

GUIDE

GUIDE

**Electric equipment for high-voltage substations – Common recommendations
for product and system standards –
Part 1: AC (alternating current)**

**Matériels électriques pour postes haute tension – Recommandations communes
pour les normes de produits et de réseaux –
Partie 1: AC (courant alternatif)**



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2023 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

IEC Secretariat
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, ...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch

Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

A propos de l'IEC

La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC

Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Recherche de publications IEC - webstore.iec.ch/advsearchform

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études, ...). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et une fois par mois par email.

Service Clients - webstore.iec.ch/csc

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch

Découvrez notre puissant moteur de recherche et consultez gratuitement tous les aperçus des publications. Avec un abonnement, vous aurez toujours accès à un contenu à jour adapté à vos besoins.

Electropedia - www.electropedia.org

Le premier dictionnaire d'électrotechnologie en ligne au monde, avec plus de 22 300 articles terminologiques en anglais et en français, ainsi que les termes équivalents dans 19 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

GUIDE

GUIDE

**Electric equipment for high-voltage substations – Common recommendations for product and system standards –
Part 1: AC (alternating current)**

**Matériels électriques pour postes haute tension – Recommandations communes pour les normes de produits et de réseaux –
Partie 1: AC (courant alternatif)**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 29.020; 29.240.10

ISBN 978-2-8322-6306-8

**Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

CONTENTS

FOREWORD.....	5
INTRODUCTION.....	7
1 Scope.....	8
2 Normative references	8
3 Terms and definitions	8
4 Guidance in referencing IEC documents	12
4.1 "Normative references" clause in product standards.....	12
4.2 "Terms and definitions" clause in product standards	12
5 Environmental conditions.....	13
5.1 General.....	13
5.2 Normal environmental conditions	14
5.2.1 Table defining normal environmental conditions.....	14
5.2.2 Power electronic, electronic and associated equipment	15
5.3 Special environmental conditions	15
6 Ratings.....	16
6.1 General.....	16
6.2 Voltage	17
6.2.1 Highest voltage of a system, U_S	17
6.2.2 Highest voltage for equipment, U_m	18
6.2.3 Rated voltage, U_r	18
6.2.4 Rated insulation level	18
6.3 Rated frequency, f_r	18
6.4 Current	18
6.4.1 Rated current, I_r	18
6.4.2 Rated short-time withstand current	18
6.4.3 Rated peak withstand current	18
6.4.4 Rated duration of short-circuit.....	19
6.5 Rated supply voltage of auxiliary and control circuits	19
6.6 Rated supply frequency of auxiliary and control circuits	20
7 Design and construction	20
7.1 Requirements for liquids and gases in equipment	20
7.2 Earthing of equipment.....	20
7.3 Low-voltage part of equipment	20
7.4 Marking.....	21
7.5 Electronic name plate	21
7.6 Degrees of protection provided by enclosures.....	21
7.6.1 Protection of persons against access to hazardous parts and protection of the equipment against ingress of solid foreign objects	21
7.6.2 Protection of equipment against ingress of water	21
7.6.3 Protection of equipment against mechanical impact under normal service conditions	22
7.7 Creepage distances	22
7.8 Fire hazard	22
7.9 Noise level.....	22
7.10 Electromagnetic compatibility (EMC).....	22

7.10.1	General	22
7.10.2	Emissions	23
7.10.3	Immunity	23
7.11	Mechanical stresses on terminals	24
7.12	Interfaces	24
8	Tests	24
8.1	General	24
8.1.1	Overview	24
8.1.2	Types of test	24
8.1.3	Sequencing and grouping of tests	25
8.1.4	Information for identification of specimens	25
8.1.5	Information to be included in type-test reports	25
8.2	Type tests	25
8.2.1	Overview	25
8.2.2	Dielectric tests	25
8.2.3	Temperature-rise tests	25
8.2.4	Verification of protection	25
8.2.5	Electromagnetic compatibility (EMC) tests	25
8.2.6	Emission tests on LV parts of equipment	26
8.2.7	Mechanical stresses on terminals	26
8.2.8	Impact of environmental stresses on products	26
8.3	Routine tests	26
8.4	Special tests	26
8.5	Sample tests	26
8.6	Commissioning tests	26
9	Rules for transport, storage, erection, operation and maintenance	27
10	Safety	27
10.1	General	27
10.2	Electrical aspects	28
10.3	Thermal and mechanical aspects	28
10.3.1	General	28
10.3.2	Mechanical aspects	28
10.3.3	Thermal aspects	28
10.4	Connection to other equipment	28
11	Effects of product standards on the natural environment	29
Annex A (normative)	Identification of test specimens	30
Annex B (normative)	Electronic nameplate	31
B.1	General	31
B.2	Device name plate (DPL)	32
Bibliography		34
Table 1 – Normal environmental conditions		14
Table 2 – Normal environmental conditions - power electronic, electronic and associated equipment		15
Table 3 – Special environmental conditions		16
Table 4 – DC supply voltage		19
Table 5 – Auxiliary contact classes		20

