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Edition 1.0 2015-11

TECHNICAL SPECIFICATION

Hybrid insulators for a.c. and d.c. high-voltage applications – Definitions, test methods and acceptance criteria

IEC TS 62896:2015-11(en)

International Electrotechnical Commission

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CONTENTS

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HYBRID INSULATORS FOR A.C. AND D.C. HIGH-VOLTAGE APPLICATIONS – DEFINITIONS, TEST METHODS AND ACCEPTANCE CRITERIA

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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 62896, which is a technical specification, has been prepared by IEC technical committee 36: Insulators.

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

Enquiry draft	Report on voting
36/362/DTS	36/368/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.

The committee has decided that the contents of this publication will remain unchanged until the stability 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- withdrawn,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.

INTRODUCTION

Hybrid insulators consist of an insulating core, bearing the mechanical load protected by a polymeric housing, the load being transmitted to the core by end fittings. Despite these common features, the materials used and the construction details employed by different manufacturers may be quite different. The core is made of ceramic or glass material.

Hybrid insulators are applied as overhead line, post or hollow core equipment insulators. In order to perform the design tests, IEC 62217 shall be applied for the polymeric housing and the interfaces between core and the housing. For the core, the test standards for the respective ceramic product (IEC 60168, IEC 60383 and IEC 62155) shall be applied.

Some tests have been grouped together as "design tests", to be performed only once on insulators which satisfy the same design conditions. For all design tests of hybrid insulators, the common clauses defined in IEC 62217 are applied. As far as practical, the influence of time on the electrical and mechanical properties of the components (core material, housing, interfaces etc.) and of the complete hybrid insulators has been considered in specifying the design tests to ensure a satisfactory life-time under normally known stress conditions in service.

Polymeric housing materials that show the hydrophobicity transfer mechanism (HTM) are preferred for hybrid insulators. They are applied as a countermeasure against severe polluted service conditions. For the time being, no ageing or pollution tests have been developed for the verification of this property, but CIGRE Technical Brochure No. 442 is available for the evaluation of the retention of the hydrophobicity and the HTM of polymeric housing materials.

Artificial pollution tests for insulators with polymeric housings under AC and DC voltage stress are presently under development by CIGRE.

HYBRID INSULATORS FOR A.C. AND D.C. HIGH-VOLTAGE APPLICATIONS – DEFINITIONS, TEST METHODS AND ACCEPTANCE CRITERIA

1 Scope

This technical specification applies to hybrid insulators for a.c. and d.c. applications consisting of a load-bearing insulating solid or hollow core consisting of ceramic or glass, a housing (defined geometry, outside the insulating core) made of polymeric material and end fittings permanently attached to the insulating core.

Hybrid insulators covered by this technical specification are intended for use as suspension/tension line insulators, line post insulators, station post insulators and hollow core insulators for apparatus.

The object of this technical specification is to:

- define the terms used;
- prescribe test methods;
- prescribe acceptance criteria.

Silicone or other functional coatings (CIGRE Technical Brochure No. 478, Appendix B), booster sheds, shed extenders and rain deflectors are not within the scope of this technical specification.

This technical specification does not include requirements dealing with the choice of insulators for specific operating conditions.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-471:2007, *International Electrotechnical Vocabulary – Part 471: Insulators*

IEC 60168, *Tests on indoor and outdoor post insulators of ceramic material or glass for systems with nominal voltages greater than 1000 V*

IEC 60383-1, *Insulators for overhead lines with a nominal voltage above 1000 V – Part 1: Ceramic or glass insulator units for a.c. systems – Definitions, test methods and acceptance criteria*

IEC 60383-2, *Insulators for overhead lines with a nominal voltage above 1000 V – Part 2: Insulator strings and insulator sets for a.c. systems – Definitions, test methods and acceptance criteria*

IEC 62155, *Hollow pressurized and unpressurized ceramic and glass insulators for use in electrical equipment with rated voltages greater than 1 000 V*

IEC 62217, *Polymeric HV insulators for indoor and outdoor use – General definitions, test methods and acceptance criteria*

3 Definitions

For the purpose of this document the terms and definitions given in IEC 60050-471 and the following apply (some definitions from IEC 62217 are reproduced here for ease of reference).

