Hybrid Insulators – Another Solution for Improved Performance

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Abstract

In the past, the options available for air insulated HVAC Substation support insulators were solid core porcelain and solid core composite insulators up to 245kV. Additional RTV coatings on solid core porcelain post insulators are used to improve the pollution performance for AC applications. New developments have been made recently for hollow core composite insulators, gas filled or foam filled and larger core dimensions on solid core composite insulators. The requirements for EHV AC and UHV AC installations in terms of length, high mechanical strength, permissible deflection, creepage distance, shed profiles and pollution resistance are still a challenge for the available technologies and solutions.
Realising the needs for high strength, low deflection under loads for many applications as earthing switches - disconnectors – reactors and busbar supports PPC INSULATORS AUSTRIA began the development of Hybrid post insulators. Based on the very positive historical experience with solid core porcelain post insulators and the pollution experience of insulators with silicon rubber housings the fundamental concept of both have been used in this development. The challenge was to provide a reliable and economical solution, which combines the superior mechanical advantages of solid porcelain and the electrical advantages of silicon housing for high pollution requirements.
Selected design tests, electrical and mechanical type tests were conducted according to the relevant parts of IEC standards for composite and ceramic insulators. Also a long term test installation was planned to establish confidence in this product. The long term test installation was energised at 145kV AC in May 2012 at ESKOM Koeberg Insulator Pollution Test Station (KIPTS), South Africa and has served well its purpose in providing final qualification for the new product. 420kVAC hybrid posts were chosen for initial installations in several applications.

This paper presents the experience of PPC Insulators in developing, designing, manufacturing, testing and application of post insulators - made of ceramic and silicone - Hybrid post insulator with ceramic solid core.

KEYWORDS

Hybrid post insulator – support insulator - 420kV AC – solid ceramic core – busbar support – disconnector

1. Hybrid Post Insulators

The aim of this project was to establish Hybrid Station Post Insulators as a solution for engineers in the wide range of support functions in AC High Voltage apparatus and of support application in HVAC substations.

The porcelain solid core post insulator with external metal fittings is the most widely used station post insulator type. Standard values for electrical characteristics, mechanical characteristics and dimensions – which are essential for the interchangeability of post insulators - are given in IEC60273 [1] and ANSI C29.9 [2]. The ceramic solid core design provides superior advantages in terms of bending strength and deflection under bending load, and also for torsion load and compression load. In practise this insulator type is used for all kinds of applications where these properties are dominating requirements. Specific High Voltage Apparatus such as disconnectors and earthing switches are sensitive to deflection under load. Also bus bar support applications need high mechanical strength and stiffness to cover short circuit demands and carry wind loads without deflection. Support posts under reactors, filters and in capacitor banks face further compression loads. Many improvements in production technology [3] and design optimization [4] been realized in the last several decades.

Alternative solutions developed in terms of pollution resistance, size and weight are:

- Porcelain solid core post insulator with applications of RTV (Room Temperature Vulcanizing) silicone rubber coatings
- Solid core composite station post insulators manufactured of fiber reinforced resin tubes with silicone rubber housing
- Hollow core composite station post insulators manufactured of fiber reinforced hollow tubes with silicone rubber housing – gas or foam filled

All mentioned solutions have their merits and drawbacks. The main differences between the different solutions are visible in comparison Table I [5].

Tab. I: Comparison of different post insulator types based on the requirements for porcelain solid core type C16, BIL 1050kV

	Solid Core Porcelain	Solid Core Composite	Hollow Core Composite
Core diameter (mm)	120	80	257
Break @ (kN)	16	6	31
Routine Test (kN)	8 -10	n.a.	n.a.
Deflection (mm/kN)	10 @ 12	165	14 @ 12
Weight (kg)	260	55	120

Various developments for larger core diameters on solid core composite support insulators have been made, but this seems to be still limited by the rod production process. With respect to these developments, it is obvious that in practice the use of solid core composite insulators is limited to system voltages up to 220kV. They could not achieve the required mechanical cantilever strength and low deflection of porcelain solid core post insulators. Another approach is hollow core composite posts with gas or foam filling. Besides the complex questions of the behaviour of the filler material, this solution also demands a very large hollow core diameter to reach a deflection under bending load characteristic similar to that which a solid core porcelain insulator is able to provide.

Hybrid Outdoor post Insulators offer a solution, which combines the advantages of porcelain post insulators and polymeric post insulators without most of the respective disadvantages. An early first approach for Hybrid Outdoor Insulators was developed in the ´70s for 25 kV railway catenary insulators [6].