Table A.1 – List of drawings to be submitted by manufacturer	30
Table B.1 – Nameplate data objects of equipment interface logical nodes.....	31
Table B.2 – Attributes of DPL.....	32
Table B.3 – Common data classes (CDCs) for settings	32
Table B.4 – Attributes of VSD	33

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**ELECTRIC EQUIPMENT FOR HIGH-VOLTAGE SUBSTATIONS – COMMON
RECOMMENDATIONS FOR PRODUCT AND SYSTEM STANDARDS –****Part 1: AC (alternating current)**

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

This first edition of IEC Guide 111-1 has been prepared, in accordance with ISO/IEC Directives, Part 1, Annex A, by the IEC Advisory Committee on Transmission and Distribution (ACTAD).

This first edition of IEC Guide 111-1, together with IEC Guide 111-2, cancels and replaces the second edition of IEC Guide 111 published in 2004.

The main changes with respect to the previous edition are as follows:

- a) IEC Guide 111 is revised into two parts – Part 1 for AC and Part 2 for DC (Part 2 to be prepared);
- b) the scope of the document has been expanded to cover electric equipment in AC high-voltage substations;
- c) new definitions have been included;
- d) normal conditions have been revised;

e) a general revision of other clauses.

The text of this IEC Guide is based on the following documents:

Draft	Report on voting
SMBNC/25/DV	SMBNC/28/RV

Full information on the voting for the approval of this IEC Guide can be found in the report on voting indicated in the above table.

The language used for the development of this Guide 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 www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

INTRODUCTION

This document is for use by IEC technical committees (TCs) involved in high-voltage (HV) substation systems, such as:

TC 8, TC 13, TC 14, TC 17, TC 20, TC 22, TC 32, TC 33, TC 36, TC 37, TC 38, TC 57, TC 95, TC 99, TC 115, TC 122, TC 123.

It is of paramount importance that the IEC, through this document, ensures consistency and avoids discrepancies between standards within one system. A few discrepancies can be justified in certain cases according to the specificity of a given product or situation.

The cost of over-standardization of a component compared to utilization of the nearest linked under-standardized component should be considered. The supplementary cost does not in any way increase the reliability of the system as a whole.

Since the same external stresses (climatic, electrical, and mechanical) apply to all the components of the substations, the consistency of their technical features is vital.

The same essential requirements for safety, environmental impact, end of life, availability and integration of systems are applicable. All product standards for a single system need to fulfil these requirements with the same degree of responsibility.

The aim of this document is to provide common rules for HV substation equipment.

ELECTRIC EQUIPMENT FOR HIGH-VOLTAGE SUBSTATIONS – COMMON RECOMMENDATIONS FOR PRODUCT AND SYSTEM STANDARDS –

Part 1: AC (alternating current)

1 Scope

This part of IEC Guide 111 is a horizontal publication which gives guidance for the harmonization of product and system standards for HV substations (higher than 1 kV). It addresses AC equipment which is found in high-voltage (HV) substations in most cases.

This document contains recommendations for common specifications for all HV substation product and system standards, each of which is augmented by the technical background specific to each technical committee, which naturally retains freedom in its technical choices.

This document is applicable when developing product and systems standards for HV power electronic equipment for the AC part of the substation.

NOTE 1 IEC Guide 111-2 relating to DC (direct current) is under development. Once published, IEC Guide 111-2 will be applicable when developing product and systems standards for the HVDC part of the substation.

NOTE 2 The IEC Standardization Management Board (SMB) has decided that Guides such as this one can have mandatory requirements which shall be followed by all IEC committees developing technical work that falls within the scope of the Guide, as well as guidance which may or may not be followed. The mandatory requirements in this Guide are identified by the use of "shall". Statements that are only for guidance are identified by using the verb "should". (See ISO/IEC Directives, IEC Supplement Part 1, A.1.1.)

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

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

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

3.1

highest voltage of a system

U_s

highest value of operating voltage which occurs under normal operating conditions at any time and at any point in the system

Note 1 to entry: Transient overvoltages, due e.g. to switching operations, and abnormal temporary variations of voltage, are not taken into account.

Note 2 to entry: The highest voltage of a system is considered as the phase-to-phase operating voltage (RMS value).

[SOURCE: IEC 60050-601:1985, 601-01-23, modified – The symbol U_s and Note 2 to entry have been added.]

3.2

highest voltage for equipment

U_m

greatest value of line-to-line voltage (RMS value) for which the equipment is designed in respect of its insulation as well as other characteristics which relate to this voltage in the relevant equipment standards under normal service conditions

[SOURCE: IEC 60050-614:2016, 614-03-01, modified – The symbol U_m has been added.]

