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TECHNICAL SPECIFICATION

Selection and dimensioning of high-voltage insulators intended for use in polluted conditions –
Part 1: Definitions, information and general principles

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Part 1: Definitions, information and general principles

FOREWORD

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- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
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Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC/TS 60815-1, which is a technical specification, has been prepared by IEC technical committee 36: Insulators.

This first edition of IEC/TS 60815-1 cancels and replaces IEC/TR 60815, which was issued as a technical report in 1986. It constitutes a technical revision and now has the status of a technical specification.

The following major changes have been made with respect to IEC/TR 60815:

- Encouragement of the use of site pollution severity measurements, preferably over at least a year, in order to classify a site instead of the previous qualitative assessment (see below).
- Recognition that "solid" pollution on insulators has two components, one soluble quantified by ESDD, the other insoluble quantified by NSDD.
- Recognition that in some cases measurement of layer conductivity should be used for SPS determination.
- Use of the results of natural and artificial pollution tests to help with dimensioning and to gain more experience in order to promote future studies to establish a correlation between site and laboratory severities.
- Recognition that creepage length is not always the sole determining parameter.
- Recognition of the influence other geometry parameters and of the varying importance of parameters according to the size, type and material of insulators.
- Recognition of the varying importance of parameters according to the type of pollution.
- The adoption of correction factors to attempt to take into account the influence of the above pollution and insulator parameters.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
36/264/DTS	36/270/RVC

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all the parts in the future IEC 60815 series, under the general title *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

SELECTION AND DIMENSIONING OF HIGH-VOLTAGE INSULATORS INTENDED FOR USE IN POLLUTED CONDITIONS –

Part 1: Definitions, information and general principles

1 Scope and object

IEC/TS 60815-1, which is a technical specification, is applicable to the selection of insulators, and the determination of their relevant dimensions, to be used in high-voltage systems with respect to pollution. For the purposes of this technical specification, the insulators are divided into the following broad categories, each dealt with in a specific part as follows:

– IEC/TS 60815-2 – Ceramic and glass insulators for a.c. systems;
– IEC/TS 60815-3 – Polymeric insulators for a.c. systems;
– IEC/TS 60815-4 – *equivalent to 60815-2 for d.c. systems*[1];
– IEC/TS 60815-5 – *equivalent to 60815-3 for d.c. systems*[1].

This part of IEC 60815 gives general definitions, methods for the evaluation of pollution site severity (SPS) and outlines the principles to arrive at an informed judgement on the probable behaviour of a given insulator in certain pollution environments.

This technical specification is generally applicable to all types of external insulation, including insulation forming part of other apparatus. The term “insulator” is used hereafter to refer to any type of insulator.

CIGRE C4 documents [1], [2], [3][2], form a useful complement to this technical specification for those wishing to study in greater depth the performance of insulators under pollution.

This technical specification does not deal with the effects of snow, ice or altitude on polluted insulators. Although this subject is dealt with by CIGRE [1], [4], current knowledge is very limited and practice is too diverse.

The object of this technical specification is to

- understand and identify parameters of the system, application, equipment and site influencing the pollution behaviour of insulators,
- understand and choose the appropriate approach to the design and selection of the insulator solution, based on available data, time and resources,
- characterize the type of pollution at a site and determine the site pollution severity (SPS),
- determine the reference unified specific creepage distance (USCD) from the SPS,
- determine the corrections to the “reference” USCD to take into account the specific properties (notably insulator profile) of the "candidate" insulators for the site, application and system type,
- determine the relative advantages and disadvantages of the possible solutions,
- assess the need and merits of "hybrid" solutions or palliative measures,
- if required, determine the appropriate test methods and parameters to verify the performance of the selected insulators.

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1 At the time of writing these projects have yet to be initiated.

2 References in square brackets refer to the bibliography.

2 Normative references

The following referenced documents are indispensable for the application 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.

IEC 60038, *IEC standard voltages*

IEC 60050-471, *International Electrotechnical Vocabulary – Part 471:Insulators*

IEC 60305, *Insulators for overhead lines with a nominal voltage above 1 000 V – Ceramic or glass insulator units for a.c. systems – Characteristics of insulator units of the cap and pin type*

IEC 60433, *Insulators for overhead lines with a nominal voltage above 1 000 V – Ceramic insulators for a.c. systems – Characteristics of insulator units of the long rod type*

IEC 60507:1991, *Artificial pollution tests on high-voltage insulators to be used on a.c. systems*

IEC/TR 61245, *Artificial pollution tests on high-voltage insulators to be used on d.c. systems*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this document, the following terms, definitions and abbreviations apply. The definitions given below are those which either do not appear in IEC 60050-471 or differ from those given in IEC 60050-471.

