STATION POST INSULATORS (SPI), AN EMERGING APPLICATION FOR COMPOSITE HOLLOW CORE INSULATORS

Dr. Robert Strobl, Senior Director Product Management Power Transmission,
TE Connectivity, rstrobl@te.com
Peter Stahl, Technical Manager Axicom, TE Connectivity
pstahl@te.com

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Abstract

Station Post Insulators (SPI) are an emerging application for Composite Hollow Core Insulators. The handling of their inside, a topic of more serious regard compared to the traditional applications, is known and well defined. Ongoing standardization work within IEC will issue a new product standard (IEC 62772) very soon, by that eliminating the lack of standardization for that comparatively new application.

Index Terms — composite hollow insulator, station post insulator, moisture vapor transmission, standardization.

Nomenclature

VT: voltage transformer
CT: current transformer
LTB: life-tank breaker
DTB: dead-tank breaker
SPI: station post insulator
MVT(R): moisture vapor transmission (rate)
NWIP: new work item proposal (standardization)
CDV: committee draft for vote
CCDV: draft circulated as committee draft with vote

Introduction

Since their introduction in the 80's, composite hollow core insulators have taken an important position in the various fields of application for high voltage insulation technique, such as cable terminations, bushings, insulators for VTs/CTs, LTB and DTB etc. Although the application penetration is high, new applications are considered, in which the traditional ceramic versions are forming the today's standard.

This paper points out the approach of establishment for composite hollow core technique in the station post application environment, and highlights some technical considerations made when adapting the well-introduced composite hollow core technique to the particular needs of this new application.

Station Post Insulators

A. Landscape

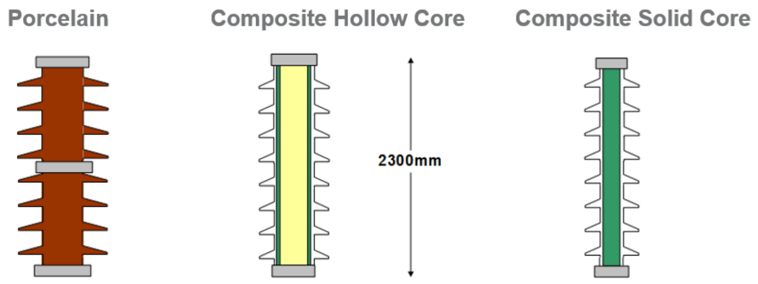
The traditional basic standard for station post insulators is IEC 60273 "Characteristics of indoor and outdoor post insulators for systems with nominal voltages greater than 1000V". However, latest revision of 1990-02 does only cover designs made from ceramic material or glass for lightning impulse withstand voltage levels above 325 kV (Um=170kV). Only for levels below equal 325 kV (Um=170 kV) also designs made from organic material are described, which's load-bearing elements are usually based on solid cores.

Also IEC 62231 "composite station post insulators for substations with a.c. voltages greater than 1000 V up to 245 kV", just under revision, vicariously shows the present limitation of composite technique to certain lengths, being a basic constriction of the today's solid core designs.

The standardization environment described above clearly points out the situation: the system voltages for todays (solid core) composite designs are limited, since the diameters (and by that finally the length) realized by this technique is limited. The higher voltage levels are served by ceramic technique, at which a stacking technique is usual to realize the needed heights up to several meters. This situation obviously suggests the composite hollow core technique being an appropriate option to cover station post applications at high lengths/voltage levels, using the well-practiced manufacturing techniques for one-piece designs up to 12 meters and even more.

B.Composite vs. Porcelain

Basically it is not possible to compare composite designs against porcelain technique in detail, since the various technical properties are too different, and direct comparison will lead to confusion and wrong conclusions anyhow. Final application data however can and should compared as a matter of course, as far as it is relevant for service, i.e. deflection under certain load, breakdown loads etc



Core diameter (mm)	200 mm	206 mm	90 mm
Weight (factor)	3,3	1,0	1,2
Deflection (factor)	0,2	1,0	8,7
Buckling (factor)	5,1	1,0	0,1

Figure. 1. Comparison of various SPI C10-1050 designs

Figure 1 shows, exemplarily for a C10-1050 SPI, a comparison of the three known designs. All being designed for a cantilever bending failing load of 10 kN and a lightning impulse withstand voltage of 1050 kV, the porcelain design will show the smallest deflection, but by far the highest weight of the triple. The composite hollow core design, set to reference in that comparison, shows a slightly lower weight than the solid variant does, at the same time having a remarkable smaller deflection. The shown buckling values were calculated to Euler 1 case, the numerical value for the composite hollow core type is around 50 tons.