3.3

rated voltage

U_r

<of equipment> voltage value assigned by a manufacturer or other entity for a specified operating condition of a component, device or equipment

Note 1 to entry: The value for the rated voltage of high-voltage equipment is generally assigned from the list of highest voltages for equipment in Tables 3, 4 and 5 of IEC 60038:2009.

Note 2 to entry: The value for the rated voltage of low voltage equipment is generally assigned from the list of nominal voltages in Tables 1 and 6 of IEC 60038:2009.

Note 3 to entry: Equipment may have more than one rated voltage value or may have a rated voltage range.

[SOURCE: IEC 60050-614:2016, 614-03-09, modified – The symbol U_r has been added.]

3.4

electric equipment

item used for such purposes as generation, conversion, transmission, distribution or utilization of electric energy, such as electric machines, transformers, switchgear and controlgear, measuring instruments, protective devices, wiring systems, current-using equipment

[SOURCE: IEC 60050-826:2004, 826-16-01]

3.5

rated value

value of a quantity used for specification purposes, established for a specified set of operating conditions of a component, device, equipment, or system

[SOURCE: IEC 60050-151:2001, 151-16-08]

3.6

rated insulation level

test voltages, under specified conditions, that the insulation is designed to withstand

Note 1 to entry: These test voltages can be for instance:

- a) rated lightning impulse and short duration power frequency withstand voltages;
- b) rated lightning and switching impulse withstand voltages (phase-to-earth).

[SOURCE: IEC 60050-421:1990, 421-09-02]

3.7

rated frequency

f_r

frequency at which the equipment is designed to operate

Note 1 to entry: The standard values of the rated frequency are 50 Hz and 60 Hz.

[SOURCE: IEC 60050-421:1990, 421-04-03, modified – "transformer or reactor" has been replaced with "equipment", the symbol f_r and Note 1 to entry have been added.]

3.8 **rated current**

I_r

RMS value of the current which equipment is designed to carry continuously under specified conditions of use and behaviour

Note 1 to entry: Rated currents for temporary or for intermittent duty are subject to agreement between manufacturer and user.

Note 2 to entry: In the area of transformers, rated power is used and not rated current.

3.9 **high voltage** **HV**

<general> set of voltage levels in excess of low voltage

Note 1 to entry: High voltage (HV) covers nominal voltages above low voltage (1,0 kV AC and 1,5 kV DC nominal) and includes medium voltage (MV), extra high voltage (EHV) and ultra high voltage (UHV).

3.10 **high voltage**

<upper voltage> set of upper voltage levels used in power systems for bulk transmission of electricity

3.11 **high voltage**

<apparatus or installation> highest of two or more voltages in an apparatus or installation

3.12 **low voltage** **LV**

<general> set of voltage levels used for the distribution of electricity where the nominal voltage is generally accepted to be up to 1 000 V for alternating current and 1 500 V for direct current

3.13 **low voltage**

<apparatus or installation> lowest of two or more voltages in an apparatus or installation

3.14 **medium voltage** **MV**

subcategory of high voltage applicable to electricity distribution in the voltage range in excess of low voltage to the upper range of electricity distribution voltages, typically up to 52 kV AC

Note 1 to entry: The upper value of distribution voltage depends on local circumstances and history or common usage.

3.15 **extra high voltage** **EHV**

subcategory of high voltage applicable to electricity transmission having a highest voltage for equipment exceeding 245 kV AC and up to 800 kV AC

3.16**ultra high voltage****UHV**

subcategory of high voltage applicable to electricity transmission having a highest voltage for equipment exceeding 800 kV AC

3.17**earthing circuit**

<of an assembly> conductors, connections, and the conducting parts of earthing devices or of the metal frame, intended to connect the high-voltage conductive parts of an assembly to the earthing point provided

Note 1 to entry: The earthing circuit can include short-circuiting circuits between poles and phase-to-earth circuits from each pole to the earthing point and/or from the short-circuiting point of phase-to-earth circuits to the earthing point provided.

[SOURCE: IEC 62271-200:2021, 3.5.107]

3.18**earthing system**

grounding system (US)

arrangement of electric connections and devices involved necessary to earth equipment or a system separately or jointly

[SOURCE: IEC 61936-1:2021, 3.7.6]

3.19**required withstand voltage**

U_{rw}

test voltage that the insulation must withstand in a standard withstand voltage test to ensure that the insulation will meet the performance criterion when subjected to a given class of overvoltages in actual service conditions and for the whole service duration

Note 1 to entry: The required withstand voltage has the shape of the co-ordination withstand voltage, and is specified with reference to all the conditions of the standard withstand voltage test selected to verify it.

[SOURCE: IEC 60071-1:2019, 3.28]

3.20**withstand voltage**

U_w

test voltage suitably selected equal to or above the required withstand voltage (U_{rw})

Note 1 to entry: For AC equipment, values of withstand voltages U_w are standardized as per IEC 60071-1.