3.1.1
reference cap and pin insulator
U120B or U160B cap and pin insulator (according to IEC 60305) normally used in strings of 7 to 9 units to measure site pollution severity

3.1.2
reference long rod insulator
L100 long rod insulator (according to IEC 60433) with plain sheds without ribs used to measure site pollution severity having a top angle of the shed between 14° and 24° and a bottom angle between 8° and 16° and at least 14 sheds

3.1.3
insulator trunk
central insulating part of an insulator from which the sheds project

NOTE Also known as shank on smaller diameter insulators.

3.1.4
shed
projection from the trunk of an insulator intended to increase the creepage distance

NOTE Some typical shed profiles are illustrated in 9.3.

3.1.5
creepage distance
shortest distance, or the sum of the shortest distances, along the insulating parts of the insulator between those parts which normally have the operating voltage between them

NOTE 1 The surface of cement or of any other non-insulating jointing material is not considered as forming part of the creepage distance.

NOTE 2 If a high resistance coating, e.g. semi-conductive glaze, is applied to parts of the insulating part of an insulator, such parts are considered to be effective insulating surfaces and the distance over them is included in the creepage distance.

[IEV 471-01-04, modified]

3.1.6
unified specific creepage distance
USCD

creepage distance of an insulator divided by the r.m.s. value of the highest operating voltage across the insulator

NOTE 1 This definition differs from that of specific creepage distance where the line-to-line value of the highest voltage for the equipment is used (for a.c. systems usually $U_m/\sqrt{3}$). For line-to-earth insulation, this definition will result in a value that is √3 times that given by the definition of specific creepage distance in IEC/TR 60815 (1986).

NOTE 2 For 'U_m' see IEV 604-03-01 [5].

NOTE 3 It is generally expressed in mm/kV and usually expressed as a minimum.

3.1.7
insulator profile parameters
set of geometrical parameters that have an influence on pollution performance

3.1.8
salt deposit density
SDD
amount of sodium chloride (NaCl) in an artificial deposit on a given surface of the insulator (metal parts and assembling materials are not included in this surface) divided by the area of this surface, generally expressed in mg/cm²

3.1.9
equivalent salt deposit density
ESDD
amount of sodium chloride (NaCl) that, when dissolved in demineralized water, gives the same volume conductivity as that of the natural deposit removed from a given surface of the insulator divided by the area of this surface, generally expressed in mg/cm²

3.1.10
non soluble deposit density
NSDD
amount of non-soluble residue removed from a given surface of the insulator divided by the area of this surface, generally expressed in mg/cm²

3.1.11
site equivalent salinity
SES
salinity of a salt fog test according to IEC 60507 that would give comparable peak values of leakage current on the same insulator as produced at the same voltage by natural pollution at a site, generally expressed in kg/m³

3.1.12
dust deposit gauge index – soluble
DDGI-S
volume conductivity, generally expressed in μS/cm, of the pollutants collected by a dust deposit gauge over a given period of time when dissolved in a given quantity of demineralized water

3.1.13
dust deposit gauge index – non-soluble
DDGI-N
mass of non-soluble residue collected by a dust deposit gauge over a given period of time, generally expressed in mg

3.1.14
site pollution severity
SPS
maximum value of either ESDD/NSDD, SES or DDGIS/DDGIN, recorded over an appropriate period of time

3.1.15
site pollution severity class
classification of pollution severity at a site, from very light to very heavy, as a function of the SPS.

3.2 Abbreviations

DDDG directional dust deposit gauge

DDGI-S dust deposit gauge index – soluble

DDGI-N dust deposit gauge index – non-soluble

D_{m} dry months (for DDDG)

ESDD equivalent salt deposit density

F_{d} fog days (for DDDG)

F_f form factor

NSD non soluble deposit

NSDD non soluble deposit density

PI pollution index (for DDDG)

SDD salt deposit density

SES site equivalent salinity

SPS site pollution severity

TOV temporary overvoltage

USCD unified specific creepage distance

4 Proposed approaches for the selection and dimensioning of an insulator

4.1 Introductory remark

To select suitable insulators from catalogues based on system requirements and environmental conditions, three approaches (1, 2 and 3, in Table 1 below) are recommended. These approaches are also shown in flowchart form in Annex A.

