भारतीय मानक

Indian Standard

IS 16683 (Part 4) : 2021
IEC TS 60815-4 : 2016

प्रदूषित स्थितियों में उपयोग होने वाले उच्च-वोल्टेज इन्सुलेटर्स — चयन और आयाम

भाग 4 डी. सी. सिस्टम के लिए इन्सुलेटर्स

High-Voltage Insulators Intended for Use in Polluted Conditions — Selection and Dimensioning

Part 4 Insulators for d.c. Systems

ICS 29.080.10

भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
मानक भवन, 9 बहादुर शाह ज़फर मार्ग, नई दिल्ली - 110002
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI - 110002
www.bis.gov.in www.standardsbis.in

November 2023 **Price Group 11**

Electrical Insulators and Accessories Sectional Committee, ETD 06

NATIONAL FOREWORD

This Indian Standard which is identical to IEC TS 60815-4 : 2016 'Selection and dimensioning of high-voltage insulators intended for use in polluted conditions — Part 4: Insulators for d.c. systems' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Electrical Insulators And Accessories Sectional Committee and approval of the Electrotechnical Division Council.

The text of the IEC standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appears referring to this standard, they should be read as 'Indian Standard'; and

b) Comma (,) has been used as a decimal marker, while in Indian Standards the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to International Standards for which Indian Standards also exists. The corresponding Indian Standards, which are to be substituted, are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC TS 61245 Artificial pollution tests on high-voltage ceramic and glass insulators to be used on d.c. systems	IS/IEC TS 61245 : 2015 Artificial pollution tests on high-voltage ceramic and glass insulators to be used on d.c. systems	Identical
IEC TS 60815-1 : 2008 Selection and dimensioning of high-voltage insulators intended for use in polluted conditions — Part 1: Definitions, information and general principles	IS 16683 (Part 1) : 2018/IEC TS 60815-1 : 2008 Selection and dimensioning of high-voltage insulators intended for use in polluted conditions: Part 1 Definitions, information and general principles	Identical
IEC TS 60815-2 Selection and dimensioning of high-voltage insulators intended for use in polluted conditions — Part 2: Ceramic and glass insulators for a.c. systems	IS 16683 (Part 2) : 2018/IEC TS 60815-2 : 2008 Selection and dimensioning of high-voltage insulators intended for use in polluted conditions: Part 2 Ceramic and glass insulators for a.c. systems	Identical
IEC TS 60815-3 Selection and dimensioning of high-voltage insulators intended for use in polluted conditions — Part 3: Polymer insulators for a.c. systems	IS 16683 (Part 3) : 2018/IEC TS 60815-3 : 2008 Selection and dimensioning of high-voltage insulators intended for use in polluted conditions: Part 3 Polymer insulators for a.c. systems	Identical

(*Continued on third cover*)

CONTENTS

INTRODUCTION

Work has been going on in CIGRE C4.303 and the IEC to produce d.c. pollution design guides that represent the current state of the art. The CIGRE work has resulted in an HV d.c. Pollution Application Guidelines brochure [1] and the IEC work in this final part of IEC 60815 – *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 4: Insulators for d.c. systems*.

The work represents a huge accumulation of pollution performance knowledge from various sources (both published and unpublished) never before collated into a single opus.

Contrary to the parts of IEC 60815 dealing with a.c., this technical specification covers both polymeric and glass and porcelain insulators for d.c. systems in a single publication. It also covers hybrid insulators (the ceramic core is fully covered by a polymer).

NOTE The present document does not apply to insulators with coatings, due to the variety of coatings to be considered. This may be reconsidered at the next revision of this technical specification, after gaining more knowledge and experience and a better definition of the coating characteristics and requirements.

The approach for d.c. insulator design and selection with respect to pollution given in this part is different to that used for a.c. The key differences are:

- A simplified approach is presented which is intended for preliminary design. However, since under d.c. pollution build-up and its effects can be more severe than under a.c., the final design should be based as much as possible on a direct pollution severity measured under d.c. for the site being studied. Equally direct evaluation of the insulators selected by this process should be considered. (A statistical design approach is available in the CIGRE guidelines for d.c. pollution [1]);
- Two approaches are considered to estimate pollution severity: one using prior d.c. site severity experience, the other using site severity measurements on a.c. or unenergised insulators;
- Correction of site severity for specific parameters that have an influence under d.c. (e.g. pollution uniformity ratio, effect of diameter on pollution accumulation, NSDD) are considered;
- Direct transfer from corrected site pollution severity to necessary USCD without any use of discrete site severity classes (as made in IEC 60815 Parts 2 and 3);
- Recognition is made of the improved performance of Hydrophobicity Transfer Materials (HTM) as a practical solution for many designs, notably at UHV, while taking into account potential hydrophobicity loss;
- Importance of the influence of altitude;
- Distinct diameter correction for flashover performance.

Although there is some positive experience with validation by testing of traditional glass and porcelain insulators, the full translation of such test results to service conditions is still under consideration. Any such experience is mainly lacking for composite insulators, since an agreed standardised testing procedure is not yet available. The problem is accentuated to porcelain/glass as well composite technology by the continuing rise in system voltages where over-design may result in unrealistic insulator lengths or heights. Hence for this first edition the verification of a chosen insulator solution by testing is entirely subject to agreement.

For polymeric, notably HTM, the pollution withstand may not be the only necessary design information. The design stress should be selected not only to avoid flashover, but also to assure a limited ageing of the insulators in service. This item is however out of the scope of the present specification.

Applications with controlled indoor environment are not included in the scope of this document.

Indian Standard

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

PART 4 INSULATORS FOR d.c. SYSTEMS

1 Scope

This part of IEC 60815, which is a Technical Specification, is applicable as first approach for the determination of the required d.c. Unified Specific Creepage Distance for insulators with respect to pollution. To avoid excessive over or under design, existing operation experience should be compared and eventually additional appropriate tests may be performed by agreement between supplier and customer.

It is applicable to:

- Glass and porcelain insulators;
- Composite and hybrid insulators with an HTM or non-HTM housing.

This part of IEC 60815 gives specific guidelines and principles to arrive at an informed judgement on the probable behaviour of a given insulator in certain pollution environments.

The structure and approach of this part of IEC 60815 are similar to those explained in Part 1, but adapted for the specific issues encountered with polluted HV d.c. insulation.

The aim of this Technical Specification is to give the user simplified means to:

- Identify issues specific to d.c. applications that can affect the choice and design process;
- Determine the equivalent d.c. Site Pollution Severity (SPS) from measurements, correcting for electrostatic effects, diameter, pollution distribution and composition;
- Determine the reference USCD for different candidate insulating solutions, taking into account materials, dimensions and risk factors;
- Evaluate the suitability of different insulator profiles;
- Discuss the appropriate methods to verify the performance of the selected insulators, if required;

This simplified process is intended to be used when comparable operational experience from existing d.c. system is incomplete or not available.

The simplified design approach might result in a solution that exceeds the physical constraints of the project. More refined approaches for such cases, e.g. using a statistical approach, are given in the CIGRE d.c. guidelines [1]. In extreme cases, e.g. for exceptionally severe site conditions, alternative solutions such as changing the line route, relocation of converter stations or using an indoor d.c. yard may need to be considered.

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.

IEC TS 61245, *Artificial pollution tests on high-voltage ceramic and glass insulators to be used on d.c. systems*

IEC TS 60815-1:2008, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 1: Definitions, information and general principles*

IEC TS 60815-2, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 2: Ceramic and glass insulators for a.c. systems*

IEC TS 60815-3, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 3: Polymer insulators for a.c. systems*

IEC TS 62073, *Guidance on the measurement of hydrophobicity of insulator surfaces*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-471:2007 and the following apply.

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

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

3.1.1
Unified Specific Creepage Distance
USCD
creepage distance of an insulator divided by the maximum operating voltage across the insulator. It is generally expressed in mm/kV

Note 1 to entry: For d.c. the maximum operating voltage is the d.c. system voltage as defined in IEC 60071-5.