Note 2 to entry: The standard impulse shapes used for withstand tests on equipment as well as the test procedures are defined in IEC 60060-1 and IEC 60071-1.

[SOURCE: IEC 60071-5:2014, 3.8, modified – The second sentence has been deleted in Notes 1 and 2 to entry.]

3.21**lightning impulse withstand voltage****LIWV**

withstand voltage of insulation with the shape of the standard lightning impulse

[SOURCE: IEC 60071-5:2014, 3.8.2]

3.22

switching impulse withstand voltage

SIWV

withstand voltage of insulation with the shape of the standard switching impulse

[SOURCE: IEC 60071-5:2014, 3.8.1]

4 Guidance in referencing IEC documents

4.1 "Normative references" clause in product standards

The use of horizontal publications is of the utmost importance for the harmonization process.

Strong reasons are needed to depart from the recommendations of horizontal publications and, in all cases, it is necessary to explain the reason for any discrepancy.

Within the fields concerned, the essential horizontal documents to be taken into account and to be mentioned in the normative references clause of each standard are the following:

- field of definitions: International Electrotechnical Vocabulary (IEV) – IEC 60050 series;
- field of voltage: IEC 60038;
- field of current: IEC 60059;
- field of insulation: IEC 60060 series, IEC 60071 series, IEC TS 60815 series and IEC 61180;
- field of temperature rise: IEC 60216 series and IEC TR 60943;
- field of degrees of protection: IEC 60529 – although IEC 60529 defines its scope as being limited to voltages not exceeding 72,5 kV, the use of IP classification and testing methods according to IEC 60529 may be extended to be used also for voltages exceeding 72,5 kV;
- field of environmental conditions affecting the equipment: IEC 60664 series, IEC 60721 series, IEC 60376, IEC 60296, IEC 60867 and IEC TR 62271-300;
- field of environmental aspects if any affected by the equipment: IEC Guide 109, IEC 62474 and IEC 62271-4;
- field of electromagnetic compatibility (EMC): IEC Guide 107; horizontal publications in the IEC 61000 series; CISPR 11, CISPR TR 18 series, CISPR 32 and CISPR 35;
- field of safety: IEC 61936-1, IEC Guide 104, IEC Guide 117, ISO/IEC Guide 51, IEC 60695 series;
- field of mechanical stresses: IEC 60865 series, IEC 62155 and IEC 62262;
- field of dependability: IEC 60300-3 series, IEC 62308;
- field of information communication: IEC/IEEE 82079-1 and IEC 62271-3.

4.2 "Terms and definitions" clause in product standards

Definitions already in the IEV should be used. If a definition already in the IEV is not satisfactory or not clear enough, the difficulty should be referred to TC 1 and solved in cooperation. New definitions should not be used unless absolutely necessary, i.e. no similar definition exists in publications on a similar subject. A similar definition may be modified with a reference to the original.

5 Environmental conditions

5.1 General

This clause should be the same for all TCs active in the area of substations. Installations, including all devices and auxiliary equipment which form an integral part of them, should be designed for operation under the climatic and environmental conditions listed below. Equipment product standards should be taken into account.

Normal environmental conditions shown in Table 1 are the environmental conditions defined for indoor and outdoor conditions in order to coordinate the application of a wide range of diverse equipment types within a single operating environment such as an electrical substation. The values chosen address the needs of the majority of applications worldwide and provide a basis for the design, specification and application of standardized equipment and installations.

Normal environmental conditions shown in Table 2 are particular environmental conditions defined for indoor conditions or enclosed conditions associated with power electronic equipment and other associated equipment. This range is defined in order to coordinate the application of power electronic equipment and other associated equipment within a single operating environment.

Technical committees may define ratings of equipment in accordance with Table 1 for general application and Table 2 for power electronic, electronic and associated applications.

Installations shall take into account the constructive provisions to find the standardized values in Table 1 and Table 2.

There are many cases where specification of values outside the conditions defined in Table 1 and Table 2 is necessary and justified. These are referred to as special environmental conditions. These cases can relate to extremes of the natural environment such as higher or lower temperatures for outdoor installations, or to the specific requirements of equipment or sub-systems such as the need to avoid sub-zero temperatures for certain equipment. The effects of enclosures or other factors that alter the environment within which equipment designed for the normal environment is situated shall be considered separately.

Special environmental conditions associated with extremes of the natural environment are summarized in Table 3 and these provide a basis for user specification of appropriate special environmental conditions for their application(s).

Special environmental conditions associated directly with the requirements of specific equipment types, such as a further-restricted operating temperature range, are detailed in the appropriate equipment standards. These equipment-specific requirements typically supersede the more general requirements for the entire electrical installation on the basis that a specifically controlled operating environment (such as a room, building or enclosure) can be provided. Whilst these conditions are considered special in the context of this document, they may be considered "normal" in the context of the specific equipment under consideration. It is common for sub-systems requiring special environmental conditions as defined in this document, to be installed within a controlled environment within an electrical installation which itself is defined as having normal environmental conditions.