It shall be noted that in the example shown the porcelain already uses stacking technique, the solid core composite already ranges on the upper length class of its technique, whereas the hollow core design is widely open for further enlargement in height/voltage even without stacking.

Composite hollow core insulators have been well introduced in several applications, and their mechanical behavior is well known and described in the relevant product standard, i.e. IEC 61462 “Composite hollow insulators – Pressurized and unpressurized insulators for use in electrical equipment with rated voltage greater than 1 000 V”. When now entering an application that traditionally was served by porcelain only, the question about comparableness is raised again and once more.

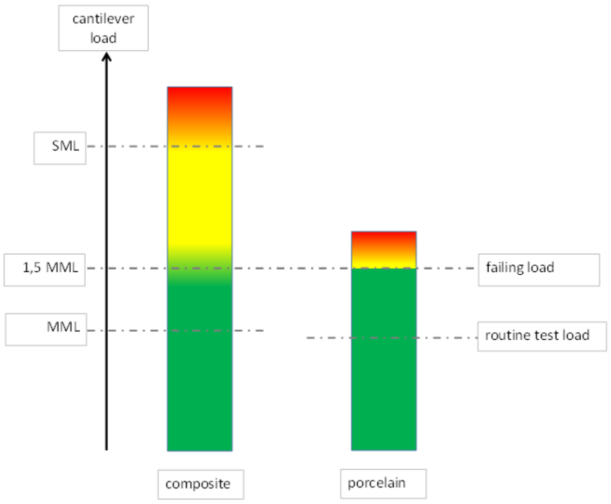


Figure 2. Comparing composite to porcelain, one approach

Due to the nature of the different materials, the mechanical properties are essentially different. Porcelain is a so to speak "digital" material, which is either sound or broken, whereas composite materials start to damage from a certain load level on. This is respected in the appropriate standards by defining the so-said damage limit, above which irreversible destructions may happen, but still without a final mechanical breakdown.

The above said is a given fact, and by that constituting an important issue whenever trying to make composites comparable to porcelains. The standardization chapter below will give some more details in that regard.

The lightweights of composite designs compared to porcelain makes them basically the first choice whenever applications with significant seismic requirements are considered. The qualification of a gas-filled 245 kV bushing for instance, performed by static calculation according IEC TS 61463 "bushings – seismic qualification", confirms a withstand to horizontal ground acceleration up to 2,9 g. This result can be directly transferred to station post applications, since the weight is the mainly determining factor in the seismic concerns.

Finally in that regard, it should be noted that actual standards consider ground accelerations of 0, 5 g even as "strong" to "very strong".

Filling the Hollow Core

A. Fillings in general

Generally, the moisture vapor ingress topic is an issue with every composite insulator exposed to environmental conditions. A composite insulator, being manufactured from fibers bound by resin matrix and covered by polymer housing, definitely has a MVTR not being zero. In principle the direction of moisture vapor transmission follows the gradient of the saturation situation of both sides, as outlined in figure 3.

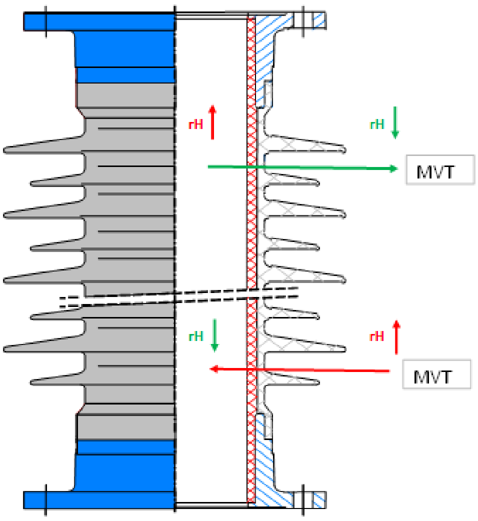


Figure 3. Moisture vapor transmission theory in principle

Simply said, moisture vapor transmits from the side with higher humidity to the side having lower humidity. In well-known applications, like cable terminations, bushings etc., in which a current-carrying conductor is in, this "internal heating" is helping to limit down the gradient, or even flip it in favor for the inside. The usually used term "natural drying" for that phenomenon is technically not correct, but matches the situation quite impressive. Furthermore, in some applications like gas-filled equipment, drying techniques are in place anyhow, which can handle the moisture vapor ingress properly.