3.1.2
Reference d.c. Unified Specific Creepage Distance
RUSCDdc
value of Unified Specific Creepage Distance for a d.c. system at a pollution site determined from ESDD and NSDD values corrected for NSDD, CUR, etc. according to this document

Note 1 to entry: This is generally expressed in mm/kV.

3.1.3
Contamination Uniformity Ratio
CUR
ratio of the pollution deposit density on the lower surface of insulators to that of the upper surface

Note 1 to entry: Referred to as Pollution Uniformity Ratio (PUR) in some countries.

Note 2 to entry: This is referred to as Contamination Uniformity Ratio in some countries.

3.1.4
Hydrophobicity Transfer Material
HTM
polymer materials which exhibit hydrophobicity and the capability to transfer hydrophobicity to the layer of pollution

Note 1 to entry: Further information on HTM is given in Annex A.

3.2 Abbreviated terms

CF	Creepage Factor
ESDD	Equivalent Salt Deposit Density
HTM	Hydrophobicity Transfer Material
NSDD	Non Soluble Deposit Density
SDD	Salt Deposit Density
SES	Site Equivalent Salinity
SPS	Site Pollution Severity
USCD	Unified Specific Creepage Distance
RUSCD	Reference Unified Specific Creepage Distance
CUR	Pollution (Contamination) Uniformity Ratio
RUSCDdc	Reference d.c. Unified Specific Creepage Distance

4 Principles

4.1 General

The overall process of insulation selection and dimensioning can be summarised as follows:

- Determination of the appropriate approach (deterministic, statistical etc.) as a function of available knowledge, time and resources as recommended in IEC TS 60815-1. The following steps concern the simplified, deterministic approach as described in IEC TS 60815-1; if the statistical approach is chosen, please refer to IEC TS 60815-1 for full details.

Therefore, using IEC TS 60815-1:

- collection of the necessary input data, notably system voltage, insulation application type (line, post, bushing, etc.);
- collection of the necessary environmental data, notably site pollution severity.

At this stage, a preliminary choice of possible candidate insulators suitable for the applications and environment may be made.

Then, using this document for:

- determination of the d.c. site severity by application of correction factors;
- determination of the reference d.c. USCD (RUSCD);
- correction of the RUSCD for each candidate insulator;
- checking the profile parameters;
- verification.

It is to be noted that in the following the USCD and the correction factors are based on a median behaviour derived from widely spread results (see [1][1]). Despite this, when the process is benchmarked against service experience the results are consistent enough to give useful orientation to identify a range of preliminary solutions (see [1]).

1 Numbers in square brackets refer to the bibliography.

4.2 Overall design process

The overall design process is shown in the flowcharts in Figures 1 and 2. From these flowcharts it can be seen that the creepage distance is only selected after multiple steps to correct site pollution measurements for the factors which can influence d.c. performance and which often have a more pronounced effect under d.c. than for a.c. The design process is complicated by several factors:

- d.c. energised insulators exhibit a greatly different pollution accumulation behaviour compared to a.c. and un-energised insulators due to electrostatic effects, this accumulation is affected by wind, particle size etc.;
- composition of the pollution (low solubility or slow-dissolving salts);
- effect of the amount of non-soluble deposit;
- CUR "Contamination Uniformity Ratio";
- effect of diameter on pollution accumulation;
- non-uniformity of the pollution layer along or around the insulator;
- effect of diameter on pollution performance;
- effect of insulator material on pollution performance.

These points are described in more detail in Figures 1 and 2.

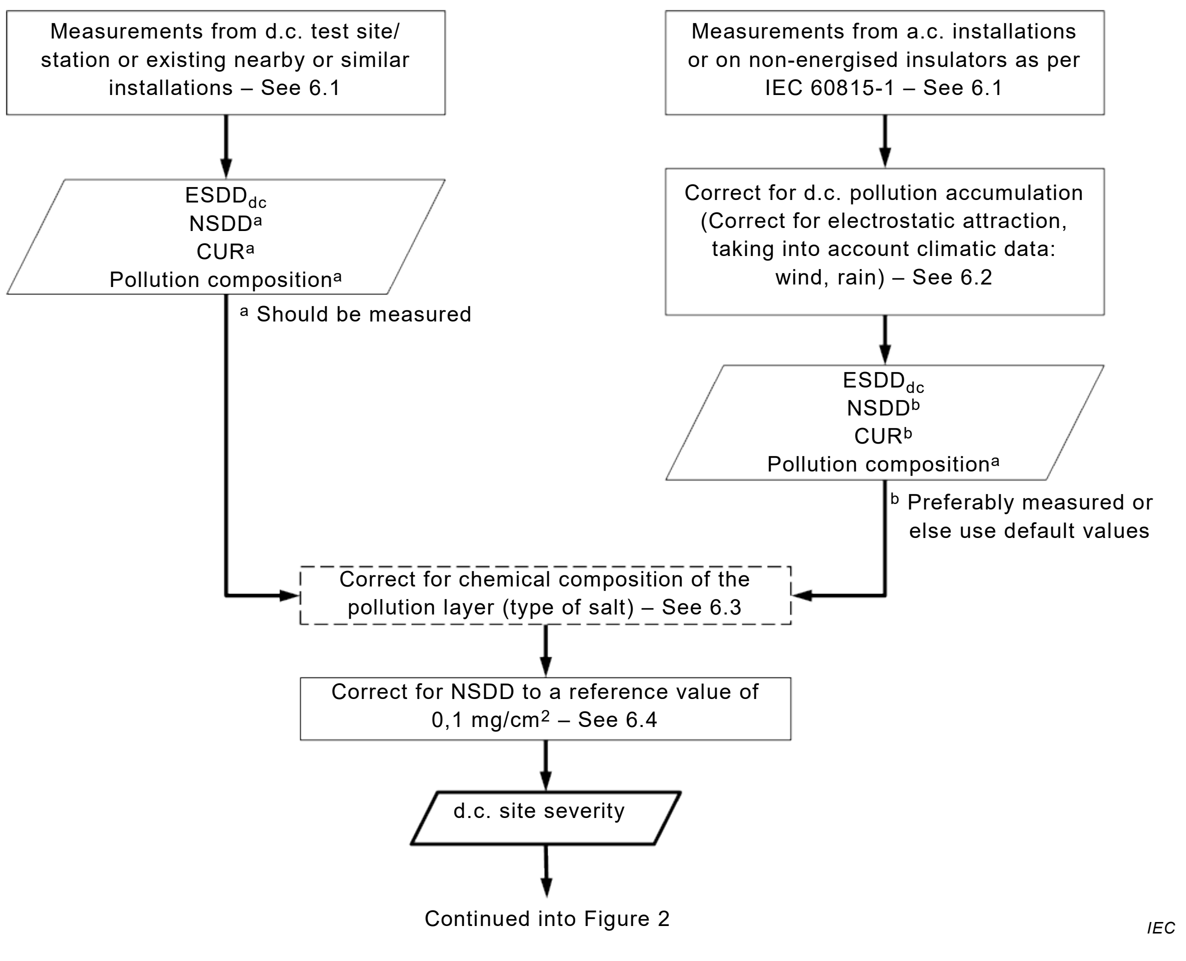


Figure 1 – Overall design process for d.c. insulation – determination of d.c. Site Pollution Severity