TCs should use the phrase "environmental conditions" in preference to "service conditions".

5.2 Normal environmental conditions

5.2.1 Table defining normal environmental conditions

Table 1 – Normal environmental conditions

			Indoor	Outdoor
a)	Ambient air temperature ^a	Upper limit	≤ 40 °C ^b	≤ 40 °C ^c
		Lower limit	≥ -5 °C	≥ -25 °C
b)	Solar radiation (clear day, noon)		Negligible	≤ 1 120 W/m ² ^d
c)	Altitude		≤ 1 000 m	≤ 1 000 m
d)	Air pollution by dust, salt, smoke, corrosive/flammable gas, vapours		Very light (Refer to IEC TS 60815 series)	Medium (Refer to IEC TS 60815 series)
e)	Ice coating ^e		-	class 1: ≤ 1 mm or class 10: ≤ 10 mm or class 20: ≤ 20 mm
f)	Wind speed		-	≤ 34 m/s (corresponds to 700 Pa) ^f
g)	Relative humidity: 24 h average one month average		≤ 95 % ≤ 90 % ^g	
	Water vapour: 24 h average one month average		< 2,2 kPa < 1,8 kPa	
	Condensation, precipitation		None ^g	
	Precipitation			^h
h)	Vibration (external to equipment), earth tremors		Negligible	Negligible
i)	Electromagnetic disturbances		According to IEC Guide 107	According to IEC Guide 107

^a On auxiliary equipment, such as relays and control switches, intended to be used in ambient air temperature below -5 °C, an agreement between supplier and user is necessary.

^b As a result of heat generated by equipment, consideration needs to be given to the temperature rise of the local environment. With some power electronic equipment, resultant ambient temperatures can rise up to 60 °C. The ambient temperature up to 60 °C takes into account the heat generated by the equipment. Where cooling facilities are not installed, special environmental conditions apply.

^c Rapid temperature changes should be taken into account.

^d Under certain conditions of solar radiation, appropriate measures, for example, roofing, forced ventilation, etc., may be necessary or derating may be used in order not to exceed the specified temperature rises. Details of global solar radiation are given in IEC 60721-2-4. Ultraviolet (UV) radiation can damage some synthetic materials. For more details see the IEC 60068 series.

^e In regions where icing can occur the resulting load on flexible conductors and on rigid busbars should be taken into account. If local experience or statistics are not available, ice coatings of 1 mm, 10 mm or 20 mm based on criteria given in IEC 62271-1 may be assumed. The density of the ice is assumed to be 900 kg/m³ in accordance with IEC 60826.

^f Characteristics of wind are described in IEC 60721-2-2.

^g For these conditions, condensation can occasionally occur. Condensation can be expected where sudden temperature changes occur in periods of high humidity. To avoid breakdown of insulation or corrosion of metallic parts due to high humidity and condensation, equipment designed for such conditions and tested accordingly should be used. Condensation can be prevented by special design of the building or housing, by suitable ventilation and heating of the station or by the use of dehumidifying equipment. This is particularly applicable for power electronic equipment.

^h Precipitation in the form of dew, condensation, fog, rain, snow, ice or hoar frost should be taken into account. Precipitation characteristics for insulation are described in IEC 60060-1 and IEC 60071-1. For other properties, precipitation characteristics are described in IEC 60721-2-2.

5.2.2 Power electronic, electronic and associated equipment

Table 2 – Normal environmental conditions - power electronic, electronic and associated equipment

			Indoor / enclosed
a)	Ambient air temperature	Upper limit	≤ 60 °C ^a
		Lower limit	≥ 5 °C
b)	Solar radiation (clear day, noon)		Negligible
c)	Altitude		≤ 1 000 m
d)	Air pollution by dust, salt, smoke, corrosive/flammable gas, vapours		No significant air pollution ^b
e)	Ice coating		-
f)	Wind speed		-
g)	Relative humidity		≤ 60 %
	Condensation		Not allowed
h)	Vibration (external to equipment), earth tremors		Negligible
i)	Electromagnetic disturbances		According to IEC Guide 107
^a As a result of heat generated by equipment, consideration needs to be given to the temperature rise of the local environment. With some power electronic equipment, resultant ambient temperatures can rise up to 60 °C. The ambient temperature up to 60 °C takes into account the heat generated by the equipment. Where cooling facilities are not installed, special environmental conditions apply.			
^b Air pollution should be minimized by adequate measures like air filtering and operation under slight overpressure. An air pollution degree of 2 (non-conductive pollution) according to IEC 60664-1 should be achieved. Temporary conductivity of the pollution caused by condensation is not permitted.			

5.3 Special environmental conditions

When high-voltage equipment is used under conditions different from the normal environmental conditions given in 5.2, the user's requirements should refer to the standardized steps given in Table 3.