Compared to the applications mentioned above, a SPI is a passive, "dead" application without any heating from inside. This creates the need to consider the handling of the inside duly.

The investigation of MVTR has been subject of different activities and publications all around the branch; exemplarily, in [1] it was found to be 33,55 g of humidity over 40 years exposition to 95% r.H. at 40°C for an OD=166mm / L=1,6 m type.

As a matter of course, moisture is a disliked companion in any high voltage insulation system, but finally the influence of such has to be considered as far as such cannot be avoided. The most tremendous happening was that in case of any gaseous filling, due to temperature changes, the dew point is met and condensation happens. Such could be a dramatic operating condition with potentially outage of the insulating system. Anyhow, also in case of any liquid or solid filling it has to be considered which influence ingressing moisture will have. The possible change of particular HV design properties, like breakdown strength, dielectric loss factor etc., have to be taken into account.

ISSUES	OPTIONS				
	None	Solid	Liquid	Gas Pressured	Foam
Internal Electric Strength	0	++	++	++	+
Leak	-	++	-	--	++
MVTR Condensation	0	++	+	0	++
Monitoring	0	++	0	--	++
Weight	++	--	-	++	++

Figure 4. Filling options for hollow core composite Station Post Insulators

Assessing the possibilities for the inside's design, the facts in a nutshell are:

- Just leaving the inside hollow is for sure the easiest method, but most depending on the particular's site environmental cycles; if high-humidity phases dominate, an internal accumulation of humidity will happen. The influence of temperature changes, especially quick ones, will lead to condensation.
- Solid filler systems show most positive assessment in any regard but the weight
- Liquid fillings are similar to solid systems, but leaking and potential monitoring needs are weak
- Gas fillings (others than ambient pressure air) may show a need of monitoring and have potentially leak issues. Condensation is also to be considered, however can be handled by conventional desiccant application.
- Foam filling shows positive assessment in all regards

B.Foam fillings in particular

Foam, mainly based on polyurethane, has been a subject of investigations in the HV industry for many years. This made it interesting to consider and qualify as an internal filling medium.

First of all, own investigations concentrated on the electrical breakdown performance. The trials showed that the breakdown strength is around 3-4 kV/mm (AC RMS) for round plate-plate configuration with sample thickness from 6, 5 to 10 mm. With specially formulated foams, it is known that the performance can even be increased [i.e. 2, 3, 4].

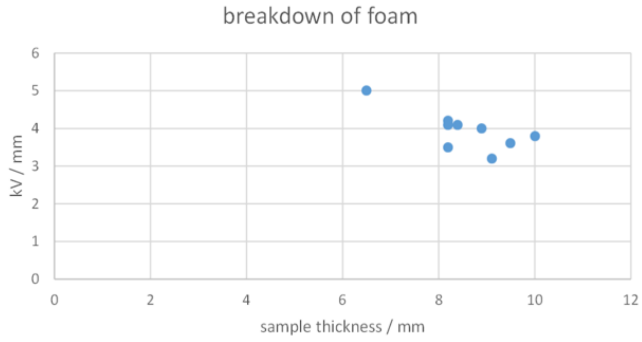


Figure 5. Breakdown strength of PUR foam, round plates

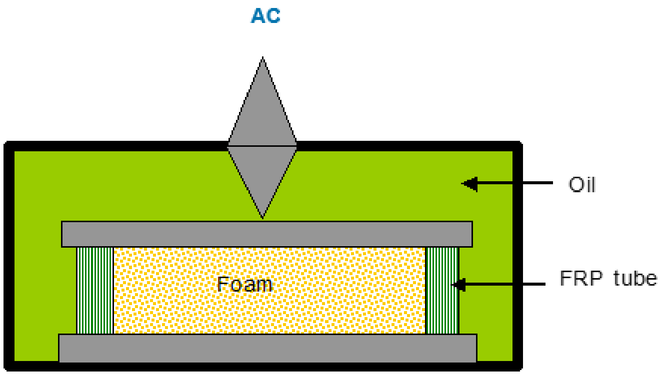


Figure 6. Breakdown strength of PUR foam, round plates

Finally the long-term behavior of the foam, and by that the electrical performance of the SPI in regard to MVT, was subject of a comprehensive test program as described below. The test scheme is shown in figure 7.