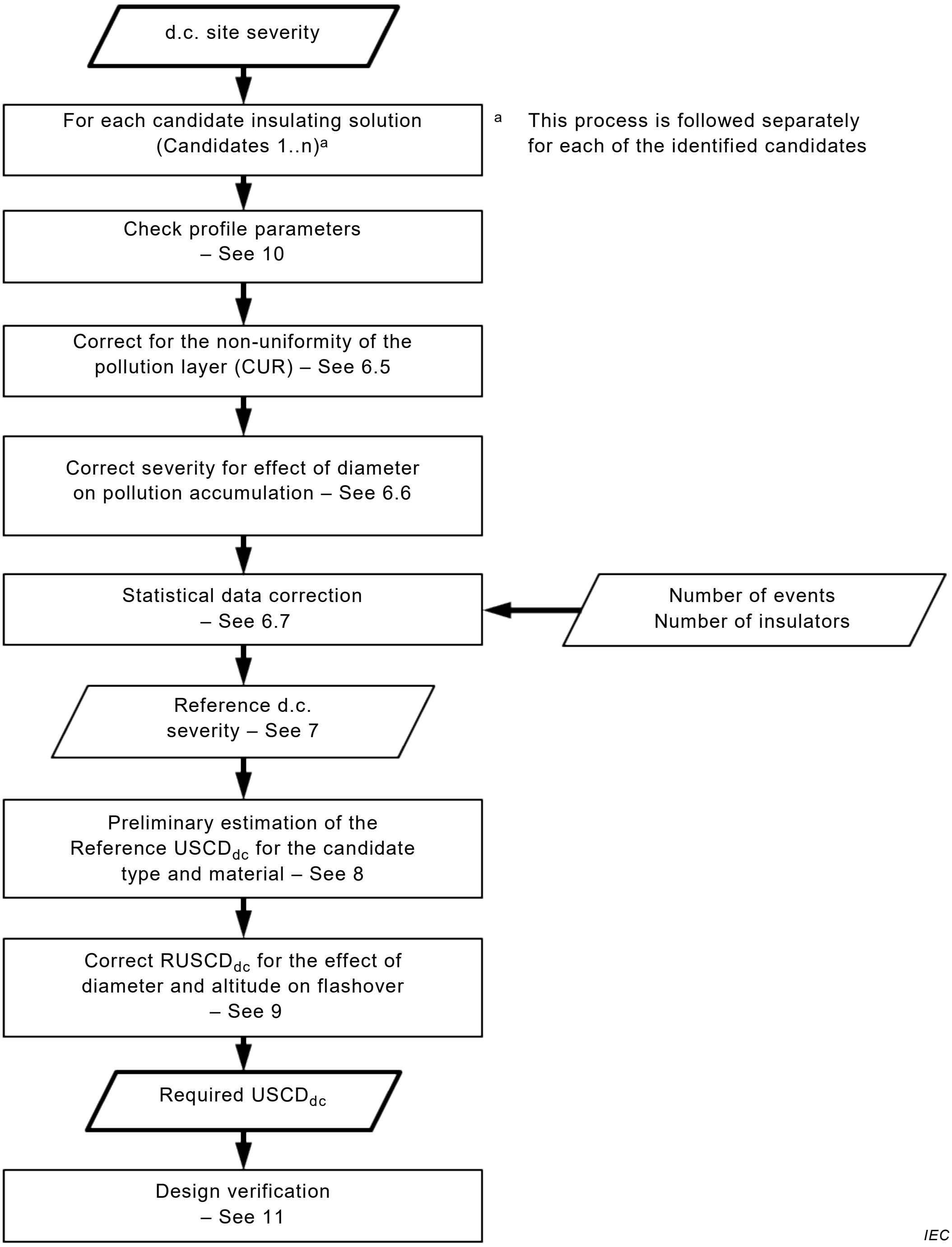


Figure 2 – Overall design process for d.c. insulation – determination of the required $USCD_{dc}$ for candidate insulating solutions

5 Materials

Polymer materials which exhibit hydrophobicity and the capability to transfer hydrophobicity to the layer of pollution are referred to in this Technical Specification as hydrophobicity transfer materials (HTM). Materials which do not exhibit hydrophobicity transfer are referred to as non-HTM. Hydrophobicity may be lost in certain conditions (see IEC TS 60815-3:2008, notably Clause 5), either temporarily or in some cases permanently. IEC TS 62073 provides guidance on the measurement of wettability of insulator surfaces (see Annex A).

Some other technologies exist that are intended to improve the pollution performance of porcelain or glass insulators under pollution, for example, semi-conducting glaze and hydrophobic coatings. At present it is not possible to give specific information on the durability of the improvement given by such technologies. The application of this document to such technologies is therefore entirely subject to agreement.

More information on the aspects of different insulating materials under HV d.c. is given in [1].

6 Site severity determination

6.1 Input data

The site severity determination is based on different possible sources of information (ordered in increasing confidence):

- The SPS, determined according to IEC TS 60815-1, using the standard glass or porcelain reference insulator;
- Similar data from un-energised or a.c. energised insulators of other types than the reference insulator, measured over a sufficiently long period (e.g. at least one year);
- Similar data from d.c. energised insulators, measured over a sufficiently long period (e.g. at least two years for sites with K_p factor >1,2, unless experience allows this period to be reduced e.g. for sites with K_p factor 1,1).

The necessary data is:

- Climatic data;
- The ESDD and NSDD from the SPS, or the SES, from one of the above sources (in the case of Type A pollution the ESDD and NSDD shall be measured separately on upper and lower shed surfaces);
- The diameter of the candidate insulator and of the reference or monitor insulator if applicable.

NOTE The terms ESDD and NSDD refer to average values ($ESDD_{ave}$, $NSDD_{ave}$) over the total measured surface (i.e. Top and Bottom combined), see Annex C of IEC TS 60815-1:2008.

6.2 d.c. pollution accumulation correction: K_p

d.c. energised insulators may accumulate more pollution than do a.c. energised or non-energised insulators, due to the permanent static electric field surrounding d.c. insulators. The ratio of d.c. to a.c. accumulated pollution (K_p factor) varies from one site to another and is the result of a complex interaction of a number of parameters. It is therefore not possible to accurately predict this ratio.

The following guidance is given with regards to the choice of K_p (see [1] for more details):

- K_p= 1 for measurements made on d.c. energised insulators for a sufficiently long time in situ;
- K_p is typically 1,1, with a range of 1 to 1,2 in areas where maximum site severities conditions are reached in short time following specific events. Typical cases are those where the wind speed is the dominant factor that determines the amount of pollution carried in the air or areas where high wind speeds prevail. A typical example is Type B pollution close to the sea;
- K_p is typically 1,6, with a range of 1,3 to 1,9 in areas where the maximum site severities conditions are reached in times of the order of a few months. These areas may be characterised by pollution either of type A or B (e.g. at some distance from the coast or from pollution sources associated with human activity) with moderate wind conditions;
- K_p is typically 2,5 with a range of 2 to 3 in areas with a pollution process increasing slowly in time (e.g. showing an increasing trend in a 1-2 year period), e.g. areas with Type A pollution, characterised by human activity such as mining, industry, roads etc., with generally mild wind conditions.

It should be noted that K_p can be higher than the values given above when the site location is characterised with extended dry periods and can be lower when there is frequent natural cleaning events such as rain. Table 1 summarises and extends the information above.

Table 1 – Typical ranges of K_p according to climatic conditions

Event Frequency	Average/Normal Wind			
	High	Moderate	Low	Dead calm
Frequent rain	1	1	1	1
Short duration extreme events	Typical: 1,1 Range: 1 to 1,2	1,1	1,2	1,3
Build-up over months	1,3	Typical: 1,6 Range: 1,3 to 1,9	1,9	3
Build-up over years	2	2,25	Typical: 2,5 Range: 2 to 3	3
Long dry periods (< 20 mm rain/month for more than 6 months)	2,5	2,75	3	Typical: 3 Range: >3

In view of the large range of possible values for K_p, it is highly recommended to determine the d.c. site pollution severity by measurements made on d.c. energised insulators, for as long a period as possible and including any seasons likely to result in higher accumulation, in order to get a more precise estimation of the d.c. ESDD.

K_p may be affected by insulator orientation either reducing or increasing self-cleaning effects.

6.3 Chemical composition of the pollution layer (Type A pollution)

It is known that the presence of slow-dissolving or low solubility salts in the natural pollution layer can reduce the severity of the pollution with respect to sodium equivalent salts. Also studies have been made on the effect of a proportion of calcium salts in the pollution layer.