By definition hybrids are insulators made of a ceramic or glass core with a polymeric housing and equipped with one or more metal fittings. Therefore this insulator technology could be applied for post insulators, as well for hollow cores and overhead line insulators.

Table II shows the qualitative characteristics of the main insulator technologies. It illustrates, that Hybrid insulators combine the main advantages of the different technologies.

Tab. II: Comparison of different insulator technologies [7]

	porcelain	RTV coated porcelain	Composite	Hybrid
Deflection under Bending Load Performance	++	++	-	++
Torsion Strength	++	++	-	++
Compression Strength	++	++	-	++
Product Lifetime	+	-	-	+
Pollution Performance	-	++	++	++
Weight	-	-	++	+
Vandalism	-	-	+	+
Maintenance	-	-	+	+
Reliability	+	+	-	+

Advantages of hybrid ceramic core insulators and Questions shared with polymeric insulators

Advantages

- porcelain is the preferred solution for bending, torsion and compression applications
- porcelains high rigidity results in low deflection under bending load
- porcelain core is made by the same production process as porcelain insulators with sheds
- the polymeric housing gives an excellent mechanical protection to the porcelain
- hybrid insulators have a lower weight compared to porcelain insulators with sheds
- polymeric housing allows thinner sheds and greater creepage distances
- polymeric housing provides improved long term pollution flashover performance
- polymeric housing protects the core from short circuit arc damage
- in case of damage on the polymeric housing only glazed porcelain is exposed
- porcelain core material is not susceptible to moisture ingress problems
- porcelain core material is not susceptible to acid attacks
- easily made for interchangeability for insulators in substations, apparatus and overhead lines
- assembling process is the same as for porcelain insulators with sheds

Shared questions

- selection of appropriate housing material
- forming an electrically stable interfacial seal between the housing and the glazed ceramic
- transport, storage and installation shall be handled like for composite insulators, CIGRE Technical Brochure 184 [8].

1.1 Standards solid core station posts

IEC 60168 - “Tests on indoor and outdoor post insulators of ceramic material or glass for systems with nominal voltages greater than 1 000 V” [9]

IEC 60273 - “Characteristics of indoor and outdoor post insulators of systems with nominal voltages grater than 1000V” [1]

ANSI C29.1 - “Test Methods for Electrical Power Insulators” [10]

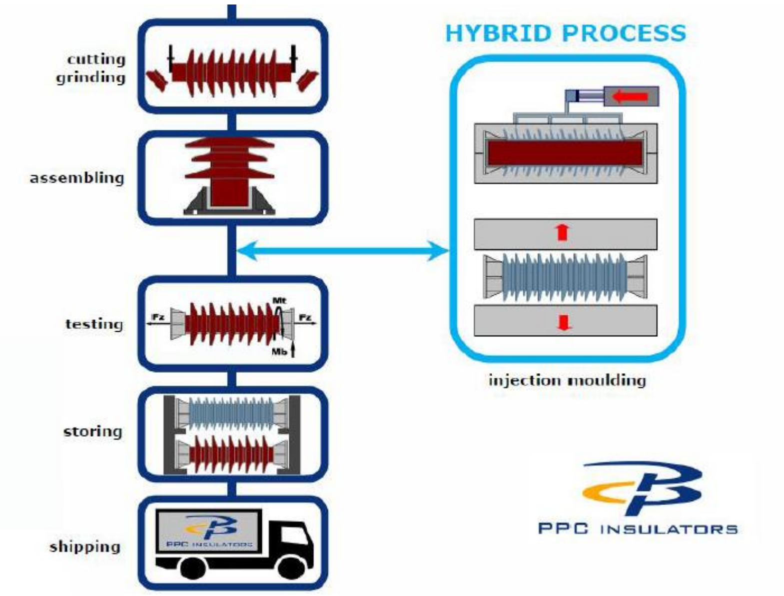
ANSI C29.9 - “Wet Process Porcelain Insulators— Apparatus, Post Type” [2]

IEC 62231 - “Composite station post insulators for substations with ac voltages greater than 1000V up to 245 kV- Definitions, test methods and acceptance criteria” [11]

IEC 60168, IEC 60273, ANSI C29.1 and ANSI C29.9 cover the full range of porcelain solid core post insulators. IEC 62231 is the relevant test standard for composite post applications and exists since 2006, but it is still limited to a nominal voltage up to 245 kV.
As discussed, the hybrid solutions combine the mechanical properties of porcelain with the pollution performance of a hydrophobic housing. Working Group (WG) 12 of IEC TC 36, under project leader Mr. Jens Seifert has worked out a technical specification specifically for hybrid insulators. The title of this Technical Specification will be IEC/TS 62896 - Hybrid Insulators for AC and DC High-Voltage applications - definitions, test methods and acceptance criteria. The final document is approved and will be published in short time. This specification will help the industry to specify hybrid insulators for the relevant applications.

