part of an installation shall be designed and constructed to withstand currents under normal conditions so that harm from high temperature cannot arise.

6.2.2 Protection against overload

Under normal conditions, installations shall be constructed in such a way that harm from high temperature cannot arise during overload situations.

Protection against overload shall be achieved by protection devices, thermal protection or circuit design.

Protection coordination studies shall be conducted.

6.3 Single fault conditions

6.3.1 General

Every part of an installation shall be designed and constructed to safely withstand currents under single fault conditions so that a tolerable level of harm from high temperature, flame or arc (explosion) is met.

Means for achieving a tolerable level of harm shall be defined by the relevant technical committees.

6.3.2 Protection against short circuit currents

For the purpose of this document, all types of short-circuit events shall be considered.

Examples include:

- three-phase;
- phase-to-phase;
- phase-to-earth and;
- double phase-to-earth.

Protection against harm from short circuit currents shall be achieved by protective devices coordinated with standard withstand levels of equipment and installation.

Methods for the calculation of short-circuit currents in three-phase AC systems are given in the IEC 60909 series.

Methods for the calculation of the thermal effects of short-circuit current are given in IEC 60865-1 and, for power cables, in IEC 60949.

Protection coordination studies shall be conducted.

6.3.3 Protection against arc faults

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

The following list are examples of measures to protect against dangers resulting from arc fault:

- Protection by design of installation
  - Operating aisles as short, high and wide as possible
  - Solid covers as an enclosure or protective barrier instead of perforated covers or wire mesh
  - Protection against operating error, established, for example, by means of the following:
    i) load break switches instead of disconnectors,
    ii) short-circuit rated fault-making switches,
    iii) interlocks,
    iv) non-interchangeable key locks.
- Protection by equipment design
  - Equipment tested to withstand internal arc fault instead of open-type equipment
  - Arc products to be directed away from operating personnel

- Protection by protective devices
  - Use of current-limiting devices
  - Very short tripping time; achievable by instantaneous relays or by devices sensitive to pressure, light or heat
  - Prevention of re-energization by use of non-resettable devices which detect internal equipment faults, enable pressure relief and provide an external indication.
- Protection by operational instructions
  - Operation from a safe distance
  - Requirements for the use of arc-flash rated personal protective equipment (PPE) in line with arc-flash energy of the installation

6.3.4 Protection against fire hazard

6.3.4.1 General

HV installations are recognized by a high level of energy and the widespread use of equipment e.g. oil filled electrical equipment. This requires risk assessment in reducing the risk to a tolerable level of hazard.

The electric installation shall be designed to prevent fire origin so far as is reasonable practicable. The installation itself, persons, livestock, and property (fire victim) shall be protected against harm arising from fire caused or spread by electrical equipment or electrical installation (fire origin).

6.3.4.2 Measures with respect to fire origin

Recognized safeguard measures shall be implemented in the design of the installation or in the electrical equipment. These include the following:

– electrical protection;
– thermal protection;
– pressure protection;
– non-combustible materials.

6.3.4.3 Measures to protect fire victim

Installations should be localized, constructed and protected in such a way that fires are prevented. Equipment where sparks, flame arcs, explosions or high temperatures can arise, should be constructed, localized and/or protected in such a way that fire is prevented in their surroundings.

The fire hazard associated with electrical HV equipment in outdoor and/or indoor electrical power 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.

For electrical power installations located in public or residential buildings, special measures shall be imposed, in accordance with existing standards or national regulations.

The use of one or more recognized safeguard measures shall be used in accordance with the evaluation of the risk.

Various preventive and protective fire safety measures shall be considered in the design of the installation, including:

– fire initiation and development and control;
– fire spread and impact and control;