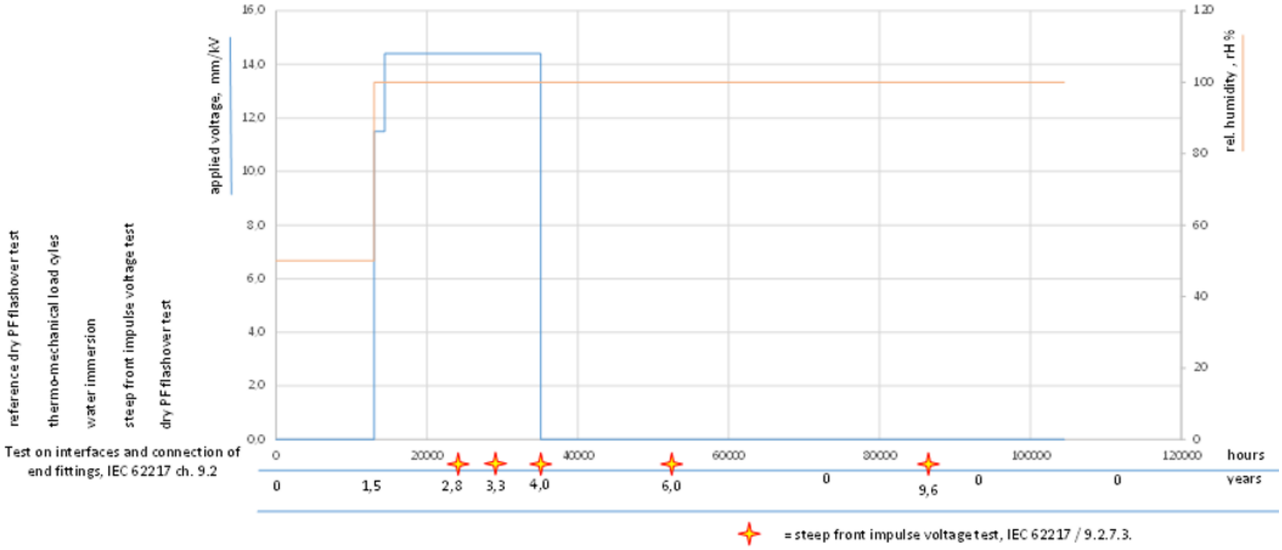


Figure 7. Long-term testing of foam filled design

Initially, as “conditioning”, a “test on interfaces and connection of end fittings” acc. IEC 61462, 7.2 / IEC62217, 9.2 was performed. This test comprises of an initial AC flashover test, thermo-mechanical load cycles as well as water immersion prestressing, followed by confirmation through steep-front impulse testing and finally an AC flashover test again. This test series was passed successfully.

After a repose period of 1,5 years in normal outdoor ambient environment, the test object was exposed to 100% r.H., at the same time energized with 11,4 mm/kV AC (after a short time, the voltage had to be reduced to 14,2 mm/kV due to lab restrictions). The voltage was kept constant for app. 2, 5 years. Counted from exposure to voltage and high humidity, after 1, 3, 1, 8 and 2, 5 years a steep front impulse voltage test (IEC 62217, 9.2.7.2.) was performed at any one time. Those did not cause any internal flashover, but only external flashovers, thus the tests were passed successfully.

The ongoing stress after 2, 5 years of exposure to voltage and humidity was by exposure to 100% r.H. only; the voltage source has not been available anymore. Two further steep front impulse verification tests had been performed, one 2 years after deenergizing, another one 5, 6 years after deenergizing. The test object has now reached app. 10, 5 years of exposure to 100%r.H.

Standardization

Hollow core composite insulators are covered by IEC 61462 "Composite hollow insulators – Pressurized and unpressurized insulators for use in electrical equipment with rated voltage greater than 1 000 V ". This standard however does not cover support insulators.

Composite solid core support insulators are covered by IEC 62231-1, Ed. 1.0: "Composite station post insulators for substations with ac voltages greater than 1 000 V up to 245 kV". This standard however does not cover hollow core types, and is furthermore limited to designs up to 245 kV.

For all material related qualification, both standards mentioned above are referring to IEC 62217 – "Polymeric HV insulators for indoor and outdoor use".