1.2 Technology - Production Process

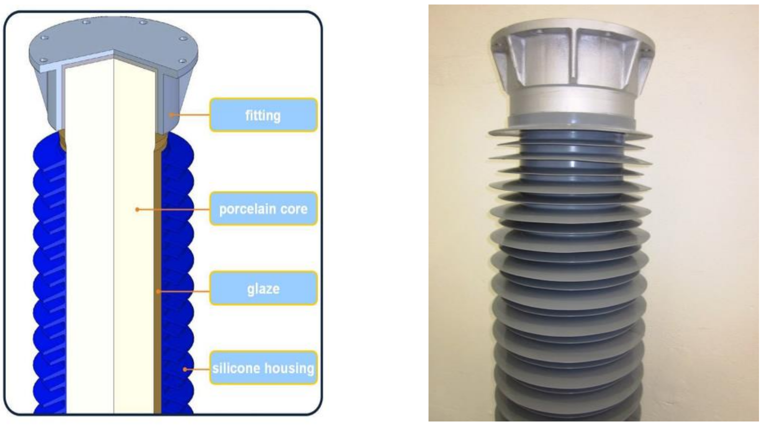
Fig. 1: principal hybrid and ceramic insulator production process (after firing)



Porcelain Isostatic Production Technology

The porcelain core is made of high-strength aluminium oxide porcelain, C130 acc. to IEC6072-3 [12]. It is manufactured by the PPC Isostatic technology taking advantage of the shorter manufacturing time. The Isostatic process provides a better dimensional control for the tight tolerances and a more consistent product compared to the conventional wet process [3].
After turning, glazing and firing, the ceramic rod is cut to the required length. Metal fittings are cemented onto the porcelain rod.

Fig. II: Hybrid solid core post insulator



Silicone Rubber Injection Moulding

The silicone rubber housing is made of HTV (High Temperature Vulcanizing) silicone rubber with a high level of ATH (Alumina Tri Hydrate) in the silicone, to address the fact that silicones could temporarily lose hydrophobicity under continuous severe pollution conditions [13]. The High Temperature, High Pressure Multi Shot Injection moulding process guarantees, that the rubber housing is fully bonded and adhered to the porcelain core, the end fitting and the cementing.