Table 1 shows the data and decisions needed within each approach. The applicability of each approach depends on available data, time and economics involved in the project. The degree of confidence that the correct type and size of insulator has been selected varies also according to the decisions taken during the process. It is intended that if "shortcuts" have been taken in the selection process, then the resulting solution will represent over-design rather than one with a high failure risk in service.

In reality, the pollution performance of the insulator is determined by complicated and dynamic interactions between the environment and the insulator. Annex B gives a brief summary of the pollution flashover mechanism.

4.2 Approach 1

In Approach 1, such interactions are well represented on an operating line, or substation, and can also be represented in a test station.

4.3 Approach 2

In Approach 2, these interactions cannot be fully represented by laboratory tests, e.g. the tests specified in IEC 60507 and IEC/TR 61245.

4.4 Approach 3

In Approach 3, such interactions can only be represented and catered for to a limited degree by the correction factors. Approach 3 can be rapid and economical for the selection and dimensioning process but may lead to under-estimation of the SPS or to a less economical solution due to over-design. The overall costs, including imposed performance requirements, have to be considered when choosing from the three approaches. Whenever circumstances permit, Approaches 1 or 2 should be adopted.

The time-scales involved in the three approaches are as follows:

- For service experience (Approach 1), a period of satisfactory operation of five to ten years can be considered as acceptable. This period may be longer or shorter according to the frequency and severity of climatic and pollution events.
- For test station experience (Approach 1), a period of investigation of two to five years can be considered as typical. This period may be longer or shorter according to the test protocol and severity.
- For measurement of site severity (Approaches 2 and 3), a period of at least one year is necessary (see 8.2).
- For estimation of site severity (Approaches 2 and 3), it is necessary to carry out research into the climate and the environment and to identify and analyse all possible pollution sources. Hence, estimation is not necessarily an immediate process and may require several weeks or months.
- For laboratory testing (Approach 2), the necessary time is a matter of weeks or months depending on the type and scale of tests.

Table 1 – The three approaches to insulator selection and dimensioning

	APPROACH 1 (Use past experience)	APPROACH 2 (Measure and test)	APPROACH 3 (Measure and design)
Method	• Use existing field or test station experience for the same site, a nearby site or a site with similar conditions	• Measure or estimate site pollution severity • Select candidate insulators using profile and creepage guidance hereafter • Choose applicable laboratory test and test criteria • Verify/adjust candidates	• Measure or estimate site pollution severity • Use these data to choose type and size of insulation based on profile and creepage guidance hereafter
Input data	• System requirements • Environmental conditions • Insulator parameters • Performance history	• System requirements • Environmental conditions • Insulator parameters • Time and resources available	• System requirement • Environmental conditions • Insulator parameters • Time and resources available
Decisions	• Does the existing insulation satisfy the project requirements and is it intended to use the same insulation design ?	• Is there time to measure site pollution severity?	• Is there time to measure site pollution severity?
	YES Use the same insulation design **NO** Use different insulation design, materials or size. Use experience to pre-select the new solution or size	**YES** Measure **NO** Estimate • Type of pollution determines the laboratory test method to be used • Site severity determines the test values	**YES** Measure **NO** Estimate
Selection process	• If necessary, use the profile and creepage guidance hereafter to adapt the parameters of the existing insulation to the new choice using Approach 2 or 3	• Select candidates • Test if pollution performance data is not available for candidates • If necessary, adjust selection/size according to the test results	• Use the type of pollution and climate to select appropriate profiles using the guidance hereafter • Use the pollution level and correction factors for profile design and material to size the insulation using the guidance hereafter
Accuracy	• A selection with a good accuracy	• A selection with an accuracy varying according to the degree of errors and/or shortcuts in the site severity evaluation and with the assumptions and/or limitations of the chosen laboratory test	• A possibly over or under-dimensioned solution compared with approaches 1 or 2 • A selection with an accuracy varying according to the degree of errors and/or shortcuts in the site severity evaluation and the applicability of the selected correction factors

The following clauses give more information on system requirements, environment and site pollution severity determination.

An example of a questionnaire that can be used in Approach 1 to obtain operational experience from an existing line or substation is given in Annex H.

Guidelines for using laboratory tests in Approach 2 are described in general terms in Annex F. Both deterministic and statistical design methods are available to design and select appropriate insulator solutions based on SPS and laboratory test results; a short description of these two methods is given in Annex G.

For Approach 3, required minimum unified specific creepage distance and correction factors are given in the relevant parts of this publication.