If volume conductivity measurements made during site severity evaluation according to IEC TS 60815-1:2008, Annex C, show a distinct tendency to increase with time, then this is an indication that slow-dissolving or low solubility salts are present. In such cases, it is advised to study the exact chemical composition of the pollution layer, and then to refer to the information given in [1] and [2].

6.4 Correcting for NSDD (Type A pollution)

The correction for all insulator types is:

$$K_{\mathrm{NSDD}} = \left(\frac{NSDD}{NSDD_0}\right)^{0,35}$$

Where $NSDD_0$ is 0,1 mg/cm^2 and $NSDD \geq$ 0,02 mg/cm^2.

Further details on the influence of NSDD can be found in [1].

6.5 Correcting for CUR (Type A pollution, cap and pin insulators)

CUR is the ratio of the Type A pollution deposit density (see IEC TS 60815-1) on the lower surface of insulators to that of the upper surface. This can also be expressed as the inverse, where it is called T/B (Top/Bottom Ratio).

Since CUR for open profiles is usually limited to low values, this correction is generally only applied to measurements from cap and pin insulators. Measurements from other insulators with complex or deep under-rib profiles may also require correction, but at present there is insufficient data on the necessary correction.

The measured overall ESDD (non-uniform) shall be corrected to an equivalent ESDD (uniform pollution) using:

$$K_{\mathrm{CUR}} = \left(\frac{1{,}6 \times CUR}{0{,}6 + CUR}\right) \times \left[1 - 0{,}4 \times \log_{10}\left(\frac{1}{CUR}\right)\right]^{-3}$$

Further details on the influence of pollution uniformity can be found in [1].

6.6 Effect of diameter on the pollution accumulation K_d

This correction is applied when measurements from cap and pin or smaller diameter insulators are being used to determine the equivalent pollution severity for larger diameter insulators.

The following correction, starting from an average diameter of 250 mm, is proposed for station insulators, housings, etc.:

$$K_{\mathrm{d}} = \left(\frac{D}{D_0}\right)^{-0{,}32}$$

Where D_0 = 250 mm or the average diameter of the insulator used for the site severity measurement.

No correction is necessary for suspension or line post insulators.

NOTE Average diameter calculation is shown in IEC TS 60815-2 and – 3.

If the site severity measurements are made on an insulator of same diameter as the candidate insulator, then K_d = 1.

Further details on the influence of diameter on pollution accumulation can be found in [1].

6.7 Correction for the number of similar insulators in parallel: K_s

In order to take into account the increased risk of flashover due to having many similar insulators in parallel, a correction is applied as follows:

- Many insulators in parallel (e.g. transmission line sections with more than 100 strings, assumed to be polluted to the same degree and submitted to the same environmental event):

  K_s = 1,4.

  K_s = 1
- Few insulators in parallel (e.g. station apparatus):

This correction only covers the increased risk of flashover due to many objects being submitted to the same stress (i.e. all the insulators in the same pollution environment). It does not cover the reduction of flashover voltage that can arise from the proximity of insulator strings in multiple string sets.

Correction is valid for sites with a moderate number of critical wetting events, e.g. 10 per year. For higher numbers of events a further correction may be necessary. Further details can be found in [1].

7 Determination of the reference d.c. site severity

For type A pollution, the average ESDD ($ESDD_{\mathrm{ave}}$) from the SPS is corrected to the reference d.c. ESDD ($ESDD_{\mathrm{dc}}$) by:

$$ESDD_{\mathrm{dc}} = ESDD_{\mathrm{ave}} \times K_{\mathrm{p}} \times K_{\mathrm{NSDD}} \times K_{\mathrm{CUR}} \times K_{\mathrm{d}} \times K_{\mathrm{s}}$$

For Type B pollution, the SES is corrected to the reference d.c. SES by:

$$SES_{\mathrm{dc}} = SES \times K_{\mathrm{s}} \times K_{\mathrm{d}}$$

K_{p} is not applicable to SES as the influence of electrostatic field is negligible for Type B pollution.

8 Determination of the reference d.c. USCD

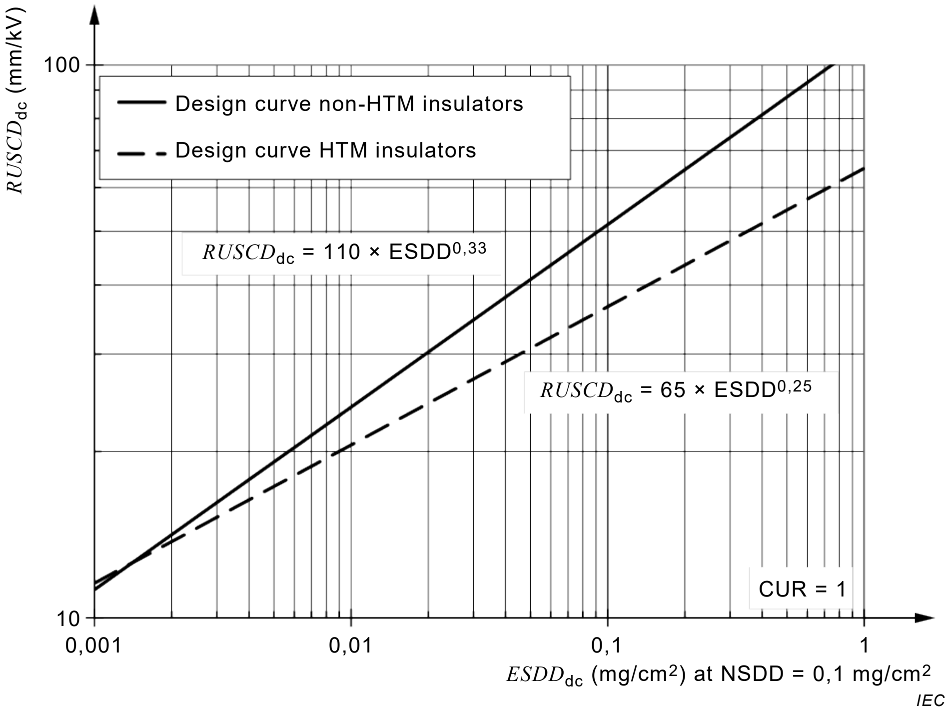


Figure 3a – Pollution type A

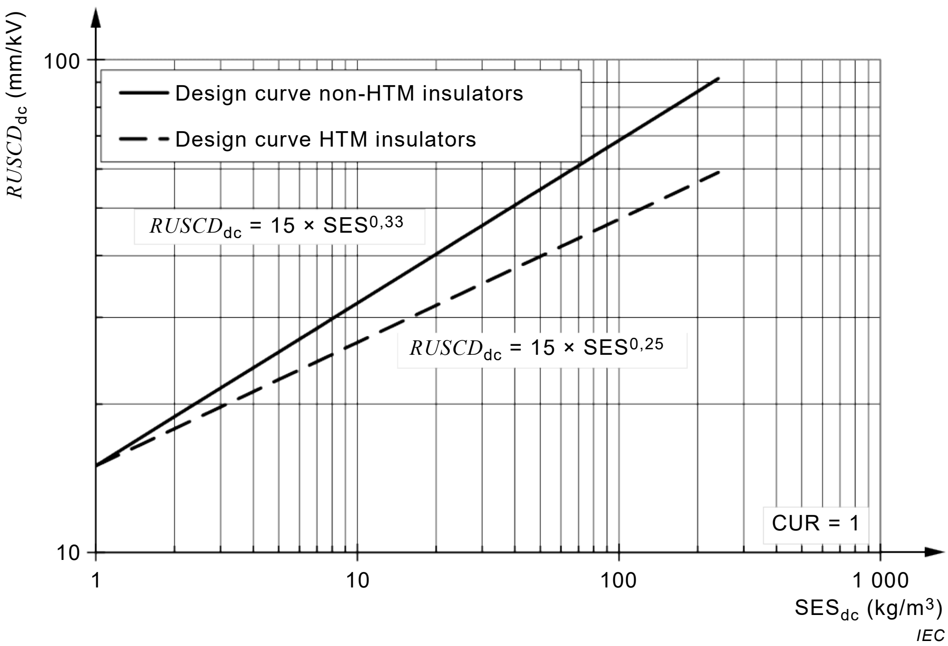


Figure 3b – Pollution type B

Figure 3 – $RUSCD_{dc}$ as a function of d.c. site pollution severity

Also taking account of laboratory information, the following equations (as illustrated in Figures 3a and 3b are proposed:

For Type A pollution:

- Non-HTM materials: $RUSCD_{dc}$ = 110 x $ESDD_{dc}^{0,33}$

- HTM materials: $RUSCD_{dc}$ = 65 x $ESDD_{dc}^{0,25}$

For Type B pollution:

- Non-HTM materials: $RUSCD_{dc}$ = 15 x $SES_{dc}^{0,33}$
- HTM materials: $RUSCD_{dc}$ = 15 x $SES_{dc}^{0,25}$

The above equations are considered as sufficient for preliminary design. However it has to be observed that both service and experimental results are rather spread, depending significantly on insulator characteristics, see [1].