When special environmental conditions prevail at the location where equipment is to be put in service, they should be specified by the user by reference to IEC 60721-1.

Table 3 – Special environmental conditions

		Special environmental conditions	Notes
a)	Ambient air temperature	Very cold climates: –50 °C to +30 °C Very hot climates: –5 °C to +50 °C	
b)	Altitude	> 1 000 m	For installation at an altitude higher than 1 000 m above sea level, the insulation level of external insulation under the standardized reference atmospheric conditions should be determined by multiplying the insulation withstand voltages required at the service location by a factor K_a in accordance with IEC 60071-2. For internal pressurized insulation, the dielectric characteristics are identical at any altitude and no special precautions need to be taken. For low-voltage auxiliary and control equipment, no special precautions need be taken if the altitude is lower than 2 000 m above sea level. For higher altitudes, see IEC 60664-1. The pressure variation due to altitude is given in the IEC 60721 series. Regarding this phenomenon, particular attention should be devoted to the following points: – thermal exchanges by convection, conduction or radiation; – efficiency of heating or air-conditioning; – operating level of pressure devices; – efficiency of diesel generating set or compressed air station; – dielectric strength of external insulation / air.
c)	Air pollution by dust, salt, smoke, corrosive/flammable gas, vapours	Heavy, or very heavy (Refer to IEC TS 60815 series)	
d)	Relative humidity		In certain regions with frequent occurrence of warm, humid winds, sudden changes of temperature can occur resulting in condensation, even indoors. In tropical indoor conditions, the average value of relative humidity measured during a period of 24 h can be 98 %.
	Water vapour		< 4 kPa
e)	Vibration (external to equipment)	According to IEC 60721-2-6	
f)	Seismic conditions	According to IEC 61936-1	

6 Ratings

6.1 General

The application of a diverse range of equipment types within a single electrical installation or system typically requires coordination of the ratings of the equipment. This document provides guidance upon the values to be coordinated (voltages, currents, times, etc) and upon the choice of the preferred values to be chosen, for example by reference to established standards such as IEC 60059 (currents) and IEC 60038 (voltages). The use of preferred values facilitates the efficient design, specification and application of standardized equipment and contributes to safe, cost-effective design of integrated installations.

Any specific interpretations of how the preferred values apply to various equipment types and any additional standardized parameters required are detailed in the specific equipment standards. Such variations are acceptable provided they do not impact the safe operation with adequate protective margins for equipment designed for standard ratings in accordance with this document (the IEC 60099 series for surge arresters is such an example).

There are cases where the adoption of these preferred ratings is not appropriate as it provides no tangible safety, economic or operational benefit. For flexible AC transmission systems (FACTS) applications, for optimization considerations, typically the rated current is adapted to the particular requirements. For stand-alone sub-systems of project-specific design, ratings may be chosen in accordance with the project specification providing that the ratings at the interface of the sub-system with the main power system are properly coordinated in line with the approach outlined in this document. For example, the provision of a specified, power electronic controlled, MVAR shunt compensation capacity can be optimized without reference to the preferred ratings detailed in this document except at the power system interface. In such cases, subject to the principles of this document being applied, the coordination of the ratings within the sub-system are the responsibility of the designer.

The common ratings and operating conditions of equipment, including their operating devices and auxiliary equipment, if any, are the rated values and operating conditions selected from the following, if applicable:

- a) highest voltage of a system (U_s);
- b) highest voltage for equipment (U_m);
- c) rated voltage (U_r) (where applicable);
- d) rated insulation level;
- e) rated frequency (f_r);
- f) rated current (I_r);
- g) rated short-time withstand current (I_k);
- h) rated peak withstand current (I_p);
- i) rated duration of short-circuit (t_k);
- j) rated supply voltage of auxiliary circuits (U_a);
- k) rated supply frequency of auxiliary circuits.

Other rated characteristics may be necessary and will be specified in the relevant IEC standards.

As defined in 3.9 at the system level, although equipment is defined in terms of the above parameters, high-voltage systems are broadly categorized into subcategories of medium voltage (MV) for distribution systems as defined in 3.14 and extra high voltage (EHV) as defined in 3.15 and ultra high voltage (UHV) as defined in 3.16 for high-capacity transmission systems.

6.2 Voltage

6.2.1 Highest voltage of a system, U_s

Generally, the highest voltage of a system is defined by the regulator or defined by a specific national regulation. Highest voltage of a system should be equal to or less than the highest voltage of equipment. Refer to 3.1 for definition.

6.2.2 Highest voltage for equipment, U_m

The standard values of the highest voltage for equipment should be selected from IEC 60038.

Under normal service conditions specified by the relevant apparatus committee, the highest voltage for equipment can be applied continuously to the equipment.

Equipment may only be used on systems having a highest system voltage less than or equal to its highest voltage for equipment. Refer to 3.2 for definition.