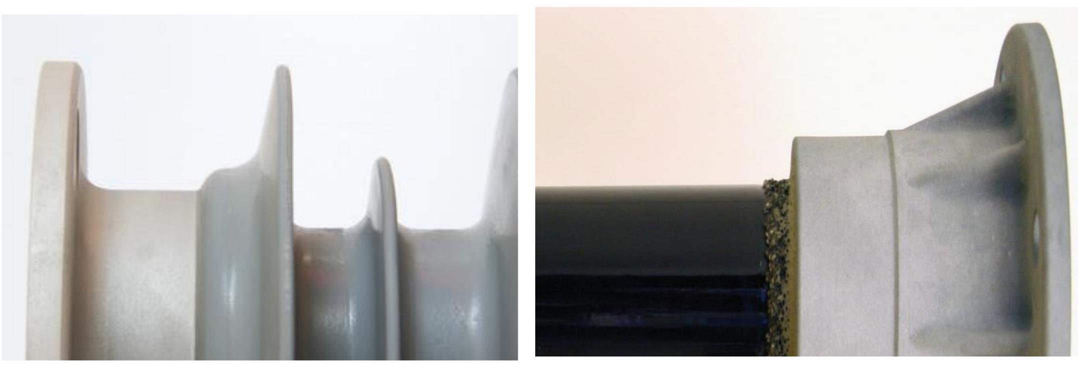
2. Support insulators for 420kV AC

Tab. III: Main data of 420kV AC busbar support insulator

TECHNICAL DATA	Specification	Hybrid Post Insulator HC10 -1550 mod.
Nominal voltage (kV)	420	420
Lightning impulse withstand voltage (kV)	1550	1550
Wet switching impulse withstand voltage (kV)	1050	1050
Wet power frequency withstand voltage (kV)	680	680
Minimum bending load (N)	10000	10000
Minimum torsion load (Nm)	6000	6000
Minimum creepage distance (53,7mm/kV)	13020	13077
Total height		3430
Arcing distance		3108
Weiht		307
Number of elements	2	2
Top metal fitting	8 x Ø 18 x 225 mm	8 x Ø 18 x 225 mm
Bottom metal fitting	8 x Ø 18 x 300 mm	8 x Ø 18 x 300 mm
Material metal fittings	malleable cast iron or spheroidal cast iron galvanized	spheroidal cast iron galvanized

The insulator column consists of 2 sections, each about half of the total height. The post is for upright application, therefore a tapered design was chosen. This leads to a larger core diameter on the bottom section to meet the higher bending moment requirement. The silicone rubber housing covers the ceramic core completely and is fully bonded to the metal fittings. Pitch circle diameters and hole-patterns are chosen according to customer specification and IEC 60273 [1]. A corona ring is applied on the top to fulfil the requested RIV characteristic and control the electrical field along the insulator surface.

Fig. III: Hybrid solid core post with impenetrable design - silicone fully bonded to the fitting [7]



2.1 Design Tests

Design tests are intended to verify the suitability of the design, materials and method of manufacturing (technology). There are no specific standards for Hybrid insulators. IEC standards used for these tests are IEC 61952 [14] and IEC 62217 [15].

The following tests were considered as relevant for the hybrid post design.

Tests on interfaces and connections of end fittings
- thermal-cycle pre-stressing
- water immersion pre-stressing
- 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
- flammability test

Tests on core material
- water diffusion test
- porosity test - the test was conducted with the relevant mechanical type tests

All tests were conducted and passed successfully.

2.1 Mechanical Type Tests

The ceramic core of the Hybrid post bears the mechanical load transmitted to the core by the end fittings. Therefore, since there is no existing hybrid standard, testing of the mechanical properties in was accordance was in accordance with IEC 60168 [9]. The insulator passed all mechanical type tests - including the porosity test. The insulator broke at bending force 14,4kN, the deflection under bending load characteristic was recorded and showed very satisfying results.

2.2 Electrical Type Tests

It has been decided to test the electrical standard properties in accordance with IEC 60168. [9]. The insulator column passed all electrical type tests. For the wet, switching impulse withstand level a specific high value was recorded, U_{10} = 1406kV.

2.3 Natural Ageing and Pollution Performance Test

In parallel a Natural Ageing and Pollution Performance Test for Outdoor Insulator was conducted at ESKOM Koeberg Insulator Pollution Test Station (KIPTS) for one year period. 145kV Hybrid post insulator specimens BIL 550kV and BIL 650kV were installed and tested in time from 01.May 2012, and in test until 30.April.2013. The test was conducted on 145kV AC on two insulator types, test results were satisfactory and showed the expected results.

3. Applications

3.1 Extension 420kVAC substation - with Hybrid Post Insulators C10-1550 mod.

Tab. IV: Summary 420kVAC support insulators

TECHNICAL DATA	Specification	Hybrid Post Insulator HC10 -1550 mod.	Hybrid Post Insulator HC10 -1550mod. underhung
Nominal voltage (kV)	420	420	420
Lightning impulse withstand voltage (kV)	1550	1550	1550
Wet switching impulse withstand voltage (kV)	1050	1050	1050
Wet power frequency withstand voltage (kV)	680	680	680
Minimum bending load (N)	10000	10000	10000
Minimum torsion load (Nm)	6000	6000	6000
Minimum creepage distance (53,7mm/kV)	13020	13077	13077
Total height		3430	3430
Arcing distance		3108	3108
Weiht		307	307
Number of elements	2	2	2
Top metal fitting	8 x Ø 18 x 225mm	8 x Ø 18 x 225mm	8 x Ø 18 x 300mm
Bottom metal fitting	8 x Ø 18 x 300 mm	8 x Ø 18 x 300 mm	8 x Ø 18 x 225 mm

The aim of this project was the extension of an existing 420kV substation with hybrid post insulators. The station is located close to a main highway, which is regularly salted during winter time. The substation is equipped with ceramic post insulator C10- 1550, creepage distance 13020mm, pollution class e – very heavy according to IEC/TS 60815-2 [16]. It was decided to keep the same creepage distance for the hybrid post insulators as on the already installed porcelain posts.
Several hybrid post insulators C10-1550mod. and C10-1550mod. underhung were installed. The installation was made in an upright position (Figure IV) for busbar support and underhung on the incoming gantry tower. All hybrid posts were equipped with field grading rings. The installation was made 2013 and has performed satisfactorily since that time.