NOTE These equations are derived from reference insulators as described in Annex B.

9 Correction of the RUSCD for each candidate insulator

9.1 Correction for the effect of diameter on pollution withstand performance C_d

In order to correct for the effect of diameter on the pollution withstand performance of the candidate insulators, a factor C_d is applied to the $RUSCD_{dc}$. This is done for non-HTM materials according to:

$$C_d = \left(\frac{D}{D_O}\right)^{0,30}$$

where D_0 = 250 mm and D is the average diameter in mm.

For HTM materials in conditions with potential partial loss of hydrophobicity:

$$C_d = \left(\frac{D}{D_O}\right)^{0,17}$$

where D_0 = 250 mm and D is the average diameter in mm.

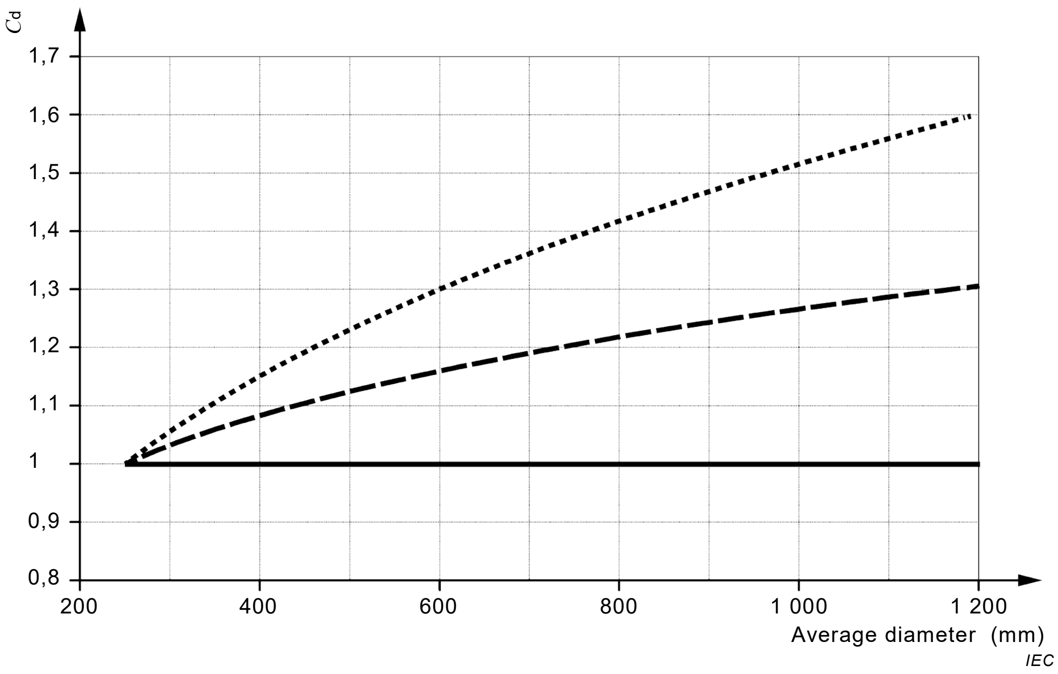
And for HTM materials in conditions with no potential partial loss of hydrophobicity:

C_d = 1

Figure 4 shows these corrections.

NOTE Quantification of HTM effect is still under consideration of CIGRE SC D1 and therefore the use of the typical reference curves in Figure 4 is subject to agreement.

For more information on the source of this correction see [1].



Key

- Dotted line: Non-HTM
- Dashed line: HTM with risk of partial hydrophobicity loss
- Solid line: HTM with no risk of hydrophobicity loss

Figure 4 – Correction for the effect of diameter on d.c. pollution withstand performance

For diameters smaller than 250 mm, the correction factor C_d may be lower than 1 (subject to agreement) [1].

9.2 Correction for altitude C_a

In d.c. it may become necessary to correct the RUSCD for altitude by the factor C_a.

NOTE This subject is currently under study by CIGRE D1.44.

Until the CIGRE results are available, the proposed correction (based on IEC 60071-1) is:

$$C_a = e^{n\left(\frac{H}{8150}\right)}$$

Where H is the height above sea-level in metres. The current design practice in industry is to use $H - 1\ 000$ instead of H in the above formula and to only apply the correction above 1 000 m.

Since the altitude correction may depend on insulator characteristics and pollution severity it is applied on a per candidate basis. Until further information is available, a value of 0,35 is suggested for n.

This correction is also used to correct test results obtained at high altitude to their sea-level value.

9.3 Determination of the required USCD for each candidate

The required USCD ($USCD_{req}$) for each candidate is determined as follows:

$$USCD_{\mathrm{req}} = RUSCD \times C_{\mathrm{d}} \times C_{\mathrm{a}}$$

10 Checking the profile parameters

10.1 General

Profile parameters are important for avoiding rain bridging, preventing local short circuiting between sheds, aiding self-cleaning, avoiding pollution “traps” and controlling local electric field stress.

Study of the effect of profile parameters under d.c. [1] has revealed that some parameters, notably Creepage Factor, can have a far greater effect than under a.c.

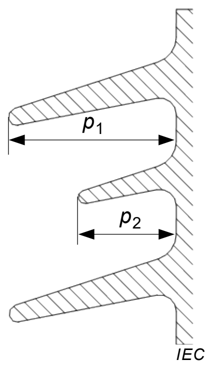
This clause follows the philosophy of IEC 60815-2 and -3. However, in these two technical specifications for a.c., the information was supported by a significant field and laboratory experience, which is much less for d.c. case of this document. It is to be clarified that the present information is a picture of the insulators currently used, without a sufficient consolidated and long field experience (see also the case of insulators with extremely high creepage factors). In the following the typical values currently used in practice for each profile parameter are given, along with limits if these are known.

An optimal profile can be influenced by too many parameters, so the following can be used to select the most appropriate profile:

- Consult data from service or test station experience to confirm the performance of the profile;
- Find an alternative profile or insulator technology;
- Verify the performance of the profile by appropriate comparative testing (e.g. order of merit comparison with other profiles).

NOTE The figures in the Subclauses 10.1 to 10.7 are intended solely to illustrate the dimensional parameters used to determine profile parameters. They are not intended to represent optimum shed shapes.

10.2 Alternating sheds defined by shed overhang



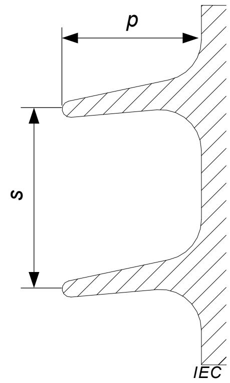
The classification of a profile as being alternating or not is based on difference in shed overhang measured from the insulator trunk to the tips of the largest and smallest sheds.

Shed overhang alone is not an important parameter, as long as the shed angle is not essentially flat (< 5°), or excessive (> 35°). The parameter is useful for defining uniform shed diameter profiles compared to alternating shed diameter profiles. However larger values of difference in shed overhang may be beneficial for vertical insulators in ice, snow and heavy rain conditions.