3.1
high voltage
HV
voltage over 1 000 V a.c. or over 1 500 V d.c. or over 1 500 V peak value

3.2
polymeric insulator
insulator whose insulating body consists of only polymer containing materials, to the ends of which coupling devices may be attached

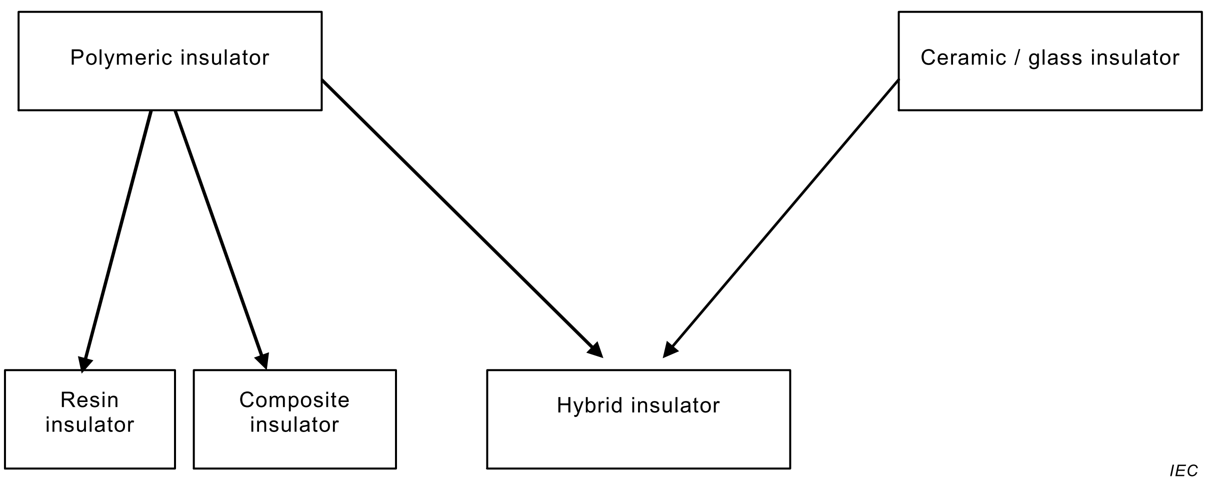
Note 1 to entry: Polymeric insulators are also known as non-ceramic insulators.

3.2.1
resin insulator
polymeric insulator whose insulating body consists of a solid shank and sheds protruding from the shank made from only one organic based housing material (e.g. cycloaliphatic epoxy)

3.2.2
composite insulator
polymeric insulator made of at least two polymeric insulating parts, namely a core and a housing, equipped with metal fittings

Note 1 to entry: Composite insulators, for example, can consist either of individual sheds mounted on the core, with or without an intermediate sheath, or alternatively, of a housing directly moulded or cast in one or several pieces on to the core.

3.3
hybrid insulator
insulator that consists of a ceramic or glass core and a polymeric housing, equipped with one or more metal fittings



Note 1 to entry: The mechanical functions are mainly characterised by the core, the electrical functions are mainly characterised by the polymeric housing. The housing may cover the core completely or partly. In the latter case the exposed portions of the ceramic core are usually covered by glaze.

3.4
core of a hybrid insulator
the internal insulating part, consisting of ceramic or glass, of a hybrid insulator which is designed to ensure the mechanical characteristics

Note 1 to entry: The core for composite insulators is defined in IEC 62217.

3.5
shank of a hybrid insulator
the section between two adjacent sheds (also known as trunk on larger insulators)

3.6
housing
external insulating part which is made of polymeric material providing necessary creepage distance and protecting the core from environment

3.7
shed
insulating part, projecting from the insulator trunk, intended to increase the creepage distance

Note 1 to entry: The shed can be with or without ribs.

[SOURCE: IEC 60050-471:2007, 471-01-15]

3.8
creepage distance
shortest distance or the sum of the shortest distances along the surface on an insulator between two conductive parts which normally have the operating voltage between them

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

Note 2 to entry: If a high resistance coating 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.

[SOURCE: IEC 60050-471:2007, 471-01-04]

3.9
arcing distance
shortest distance in air external to the insulator between the metallic parts which normally have the operating voltage between them

[SOURCE: IEC 60050-471:2007, 471-01-01]

3.10
interfaces
surface between the different materials. Various interfaces occur in most hybrid insulators, e.g.:

- between housing and fixing devices;
- between various parts of the housing; e.g. between sheds, or between sheath and sheds;
- between core and housing;

3.11
end fitting
fixing device
integral component or formed part of an insulator intended to connect it to a supporting structure, or to a conductor, or to an item of equipment, or to another insulator

Note 1 to entry: Where the end fitting is metallic, the term "metal fitting" is normally used.