6.2.3 Rated voltage, U_r

The rated value of the voltage is assigned by the manufacturer to electric equipment according to the main functionality of the device. Typically, the rated voltage is equal to the highest voltage for equipment. Refer to 3.3 for definition.

6.2.4 Rated insulation level

The rated insulation level of equipment, that is, the set of standard withstand voltages which characterize the dielectric strength of the insulation, should be selected from the standardized values given in IEC 60071-1. This shall include consideration of the required withstand voltage, switching impulse withstand voltage and lightning impulse withstand voltage.

For most instances of the highest voltage for equipment, several rated insulation levels exist to allow for the application of different performance criteria or overvoltage patterns. The choice should be made by considering the degree of exposure to fast-front and slow-front overvoltages, the type of neutral earthing of the system and the type of overvoltage limiting devices (see IEC 60071-2).

6.3 Rated frequency, f_r

The standard values of the rated frequency are 50 Hz and 60 Hz.

For special applications other rated frequency values can be used. IEC 60196 should be used to select relevant values. Refer to 3.7 for definition.

6.4 Current

6.4.1 Rated current, I_r

Refer to 3.8 for definition of rated current. The values of rated current should be selected from the R 10 series, specified in IEC 60059.

The R 10 series comprises the numbers 1; 1,25; 1,6; 2; 2,5; 3,15; 4; 5; 6,3; 8; and their products multiplied by 10^n .

6.4.2 Rated short-time withstand current

This is the RMS value of the current which the equipment can carry during a specified short time under prescribed conditions of use and behaviour.

The standard values of rated short-time withstand current should be selected from the R 10 series specified in IEC 60059.

6.4.3 Rated peak withstand current

This is the peak current associated with the first major loop of the rated short-time withstand current which equipment can carry under prescribed conditions of use and behaviour.

The rated peak withstand current should correspond to the rated frequency and the time constant of the DC component of the system.

The time constant of the DC component of the system depends strongly on the network characteristics, namely type of lines, type of transformers, nominal voltage, etc., and is the same for every piece of equipment in a single substation.

The time constant of the DC component should be 45 ms, which is adequate for most situations. For this value, the rated peak withstand current is 2,5 times the rated short-time withstand current for 50 Hz and 2,6 times the rated short-time withstand current for 60 Hz.

For other cases and for standardization purposes, the recommended time constants of the DC components are 60 ms, 75 ms and 120 ms.

For power transformers, the rated peak withstand current is given in IEC 60076-5.

6.4.4 Rated duration of short-circuit

This is the interval of time for which equipment can carry a current equal to its rated short-time withstand current.

The preferred value of rated duration of short-circuit is 1 s.

If necessary, a value lower or higher than 1 s may be chosen. The recommended values are 0,5 s, 2 s and 3 s.

NOTE For transformers, the rated duration of short-circuit is 2 s.

6.5 Rated supply voltage of auxiliary and control circuits

The supply voltage of auxiliary and control circuits should be understood to mean the voltage measured at the circuit terminals of the apparatus itself during its operation, including, if necessary, the auxiliary resistors or accessories supplied or required by the manufacturer to be installed in series with it, but not including the conductors for the connection to the electricity supply.

The rated supply voltage should be selected from the standard values given in Table 4 for DC (tolerance –15 %, +10 %) and in IEC 60038 for AC except for equipment with a self-contained auxiliary voltage supply.

Table 4 – DC supply voltage

DC supply voltage V
24
48
60
110
125
220
250

6.6 Rated supply frequency of auxiliary and control circuits

Where AC supply is used for auxiliary and control circuits, the standard values of rated supply frequency are the rated frequency of the main circuit. Auxiliary supply and control circuits may be DC.

7 Design and construction

7.1 Requirements for liquids and gases in equipment

Product standards using liquid or gas for insulation should refer to the relevant horizontal standards including:

- IEC 60376 and IEC 62271-4 for SF₆ and gases for insulation and/or switching, or
- IEC 60480 for treatment of used SF₆, or
- IEC 60296, IEC 60836, IEC 60867, IEC 61099 and IEC 62770 for various oils.

7.2 Earthing of equipment

The frame of each equipment should be provided with a reliable earthing terminal for connection to an earthing conductor suitable for specified fault conditions. The earthing connection should be designed in such a way that catalytic corrosion is minimized. Conductive parts of the equipment intended to be connected to the earthing system may be designed to be part of the earthing circuit. The connecting point should be marked with the "protective earth" symbol, as indicated by symbol IEC 60417-5019:2006-08.

7.3 Low-voltage part of equipment

Low-voltage part of equipment, such as auxiliary and control equipment, can utilize physical contacts and relays or can utilize electronic technologies.

For components utilizing physical contacts and relays, refer to IEC 62271-1 and IEC 60255-1.

For components using electronic and associated technologies, refer to the IEC 62063 series and IEC 60255-26 for EMC and IEC 60255-27 for electrical safety.