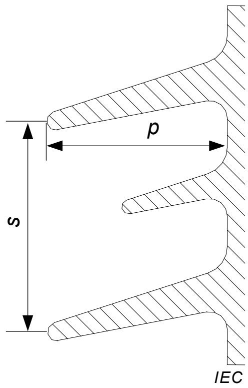
Not applicable to cap and pin insulators or multi-shed pin insulators.

Parameter	Glass and Porcelain Insulators	Composite & Hybrid Insulators, non-HTM	Composite & Hybrid Insulators HTM
Overhang	Non-alternating: p_1-p_2 < 20 mm Alternating: p_1-p_2 ≥ 20 mm	Non-alternating: p_1-p_2 < 15 mm Alternating: p_1-p_2 ≥ 15 mm	Non-alternating: p_1-p_2 < 15 mm Alternating: p_1-p_2 ≥ 15 mm

10.3 Spacing versus shed overhang



Uniform sheds



Alternating sheds

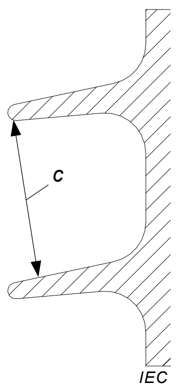
Spacing versus shed overhang is ratio of the vertical distance between two similar points of successive sheds of the same diameter (spacing) and the maximum shed overhang.

This parameter, as well as those described in clauses 10.4, 10.5 and 10.6, involve shed-to-shed spacing and are important for the avoidance of “shorting out” creepage distance bridged by a shed-to-shed arc especially under heavy rain conditions.

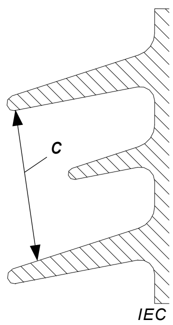
Not applicable to cap and pin insulators or multi-shed pin insulators.

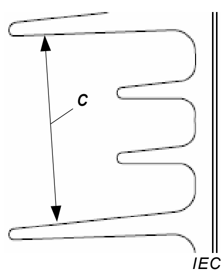
Parameter	Glass and Porcelain Insulators	Composite & Hybrid Insulators, non-HTM	Composite & Hybrid Insulators HTM
s/p	Usually ≥ 1 Generally never below 0,9	Usually ≥ 1 Generally never below 0,85	Usually ≥ 0,80 Generally never below 0,70

10.4 Minimum distance between sheds



Uniform sheds





Alternating sheds

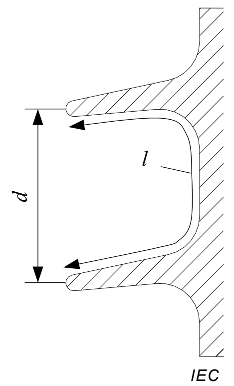
c is the minimum distance between adjacent sheds of the same diameter, measured by drawing a perpendicular line from the lowest point of rim of the upper shed to the next shed below of the same diameter.

Minimum distance between sheds is one of the more important characteristics for insulator profile evaluation. Shed-to-shed arcing for small shed spacing can negate any effort to improve performance by adding creepage distance.

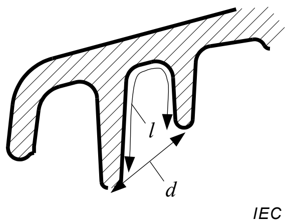
Not applicable to cap and pin insulators or pin insulators.

Parameter	Glass and Porcelain Insulators	Composite & Hybrid Insulators, non-HTM	Composite & Hybrid Insulators HTM
c	Typical minimum: 60 mm (70 mm for insulators with underribs) Rarely less than 60 mm		Typical minimum: 45 mm Rarely less than 40 mm For average diameters >250 mm rarely less than 55 mm*
*NOTE Only for surge arresters, positive service records with c = 46 mm and average diameters of up to 310 mm are available.			

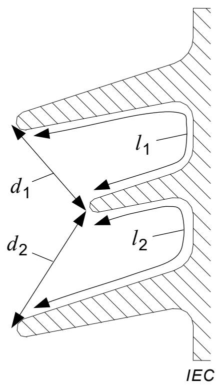
10.5 Creepage distance versus clearance

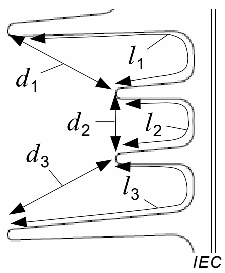


Plain sheds



Cap and pin





Alternating sheds

d is the straight air distance between two points on the insulating part or between a point on the insulating part and another on a metal part.

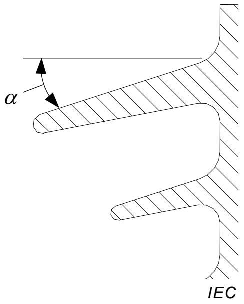
l is the part of the creepage distance measured between the above two points.

l/d is the highest ratio found on any section, for example on the underside of a cap and pin insulator.

Creepage distance versus clearance is a more localised check of the risk of bridging by arcs when dry bands or uneven hydrophobicity occur. It is also important in avoiding localised pollution build-up in deep and narrow sections of the profile.

Parameter	Glass and Porcelain Insulators	Composite & Hybrid Insulators, non-HTM	Composite & Hybrid Insulators HTM
l/d	Typical maximum: 4 Rarely more than 4,5		Usually in accordance with IEC TS 60815-3

10.6 Shed angle



For rounded sheds, α is measured at the mid-point.

Open profiles allow for more efficient natural washing of insulator surfaces, provided the shed angle is not so low as to impede excess water run-off.

Not applicable to pin insulators.

Parameter	Glass and Porcelain Insulators	Composite & Hybrid Insulators, non-HTM	Composite & Hybrid Insulators HTM
α	Typically 0° to 25° Rarely more than 30° For horizontal insulators with α<30°, the typical maximum is 20°		

10.7 Creepage factor

The creepage factor CF is equal to l/S where:

l is the total creepage distance of the insulator unit,

S is the arcing distance of the insulator unit.

For cap and pin insulators CF is determined for a string of 5 insulators or more.

CF is a global check of the overall density of creepage distance. If the requirements in 10.3, 10.4 and 10.5 are met, the creepage factor requirement is usually automatically respected.

CF values encountered in d.c. are often higher than those used for a.c. The main reason for this is that in general, a higher creepage distance is needed in a given insulator length in d.c. Nevertheless, it is important to bear in mind that greatly increasing CF can have a null or even negative effect on performance and may even lead to local stress concentration that may be damaging for some materials.

Parameter	Glass and Porcelain Insulators	Composite & Hybrid Insulators, non-HTM	Composite & Hybrid Insulators HTM
CF	Cap & pin typically below 3,4 Rarely greater than 3,75	Line insulators typically below 4,5 Rarely greater than 4,8	Typically below 4,5 Rarely greater than 4,8
	Posts, long rods and hollow cores typically below 3,5 Rarely greater than 4,0	Post and hollow cores typically below 4,4 Rarely greater than 4,6	

11 Design verification

11.1 General

A final step in the design procedure is to perform a detailed evaluation of the insulation design, including any mitigation measures, to verify compliance with the required performance criterion. CIGRE indicates that one of the following approaches is generally followed [1]:

- by operating experience; or by
- laboratory testing.

11.2 Operating experience

This approach can be used if service experience from existing d.c. installations in similar conditions utilising similar insulators is available – extrapolation of results is feasible. The design is acceptable if the deduced performance conforms to the set requirements.

11.3 Laboratory testing

Depending on agreement between the manufacturer and the user, laboratory testing or existing test results may be utilised as part of the design verification process.

- For non-HTM insulators this may take the form of either a specific test simulating a specific environment or a standard test according to the existing standard, i.e. IEC TS 61245. The pertinence of the results of such testing is questionable, as laboratory tests can never fully replicate service conditions [1, Clause 7].
- For HTM insulators current knowledge on the correlation between d.c. laboratory tests and service performance is limited. IEC and CIGRE are working to remedy this situation.