[SOURCE: IEC 60050-471:2007, 471-01-06]

3.12
connection zone
zone where the mechanical load is transmitted between the insulating body and the fixing device

3.13
coupling
part of the fixing device which transmits load to the hardware external to the insulator

3.14
tracking
process which forms irreversible degradation by formation of conductive paths (tracks) starting and developing on the surface of an insulating material

Note 1 to entry: Tracking paths are conductive even under dry conditions.

3.15
erosion
irreversible and non-conducting degradation of the surface of the insulator that occurs by loss of material, which can be uniform, localized or tree-shaped

Note 1 to entry: Light surface traces, commonly tree-shaped, can occur on hybrid insulators as on ceramic and glass insulators, after partial flashover. These traces are not considered to be objectionable as long as they are non-conductive. When they are conductive they are classified as tracking.

3.16
crack
any internal fracture or surface fissure of depth greater than 0,1 mm

3.17
puncture
permanent loss of dielectric strength due to a disruptive discharge passing through the solid insulating material of an insulator

[SOURCE: IEC 60050-471:2007, 471-01-14]

4 Identification

Each insulator shall be marked with the name or trade mark of the manufacturer and the year of manufacture. In addition, each insulator shall be marked with the rated characteristics specified in the applicable IEC product standards for ceramic or glass insulators. These markings shall be legible, indelible and their fixings (if any) weather- and corrosion-proof.

5 Environmental conditions

The normal environmental conditions to which insulators are submitted in service are defined in IEC 62217.

6 Tolerances

Unless otherwise agreed, a tolerance of

- $\pm(0,04 \times d + 1,5)$ mm when $d \leq 300$ mm,

- ±(0,025 × *d* + 6) mm when *d* > 300 mm with a maximum tolerance of ±50 mm,

shall be allowed on all dimensions for which specific tolerances are not requested or given on the insulator drawing (*d* being the dimension in millimetres).

The measurement of creepage distances shall be related to the design dimensions and tolerances as determined from the insulator drawing, even if this dimension is greater than the value originally specified. When a minimum creepage is specified, the negative tolerance is also limited by this value.

In the case of insulators with a creepage distance exceeding 3 m and a uniform shed profile, it is permissible to measure a short section (approximately 1 m in length) of the insulator and then extrapolate.

7 Classification of tests

7.1 Design tests

These tests are intended to verify the suitability of the design, materials and method of manufacture (technology). A hybrid insulator design is defined by:

- materials of the core, housing and their manufacturing method;
- material of the end fittings, their design and method of attachment (excluding the coupling);
- layer thickness of the housing over the core (including a sheath where used);
- diameter of the core.

Design tests have to be performed in accordance with Table 1. Sampling, test procedures and acceptance criteria shall apply as in the standards referenced in Table 1.

When changes in the design occur, re-qualification shall be carried out in accordance with Table 1.

When a hybrid insulator is submitted to the design tests, it becomes a parent insulator for a given design and the results shall be considered valid for that design only. This tested parent insulator defines a particular design of insulators which have all the following characteristics:

a) same materials for the core and housing and same manufacturing method;
b) same material of the fittings, the same design, and the same method of attachment;
c) same or greater minimum layer thickness of the housing over the core (including a sheath where used);
d) same or smaller stress under mechanical loads;
e) same or greater cross-diameter of the core;
f) equivalent housing profile parameters, see Note (1) of Table 1.

7.2 Type tests

The type tests are intended to verify the main characteristics of a hybrid insulator, which depend mainly on its materials, shape and size. Type tests in accordance with Table 1 shall be applied to hybrid insulators, the class of which has passed the design tests. They shall be repeated only when the type or material of the hybrid insulator is changed (see Table 1). The type tests shall be performed, depending on type and application, according to the type tests defined in:

- IEC 60168 for solid core station post insulators,
- IEC 60383 for overhead transmission line insulators (cap and pin and long rod and line post type),

- IEC 62155 for hollow core insulators,

7.3 Sample tests

The sample tests are for the purpose of verifying other characteristics of hybrid insulators, including those which depend on the quality of manufacture and on the materials used. They are made on insulators taken at random from lots offered for delivery. Sample tests shall be applied in accordance with IEC 60168, IEC 60383 or IEC 62155 for the respective kind of products.