For performance of the equipment contact outputs (mechanical and static), refer to IEC 61810-1 and IEC 60255-1.

The main characteristics of auxiliary contacts should be taken from the rated values given in Table 5.

Table 5 – Auxiliary contact classes

Class	Direct current		
	Uninterrupted	Short time	Break capability
1	10 A	100 A/30 ms	2 A at 220 V
2	2 A	100 A/30 ms	100 mA at 220 V
3	200 mA	1 A/30 ms	50 mA at 48 V
4	5 A	30 A/200 ms	100 mA at 220 V

Auxiliary contacts should be suitable for their intended duty in terms of environmental conditions and making and breaking capacity.

Auxiliary and control equipment and their circuits, except for short lengths of wire at the terminals of instrument transformers, tripping coils, auxiliary contacts, etc., should be segregated from the main circuit by either earthed metallic partitions or insulating partitions.

Auxiliary equipment requiring attention during service should be accessible without risk of direct access to high-voltage parts.

Components of auxiliary and control circuits should comply with applicable IEC standards, if any.

For particular applications, different values may be specified to the manufacturer.

7.4 Marking

Equipment and its operating devices, if any, should have permanent marking containing the necessary information, such as the name or trademark of the manufacturer, the year of manufacture, the manufacturer's type designation, the serial number, the rated characteristics etc., as specified in the relevant IEC product standards. If equipment bearing the same distinctive designation (model number) is manufactured at more than one location, the manufacturing location (factory location can be in code) shall be marked on the equipment.

For outdoor equipment, the markings and their fixings should be weather- and corrosion-proof.

If the equipment consists of independent poles, each pole should be provided with a mark (for example, on a nameplate).

Technical characteristics on marking and in documents which are common to high-voltage equipment should be represented by the same symbols. Such characteristics and their symbols should follow IEC 60027-1.

7.5 Electronic name plate

Product committees should define the requirements with respect to the provision of electronic nameplates for the equipment. If so, the data should be as defined within the framework of the appropriate data model of the IEC 61850 series. Refer to Annex B for details.

7.6 Degrees of protection provided by enclosures

7.6.1 Protection of persons against access to hazardous parts and protection of the equipment against ingress of solid foreign objects

Refer to IEC 60529 with a minimum degree of IP2X, subject to the product committee's decision.

7.6.2 Protection of equipment against ingress of water

Refer to IEC 60529 with a minimum degree of IP2X, subject to the product committee's decision.

No minimum degree of protection against harmful ingress of water according to the second characteristic numeral of the IP code is specified (second characteristic numeral X).

Equipment for outdoor installation provided with additional protection features against rain and other weather conditions should be specified by means of the supplementary letter W placed after the second characteristic numeral, or after the additional letter, if any.

For high-voltage equipment, the supplementary letter H may be placed after the second characteristic numeral. The product committee shall state clearly the additional procedure to be carried out during tests for such classification.

7.6.3 Protection of equipment against mechanical impact under normal service conditions

The mechanical impact withstand level should be selected according to IEC 62262 (IK code).

7.7 Creepage distances

The IEC TS 60815 series gives general rules that assist in choosing ceramic, glass or polymeric insulators which give satisfactory performance under polluted conditions.

IEC 60664-1 gives general rules for the design of low-voltage equipment in operation under conditions of working voltage and pollution degree.

NOTE IEC 60664-4 applies to equipment for use up to 2 000 m above sea level having a rated voltage up to AC 1 000 V with rated frequencies up to 30 kHz, or a rated voltage up to DC 1 500 V.

7.8 Fire hazard

The materials should be chosen or the parts designed according to the IEC 60695 series in such a way that they retard the propagation of fire in the equipment and reduce harmful effects on the environment. In cases where product performance requires the use of flammable materials, product design should take flame retardation into account.

Application guidance on fire prevention measures on static var compensators (SVC) and flexible AC transmission systems (FACTS) and their valve halls, in accordance with the IEC 60695 series, is given in IEC TR 62757.

7.9 Noise level

If noise-level limits (continuous and/or transient) are given (usually by administrative authorities), they should be achieved by appropriate measures such as:

- using sound insulation techniques against sound transmitted through air or solids;
- using low-noise equipment.

Criteria for noise evaluation for different places and different periods of day are given in ISO 1996-1.

7.10 Electromagnetic compatibility (EMC)

7.10.1 General

EMC describes the ability of electronic and electrical systems or components to work correctly when they are close together. In practice this means that the electromagnetic disturbances from each item of equipment shall be limited and that each item shall have an adequate level of immunity to the disturbances in its environment.

Product committees should refer to IEC Guide 107 for guidance on the drafting of electromagnetic compatibility publications.

EMC product standards look at both emissions and immunity in the light of every kind of disturbance relevant to the product in its given environment. The product committees developing these publications should refer to the basic EMC standards as far as possible. In particular, emission levels higher than those specified in the generic emission standards or in applicable EMC product family standards shall not occur.