If testing is nevertheless required, then careful attention shall be paid to the determination of the test parameters, notably the applied pollution severity, which shall be agreed in detail between the user and manufacturer.

Annex A
(informative)

Hydrophobicity transfer materials

A.1 Qualitative flashover behaviour

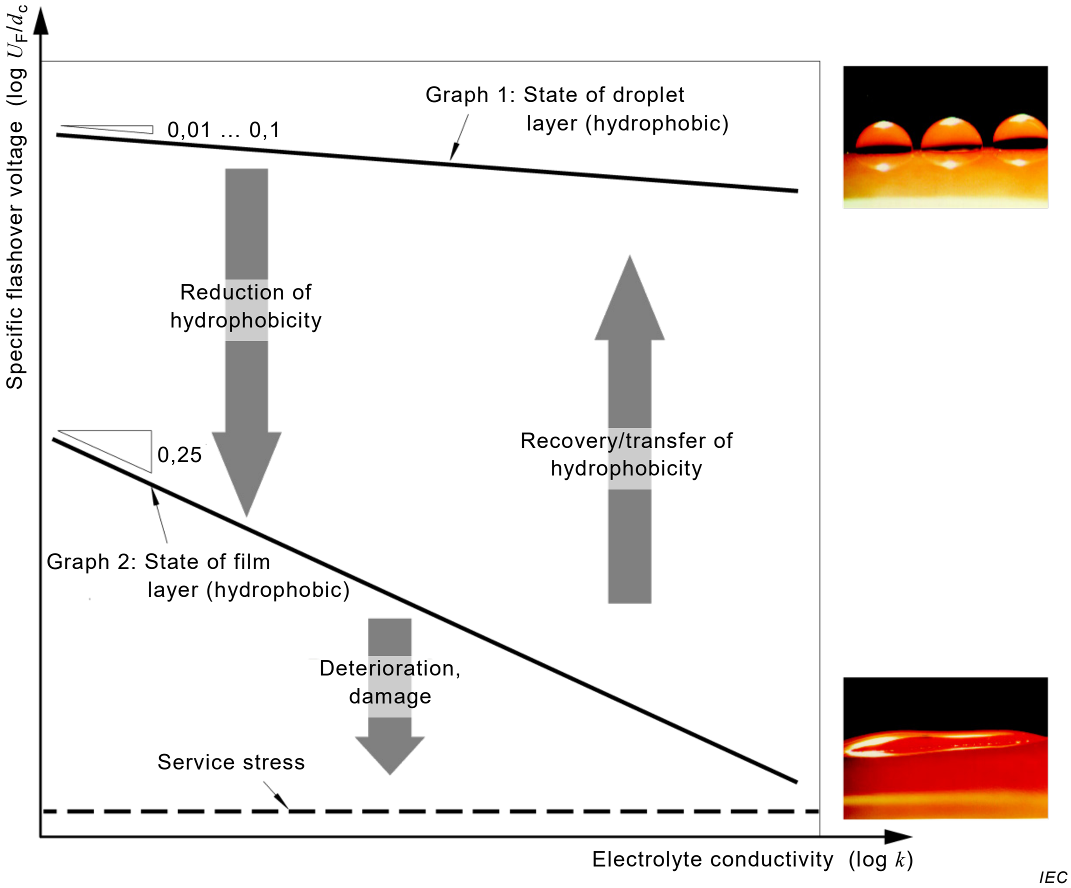


Figure A.1 – Dependency of specific flashover voltage over conductivity of an electrolyte (parameter: wettability of surface)

Figure A.1 shows the qualitative flashover behaviour in dependence on the conductivity of the electrolyte for a hydrophobic (e.g. silicone rubber) (Graph 1) and a hydrophilic (e.g. glass, porcelain) (Graph 2) surface. Hydrophobic surfaces form a discrete droplet layer under wet conditions which leads to a suppression of the leakage current compared to hydrophilic surfaces. This results in a significant lower dependence of the conductivity of the electrolyte on the flashover voltage which is expressed by a significant lower decrease of Graph 1 (so called pollution flashover exponent of 0,01…0.1) compared to Graph 2 (pollution flashover exponent of 0,25). If irreversible damage or deterioration occurs (e.g. by tracking), the specific flashover voltage can fall below the values characteristic for a film layer state. The figure shows the impact of the dynamic behaviour of hydrophobicity. It comprises the:

- retention of hydrophobicity against certain stresses like partial discharges under wet conditions (water droplet corona),
- recovery of hydrophobicity after a resting period, and
- transfer of hydrophobicity into polluted surfaces.

A reduction of hydrophobicity will cause a reduction of the specific flashover voltage towards the film layer state. Recovery as well as transfer can raise the specific flashover voltage again to the initial hydrophobic state. In this figure it is shown on principle without considering any time effects.

For this document it is assumed that a polymeric insulating material which has the ability to transfer hydrophobicity into an accumulated pollution layer is expected to have the ability for recovery after a reduction or loss of hydrophobicity. Therefore, the appellation “HTM” represents the dynamic hydrophobicity properties altogether. Examples of polymeric non-HTM are Epoxy resins, EPDM, EVA as well as glass and porcelain. Service proven as HTM, silicone rubber are recognised for, however the individual recipe including kind and treatment of fillers can play a vital role for the HTM dynamics.

The model description applies the a.c. and d.c. applications and will be moved to IEC TS 60815-1 during the next maintenance.

Annex B
(informative)

Dependence of USCD on pollution severity

B.1 Pollution type A

The collected experience on d.c. overhead lines together with the proposed design curve for line insulators is shown in Figures B.1 and B.2, with reference to type A contamination.

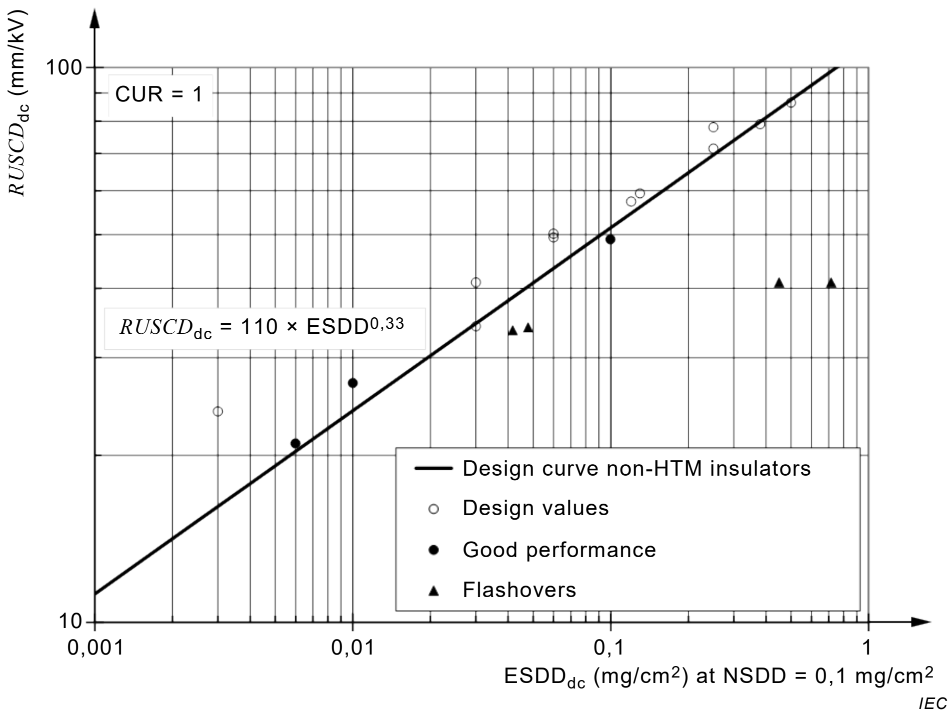


Figure B.1 – d.c. overhead lines. Collected field experience on non HTM insulators (uncoated glass and porcelain insulators)

The comparison of the field data with the required creepage distances indicates that:

- Designs with creepage distances lower than the design curve are likely to have unsatisfactory performance;
- Designs with creepage distances in accordance with the proposed design curve result in good performance;
- Recent designs are in accordance with the proposed design curve.