7.4 Routine tests

The aim of these tests is to eliminate hybrid insulators with manufacturing defects. They are made on every hybrid insulator offered for acceptance. Routine tests shall be applied in accordance with IEC 60168, IEC 60383 or IEC 62155 for the respective kind of products.

Table 1 – Required tests

IF a new design is made or if the change in insulator design concerns:		**THEN** the following tests shall be repeated:							
		Design Tests						**Type Tests** c)	
		Interfaces and connections of end fittings	Hardness test	Accelerated weathering test	Tracking and erosion test	Flammability test	Porosity Test b)	Mechanical type tests d)	Electrical type tests d)
1	Housing materials	**X**	**X**	**X**	**X**	**X**			**X**
2	Housing profile a)	**X**			**X**				**X**
3	Core material	**X**					**X**	**X**	
4	Core diameter c)	**X**					**X**	**X**	
5	Core and end-fitting manufacturing process	**X**					**X**	**X**	
6	Core and end-fitting assembly process	**X**						**X**	
7	Housing manufacturing process	**X**	**X**	**X**	**X**	**X**			
8	Housing assembly process	**X**			**X**				
9	End fitting material	**X**						**X**	
10	End fitting connection zone design	**X**						**X**	
11	Core/housing/end fitting interface design	**X**							
12	Type of insulator							**X**	**X**

a) Variations of the profile within following tolerances do not constitute a change (IEC 62217):

Overhang:	±15 %
Diameter:	+15 %, –0 %
Thickness at base and tip:	±15 %
Spacing:	±15 %
Shed inclinations:	±3°
Shed repetition:	Identical

b) Porosity test acc. to IEC 60383 (for porcelain only)

c) Variations of the core diameter within ±20 % do not constitute a change. However, the type tests shall be performed in case of change of core diameter

d) Mechanical and electrical type tests shall be carried out according to product test standards for ceramic or glass Insulators. It is permissible to perform the mechanical type tests without the polymeric housing.

8 Design tests

8.1 General

These tests consist of the tests prescribed in IEC 62217 as listed in Table 2. The design tests are performed only once and the results are recorded in a test report. Each part can be performed independently on new test specimens. The hybrid insulator of a particular design will be qualified only when all insulators or test specimens pass the design tests.

Table 2 – Design tests

Tests on interfaces and connections of end fittings
thermal-cycle pre-stressing
water immersion pre-stressing
Verification tests:
visual examination
steep-front impulse voltage test
dry power frequency voltage test
Tests on shed and housing material
hardness test
accelerated weathering test
tracking and erosion test – see 8.2.3 for specimens
flammability test
Tests on core material
porosity test

8.2 Tests on interfaces and connections of end fittings

8.2.1 General

Three insulators assembled on the production line shall be tested. The insulation length (metal to metal spacing) shall be not less than 800 mm. Both metal fittings shall be the same as on standard production insulators. The end fittings shall be assembled so that the insulating part from the fitting to the closest shed shall be identical to that of the production line insulator.

If the manufacturer only has facilities to produce insulators shorter than 800 mm, the design tests may be performed on insulators of those lengths available to him, but the results are only valid for up to the lengths tested.

8.2.2 Pre-stressing

8.2.2.1 Thermal cycle test

The specimens are submitted to temperature cycles under no mechanical load as described in Figure 1, the 24 h temperature cycle being repeated four times. Each 24 h cycle has two temperature levels with a duration of at least 8 h, one at +50 °C ± 5 K, the other at –35 °C ± 5 K. The cold period shall be at a temperature at least 85 K below the value actually applied in the hot period. The pre-stressing can be conducted in air or any other suitable medium.