Fig. IV: Extension of 420kV AC substation with Hybrid solid core post insulators HC10 -1550 mod.

3.2 Replacement 420kVAC substation - with Hybrid Post Insulators C8-1550

Tab. V: Summary 420kV AC support insulators

TECHNICAL DATA	Specification	Post Insulator C8 -1550 - II	Hybrid Post Insulator HC8 -1550
Nominal voltage (kV)	420	420	420
Lightning impulse withstand voltage (kV)	1550	1550	1550
Wet switching impulse withstand voltage (kV)	1175	1175	1175
Wet power frequency withstand voltage (kV)	680	680	680
Minimum bending load (N)	8000	8000	8000
Minimum torsion load (Nm)	4000	4000	4000
Minimum nominal creepage distance (53,7mm/kV)	13020	13680	12540
Total height	3350	3350	3350
Arcing distance			3108
Weiht		327	296
Number of elements	2	2	2
Top metal fitting	8 x Ø 18 x 225mm	8 x Ø 18 x 225mm	8 x Ø 18 x 225mm
Bottom metal fitting	8 x Ø 18 x 275 mm	8 x Ø 18 x 275 mm	8 x Ø 18 x 275 mm
Note		with RTV coating	

The aim of this project was replacement of installed ceramic post with RTV coating with hybrid post insulators. The station is located in an area with harsh pollution environment not far from the sea side. Therefore the station is equipped with ceramic post insulator C8 - 1550, creepage distance 13680mm, and additional RTV coating was applied. For the replacements it was important to guarantee the same mechanical performance, while keeping the specified post height and connecting details on top and bottom.
Several hybrid post insulators C8-1550 were installed. The installation was made in an upright position for bus bar support and reactor support (Figure V). The installation was made in 2013 and has performed satisfactorily since that time.

Fig. V: Replacement in 420kV AC substation with Hybrid solid core post insulators HC8 -1550

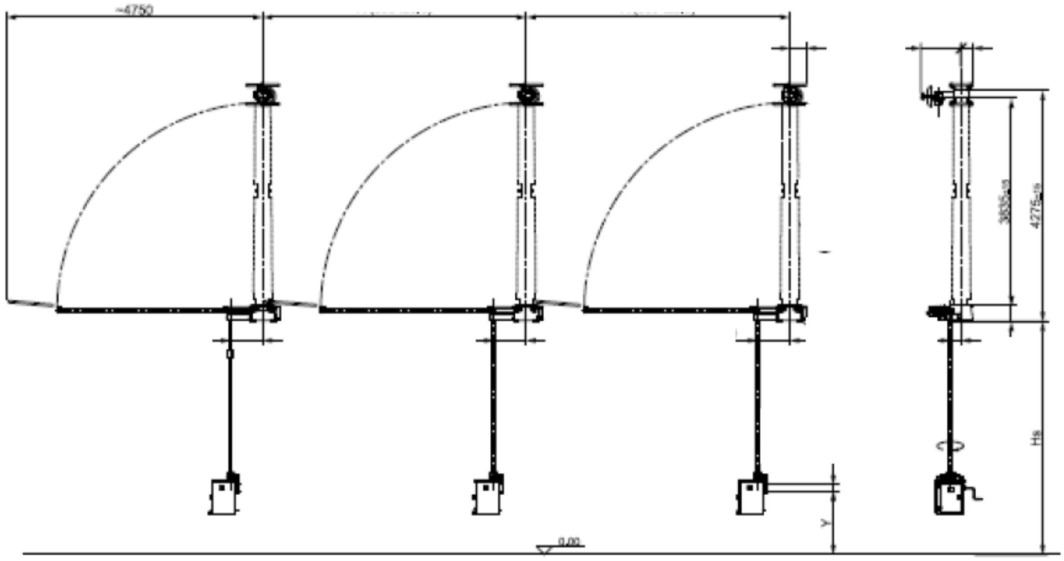
3.3 New 420kV AC substation - with Hybrid Post Insulators C15,5-1675 mod.