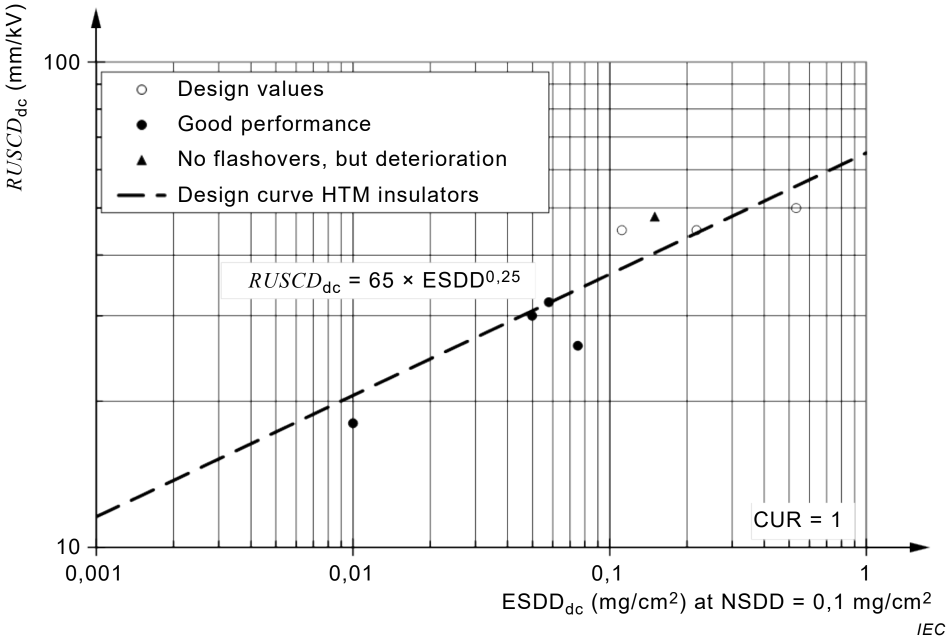


Figure B.2 – d.c. overhead lines. Collected field experience on HTM insulators (composite line insulators)

The comparison of the field data with the required creepage distances indicates that:

- Designs with creepage distances lower than the design curve are likely to have unsatisfactory performance;
- Designs with creepage distances in accordance with the proposed design curve result in good performance;
- Recent designs are in accordance with the proposed design curve.

The curves interpolating the data for line insulators with creepage factors of about 3,3 for non HTM insulators and lower than 4 for composite insulators, are extended as a first approximation to the case of station insulators of small diameter (diameter less than 250 mm).

The extension of the curve to high creepage factors has to take into account that by increasing the creepage factor the efficiency of the profile decreases, as shown in the example of Figure B.3 (Figure 36 of CIGRE brochure N° 518:2012 [1])

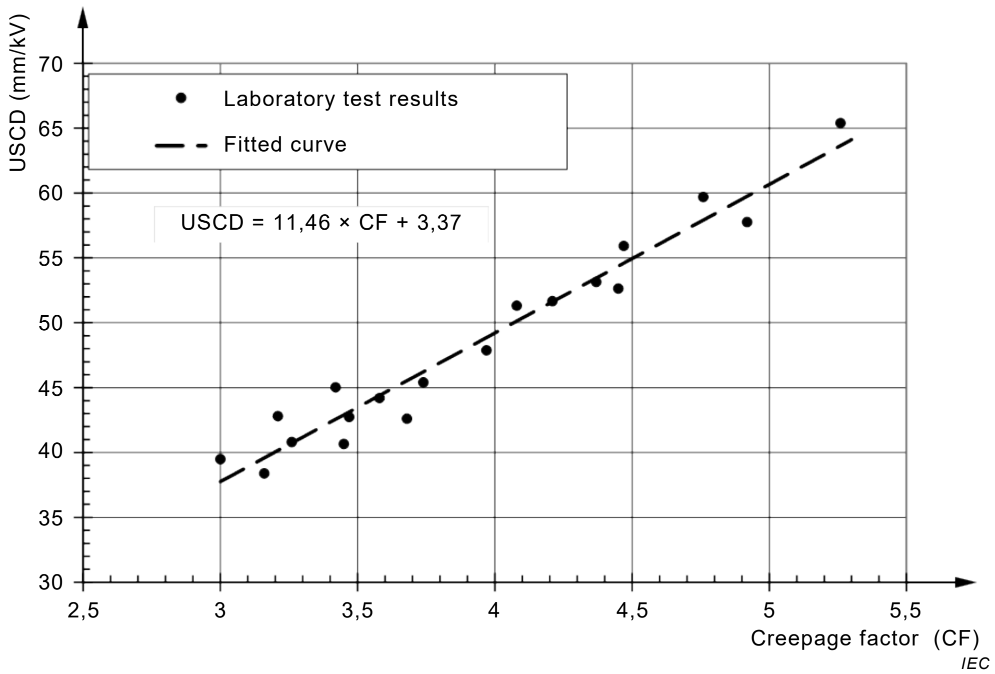


Figure B.3 – Composite insulators: Example of the influence of CF on USCD (laboratory tests), see CIGRE Brochure [1] for more details

B.2 Pollution Type B

In the absence of significant field experience a similar trend was assumed for pollution types A and B and consequently a similar ratio between the design curves for HTM and non HM insulators was selected.

Bibliographic References

[1] CIGRE C4.303 CIGRE – Guidelines for the selection and dimensioning of insulation for outdoor applications – the d.c. case, CIGRE brochure N° 518-2012

[2] CIGRE Taskforce 33.04.01 – "Polluted insulators: A review of current knowledge", CIGRE brochure N° 158-2000

(*Continued from second cover*)

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC TS 62073 Guidance on the measurement of hydrophobicity of insulator surfaces	IS/IEC TS 62073 : 2016 Guidance on the measurement of hydrophobicity of insulator surfaces	Identical

Only English language text has been retained while adopting it in this Indian Standard, and as such the page numbers given here are not the same as in the International Standard.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Bureau of Indian Standards

BIS is a statutory institution established under the *Bureau of Indian Standards Act*, 2016 to promote harmonious development of the activities of standardization, marking and quality certification of goods and attending to connected matters in the country.

Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the website-www.bis.gov.in or www.standardsbis.in.

This Indian Standard has been developed from Doc No.: ETD 06 (18043).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002
Telephones: 2323 0131, 2323 3375, 2323 9402 *Website*: www.bis.gov.in

Regional Offices: *Telephones*

Central	: 601/A, Konnectus Tower -1, 6th Floor, DMRC Building, Bhavbhuti Marg, New Delhi 110002	2323 7617
Eastern	: 8th Floor, Plot No 7/7 & 7/8, CP Block, Sector V, Salt Lake, Kolkata, West Bengal 700091	2367 0012 2320 9474
Northern	: Plot No. 4-A, Sector 27-B, Madhya Marg, Chandigarh 160019	265 9930
Southern	: C.I.T. Campus, IV Cross Road, Taramani, Chennai 600113	2254 1442 2254 1216
Western	: Plot No. E-9, Road No.-8, MIDC, Andheri (East), Mumbai 400093	2821 8093

Branches : AHMEDABAD. BENGALURU. BHOPAL. BHUBANESHWAR. CHANDIGARH. CHENNAI. COIMBATORE. DEHRADUN. DELHI. FARIDABAD. GHAZIABAD. GUWAHATI. HIMACHAL PRADESH. HUBLI. HYDERABAD. JAIPUR. JAMMU & KASHMIR. JAMSHEDPUR. KOCHI. KOLKATA. LUCKNOW. MADURAI. MUMBAI. NAGPUR. NOIDA. PANIPAT. PATNA. PUNE. RAIPUR. RAJKOT. SURAT. VISAKHAPATNAM.

Published by BIS, New Delhi