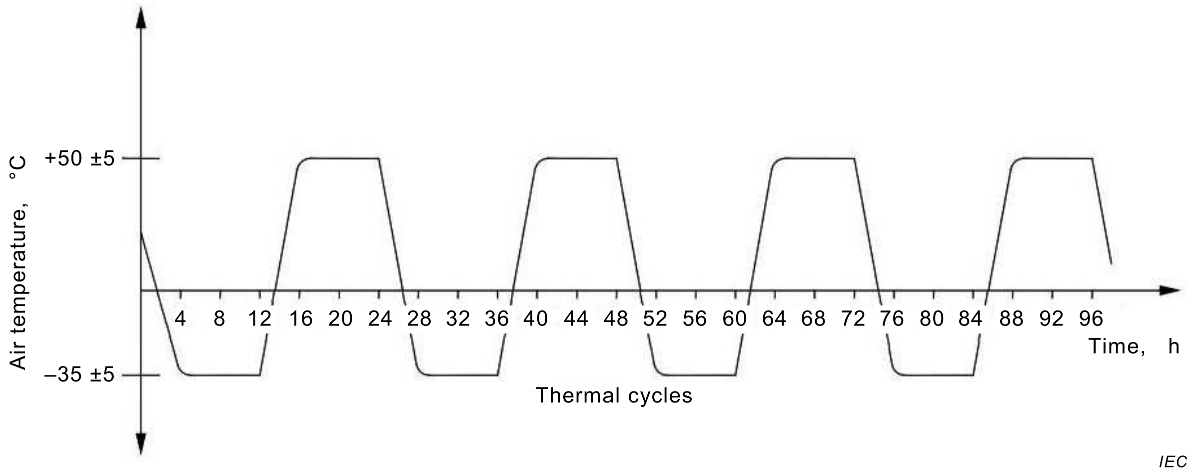


Figure 1 – Thermal cycle test

The cycles may be interrupted for maintenance of the test equipment for a total duration of 2 h. The starting point after any interruption shall be the beginning of the interrupted cycle.

8.2.2.2 Water immersion pre-stressing

Shall be performed according to IEC 62217.

8.2.3 Verification tests

8.2.3.1 General

Shall be performed according to IEC 62217.

8.2.3.2 Visual examination

Shall be performed according to IEC 62217.

8.2.3.3 Steep-front impulse voltage test

Shall be performed according to IEC 62217.

If necessary for insulators with a nominal length < 500mm, the test arrangement only of 61211 may be used.

8.2.3.4 Dry power frequency voltage test

Shall be performed according to IEC 62217.

8.3 Tests on Shed and Housing Material

8.3.1 Hardness test

Shall be performed according to IEC 62217.

8.3.2 Accelerated weathering test

Shall be performed according to IEC 62217.

8.3.3 Tracking and erosion test

IEC 62217 specifies that the creepage distance shall be between 500 mm and 800 mm. If the manufacturer only has facilities to produce insulators with creepage shorter than 500 mm, the design tests may be performed on insulators of those lengths he has available, but the results are only valid for up to the tested lengths.

If the insulator design does not allow samples with this creepage distance requirement, (e.g. insulators with one shed) then the original insulator shall be used as test sample and the line-to-earth voltage as specified by the manufacturer shall be applied as test voltage.

8.3.4 Flammability test

Shall be performed according to IEC 62217.

9 Type tests

9.1 General

One insulator type is electrically defined by the arcing distance, creepage distance, shed inclination, shed diameter and shed spacing. The electrical type tests shall be performed only once on insulators satisfying the above criteria for one type and shall be performed with arcing and/or corona devices, if they are an integral part of the insulator type.

One insulator type is mechanically defined by the core diameter and the method of attachment of the metal fittings. The mechanical type tests shall be performed only once on insulators satisfying the above criteria for each type.

The electrical and/or mechanical type tests shall be repeated only when one or more of the above mentioned characteristics are changed.

9.2 Electrical tests

The electrical tests for line insulators shall be performed according to IEC 60383-1 and IEC 60383-2 to confirm the specified values. Electrical tests for station post insulators shall be performed according to IEC 60168. No electrical type tests are required for hollow core insulators.

Interpolation of electrical test results may be used for insulators of intermediate length, provided that the factor between the arcing distances of the insulators whose results form the end points of the interpolation range is less than or equal to 1,5. Extrapolation is not allowed.

9.3 Mechanical tests

The mechanical type tests shall be performed according to the respective product standard for the kind of ceramic or glass insulator (e.g. post, longrod, cap and pin type etc.).

10 Sample tests

The sample tests shall be performed according to the respective product standard for the kind of insulator (e.g. post, longrod, cap and pin type etc.).

11 Routine tests

The routine tests shall be performed according to the respective product standard for the kind of insulator (e.g. post, longrod, cap and pin type etc.).