Tab. VI: Summary 420kVAC support insulators

TECHNICAL DATA	Specification	Hybrid Post Insulator HC15,5 -1675mod.
Nominal voltage (kV)	420	420
Lightning impulse withstand voltage (kV)	1675	1675
Wet switching impulse withstand voltage (kV)	1050	1050
Minimum bending load (N)	15500	15500
Minimum torsion load (Nm)	6000	6000
Minimum nominal creepage distance (53,7mm/kV)	13020	14552
Total height	3835	3835
Arcing distance		3486
Weiht		434
Number of elements	2	2
Top metal fitting	8 x Ø 18 x 254mm	8 x Ø 18 x 254mm
Bottom metal fitting	8 x Ø 18 x 356 mm	8 x Ø 18 x 356 mm

The aim of this new project was to equip a certain section with hybrid post insulators.
Several hybrid post insulators C15,5-1675mod. were installed. The installation was made in an upright position for busbar support and earthing switch. (Figure VI). schematic of a Three-Pole earthing switch.

Fig. VI: Schematic of three-pole earthing switch 420kV AC with Hybrid solid core post insulators C15,5-1675 mod.



4. Conclusion

AC Hybrid post insulators are available to allow engineers to design HVAC air insulated substations using pollution resistant and maintenance free insulators. This type of post insulator combines the advantages of traditional porcelain and silicone rubber housing without compromise. This allows the use of this type of post insulator for a wide range of support applications in new, extension, and replacement projects as presented in this paper.

Design tests, electrical and mechanical type tests were conducted according to the existing composite and porcelain post standards and were passed successfully. Long term natural ageing and pollution performance testing was conducted for the new product.

A Hybrid insulator test standard does not exist yet. In the mean time, the first draft with the title "IEC/TS 62896 Hybrid Insulators for AC and DC High-Voltage applications - definitions, test methods and acceptance criteria" has been approved and will be published soon. The new standard will help the industry in specifying hybrid insulators.

Several installations in 420kV AC substations for different environmental conditions were made and have performed very well since installation.

Acknowledgment

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References

[1] IEC 60273, Characteristics of indoor and outdoor post insulators for systems with nominal voltages greater than 1000 V (IEC 60273: 1990).

[2] ANSI/NEMA C29-9, Wet Process Porcelain Insulators - Apparatus, Post Type (ANSI/NEMA C29-9 - 1983 (R2012)).

[3] R. Axelsson, T. Johansson, "Development Trends Regarding Improvements of Porcelain Insulators", Electrical Insulation and Dielectric Phenomena, Annual Report 1998, Vol. 1, pp. 60 - 63.

[4] T. Johansson, G. Gödel, P. Maloney, "Optimized Insulators for Different Environments and Applications", INMR World Congress on Insulators, 2009.

[5] N. Mikli, P. Stahl, B. Räth, M. Hurnicki, T. Hummerston ," A new generation of Composite Support Insulators for UHV DC and AC systems", CIGRE 2012, A3-111.

[6] J. S. T. Looms, "Hybrid Outdoor Insulators", IEEE Electrical Insulation Magazine, July/August 1988- Vol. 4, No. 4.

[7] PPC Insulators, "Hybrid Insulator", "Brochure 2011.

[8] CIGRE WG 22.03, Composite Insulator Handling", TB 184, April 2001.

[9] IEC 60168, Tests on indoor and outdoor post insulators of ceramic material or glass for systems with nominal voltages greater than 1 000 V, (IEC 60168: 2001).

[10] ANSI/NEMA C29-1, Test Methods for Electrical Power Insulators (ANSI/NEMA C29-1 -1988 (R2012)).

[11] IEC 62231, Composite station post insulators for substations with ac voltages greater than 1000 V up to 245 kV - Definitions, test methods and acceptance criteria (IEC 62231: 2006).

[12] IEC 60762-3, Ceramic and glass-insulating materials – Part 3: Specifications for individual materials (IEC 60672-3: 1997).

[13] J.M. GEORGE, "Review of Polymer Materials and Design Considerations Based on Field Experience and Laboratory Testing", INMR World Congress on Insulators, 2009.

[14] IEC 61952, Insulators for overhead lines – Composite line post insulators for A.C. systems with a nominal voltage greater than 1 000 V – Definitions, test methods and acceptance criteria (IEC 61952: 2008).

[15] IEC 62217, Polymeric insulators for indoor and outdoor use with a nominal voltage > 1000 V - General definitions, test methods and acceptance criteria (IEC62217: 2005).

[16] 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 60815-2: 2008).