5 Input parameters for the selection and dimensioning of insulators

The selection and dimensioning of outdoor insulators is an involved process; a large number of parameters have to be considered for a successful result to be obtained. For a given site or project, the required inputs are considered under three categories: system requirements, environmental conditions of the site and insulator parameters from manufacturer's catalogues. Each of these three categories contains a number of parameters as indicated in Table 2 below. These parameters are further discussed in later clauses.

Table 2 – Input parameters for insulator selection and dimensioning

System requirements	Environmental conditions	Insulator parameters
Type of system:	Pollution types and levels:	Overall length:
Maximum operating voltage across the insulation	Rain, fog, dew, *snow and ice*[a]	Type
Insulation co-ordination parameters	Wind, storms	Material
	Temperature, humidity	Profile
Imposed performance requirements	Altitude	Creepage distance
Clearances, imposed geometry, dimensions	*Lightning, earthquakes*	Diameters
	Vandalism, animals	Arcing distance
Live line working and maintenance practice	*Biological growths*	*Mechanical and electrical design*

[a] Non pollution related parameters are given in *italics* and are not dealt with in this technical specification; however, they may influence or limit the choice of the type of insulator to be used.

6 System requirements

System requirements shall be taken into account for the selection and dimensioning of outdoor insulation. The following points may strongly influence insulator dimensioning and therefore need to be considered.

- *Type of system (a.c. or d.c.)*

  It is well known from service and from laboratory test results that, for the same pollution conditions, some d.c. insulation may require a somewhat higher value of unified specific creepage distance compared to a.c. insulation. This effect will be dealt with in detail in future parts of IEC 60815 dealing with d.c. systems.

- *Maximum operating voltage across the insulation*

  Usually an a.c. system is characterized by the highest voltage for equipment U_m (see IEC 60038).

  Phase-to-earth insulation is stressed with the phase-to-earth voltage $U_{ph\text{-}e} = U_m/\sqrt{3}$.

  Phase-to-phase insulation is stressed with the phase-to-phase voltage $U_{ph\text{-}ph} = U_m$.

  In the case of a d.c. system, usually the maximum system voltage is equal to the maximum line-to-earth voltage. In the case of mixed voltage waveforms, the r.m.s. value of the voltage may need to be used.

- *Overvoltages*

  The effects of transient overvoltages need not be considered due to their short duration..

Temporary overvoltages (TOV) may occur due to a sudden load release of generators and lines or line-to-earth faults and cannot always be ignored.

NOTE The duration of the TOV depends on the structure of the system and can last for up to 30 min or even longer in the case of an isolated neutral system. Depending on the duration of the TOV and its probability of occurrence, the combined effect of TOV and insulator pollution may have to be considered. CIGRE 158 [1] gives information on this subject and on other risks such as cold switch-on.

- *Imposed performance requirements*

  Longitudinal insulation used for synchronization can be stressed up to a value of 2,5 times the phase-to-earth voltage.

  Some customers may require performance levels for outdoor insulation with regard to availability, maintainability and reliability. This may be specified, for example, as the maximum number of pollution flashovers allowed per station, or per 100 km line length, over a given time. Such requirements may also include a maximum outage time after a flashover.

  In addition to the insulator dimensioning according to the site conditions, imposed requirements could become the controlling factor for the insulator parameters.

- *Clearances, imposed geometry and dimensions*

  There could be several cases, or a combination thereof, where special solutions for insulation types and dimensions are required.

  Examples include:

  – compact lines and substations;

  – unusual position of an insulator;

  – unusual design of towers and substations;

  – insulated conductors;

  – lines or substations with a low visual impact.

7 Environmental conditions

7.1 Identification of types of pollution

There are two main basic types of insulator pollution that can lead to flashover:

Type A: where solid pollution with a non-soluble component is deposited onto the insulator surface. This deposit becomes conductive when wetted. This type of pollution can be best characterized by ESDD/NSDD and DDGIS/DDGIN measurements. The ESDD of a solid pollution layer may also be evaluated by surface conductivity under controlled wetting conditions.

Type B: where liquid electrolytes are deposited on the insulator with very little or no non-soluble components. This type of pollution can be best characterized by conductance or leakage current measurements.

Combinations of the two types can arise.

Annex A gives a short description of the pollution flashover mechanisms for type A and type B pollution.

7.1.1 Type A pollution

Type A pollution is most often associated with inland, desert or industrially polluted areas (see 7.2). Type A pollution can also arise in coastal areas in cases where a dry salt layer builds up and then rapidly becomes wetted by dew, mist, fog or drizzle.