Annex A
(informative)

Comparison between hybrid insulators and glass fibre cored polymeric housing and porcelain insulators

A.1 History

The problem of vandal resistance on railway catenary insulators lead in the UK to an examination of the use of plastic insulators to replace the porcelain insulators in common use at the time in the seventies [13] [1].. Pultruded epoxy resin bonded glass fibre rod using E glass had been developed for the high voltage switchgear industry and this rod was used in the development of under bridge arm HV insulators for the 25 kV catenary. At the time it was only available in diameters up to 25 mm. The tie and strut porcelain insulators had typically 70 mm core diameter and portal post insulators up to 80 mm core diameters. To obtain similar mechanical properties in bending and compression it was necessary to use a glass fibre core of around 50 mm in diameter and these were not available in pultruded form with the necessary freedom from longitudinal electrical weaknesses.

It was proposed therefore to make polymeric housed insulators using cylindrical porcelain cores of the same core diameter and with the same end fittings as the existing porcelain insulators. This would ensure that they were identical in mechanical performance and part replacements for the existing porcelains [14] [15].

A.2 Comparison between porcelain and pultruded GFRP[2] rod

Material/Property	Glazed porcelain	Pultruded GFRP rod
Tensile strength MPa	80 to 100	1 300 to 1 600
Compressive strength MPa	500 to 800	600 to 800
Tensile modulus GPa	60 to 100	40 to 60

The torsional strength and torsional modulus of pultruded GFRP rod are largely controlled by the bonding resin which has typically one tenth of the strength and modulus of the glass fibre itself.

A.3 Advantages of hybrid insulators over conventional porcelain insulators

A.3.1 The core mechanical part is made by a simple extrusion process and this gives a low weight, low cost mechanical part with consistent mechanical properties compared to a shedded porcelain.

A.3.2 The polymeric housing offers some protection to the core and more resistance to impact damage than the vulnerable sheds of a conventional porcelain.

A.3.3 The hybrid insulator is typically half to a quarter the weight of the conventional and this reduces transport costs, transport and installation breakages and eases installation.

A.3.4 The use of a polymeric housing normally allows thinner sheds and greater creepage distances with improved long term pollution flashover performance.

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1 Numbers in square brackets refer to the bibliography.

2 GFRP = Glass fiber reinforced plastic.

A.3.5 The polymeric housing protects the core from short circuit arc damage which can fracture conventional ceramic long rod insulators.

A.4 Advantages of hybrid insulators over glass fibre cored insulators

A.4.1 It is common for conventional polymeric insulators to first show dry band arcing or electrochemical damage on the insulation next to the end fittings. By leaving an exposed glazed porcelain band at this point, the partial discharges take place over the glazed porcelain surface, and not over a more vulnerable polymeric housing.

A.4.2 The core material is not susceptible to moisture ingress problems. If the housing is damaged, the porcelain core itself remains unaffected by moisture ingress.

A.4.3 As discussed, they can be easily made as part replacements for conventional porcelain posts used in substations, switchgear and overhead lines.

A.4.4 The manufacturing processes are relatively much easier to control compared to making resin/glass fibre rod, and crimping on end fittings.

A.4.5 Post insulators can include the same lipped and grooved ends to accept OHL conductors that are used on conventional line posts.

A.5 Problems shared with polymeric insulators

A.5.1 Selection of appropriate housing material. Long-term stability such as UV weathering resistance, retention of hydrophobicity and tracking and erosion resistance have to be considered.

A.5.2 Forming an electrically stable interfacial seal between the housing and the glazed ceramic core. This is normally done with either a suitable mastic material, an RTV silicone material, or the housing may be “moulded in place” using appropriate coupling agents, as is done with resin glass cores.

A.6 Transport, storage and installation

Hybrid insulators shall be handled like composite insulators. In addition to the requirements of IEC 62217, information on handling of composite insulators can be found in CIGRE Technical Brochure 184 [11]

Bibliography

[1] IEC 60273, *Characteristic of indoor and outdoor post insulators for systems with nominal voltages greater than 1000 V*

[2] IEC 60305, *Insulators for overhead lines with a nominal voltage above 1000 V – Ceramic or glass insulator units for a.c. systems – Characteristics of insulator units of the cap and pin type*

[3] 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*

[4] IEC 60720, *Characteristics of line post insulators*

[5] IEC 61109, *Insulators for overhead lines – Composite suspension and tension insulators for a.c. systems with a nominal voltage greater than 1 000 V – Definitions, test methods and acceptance criteria*

[6] IEC 61211, *Insulators of ceramic material or glass for overhead lines with a nominal voltage greater than 1 000 V – Impulse puncture testing in air*

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