The lack of definition by a product standard was identified when performing the first projects with customers almost ten years ago. However it took some time until IEC accepted a NWIP around 2011. The creation of the upcoming standard IEC 62772 – "Composite Hollow Core Station Post Insulators for substations with a.c. voltage greater than 1000 V and d.c. voltage greater than 1500 V" is linking the existing standards mentioned above, hence building a product standard for the discussed application.

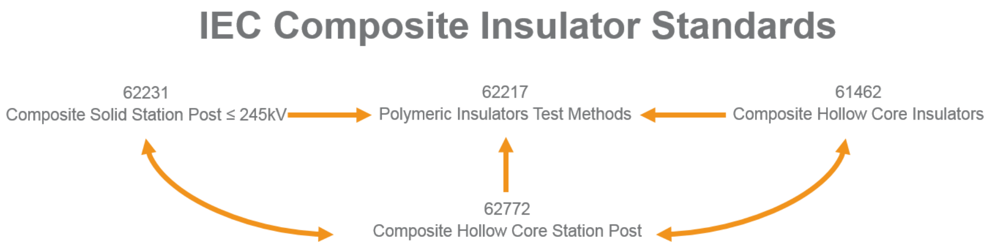


Figure 8. Building IEC 62772 "Composite hollow core station Post"

The upcoming IEC 62772 will refer to IEC 61462 for composite hollow core concerns, to IEC 62231 for composite station post concerns, and to IEC 62217 for all material related concerns. By that, an embracing system is provided for all composite hollow core insulator related applications of today.

As mentioned above, one main topic in creating the standard was to furthermore manage an appropriate link to the existing philosophies regarding station post applications, namely laid down in IEC 62231 and IEC 60273, in order to make the new system understandable and easy to accept for users.

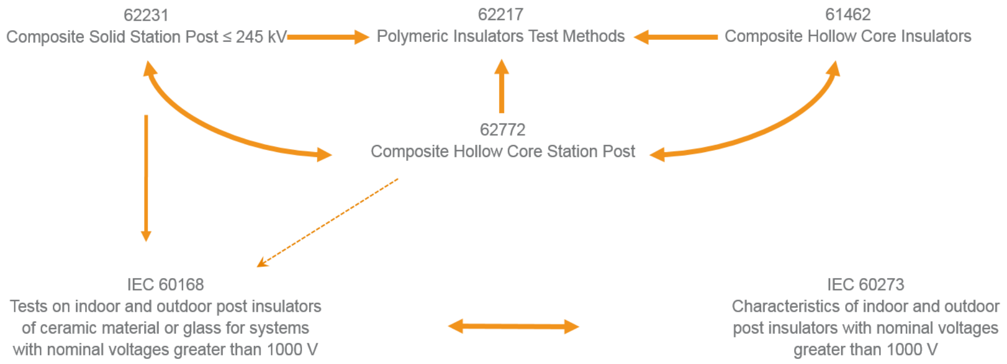


Figure 9. The link to the existing station post world

The composite hollow core insulator standard, IEC 61462, does not specify tests in regard to torsion and compression loads, since the applications served so far do not constitute a need for such. The existing descriptions in IEC 62231 of such, including the appropriate qualification tests, were transferred to the new standard IEC 62772 identically. The capabilities of hollow core designs are not considered to lay any constrictions on the application.

The most exciting topic was how to align the different bending load definitions, in order to tie in with the already well introduced MDCL concept of IEC 62231 for composite solid station post designs.

Finally the alignment was made by setting the MDCL (maximum design cantilever load acc. IEC 62231, load level above which damage to the insulator begins to occur and that should not be exceeded in service) equal to 1, 25 times of MML (maximum mechanical (cantilever) load acc. IEC 61462 which is expected to be applied to the composite hollow core insulator in service). This will constitute the following testing conditions and relations:

a) Thermal-mechanical prestressing
This prestressing as part of the interfaces-and-connection-of-endfittings-test is performed at 0, 5 SML (specified mechanical load). Since per definition (IEC 61462) SML=2,5MML, this means 0,5SML = 1 MDCL.

b) Test for the verification of the maximum design cantilever load (MDCL), “96h test”

This test is performed at 1,1 MDCL, which corresponds to 1,375xMML in the IEC 61462 understanding, and which still remains below the defined damage limit of 1,5xMML therein.

The definitions in IEC 61462 are clearly given: The damage limit is equal 1, 5 times the maximum mechanical load (MML) for service, and the specified mechanical load SML, which is the minimum breaking load for type testing, is equal 2, 5 times MML.

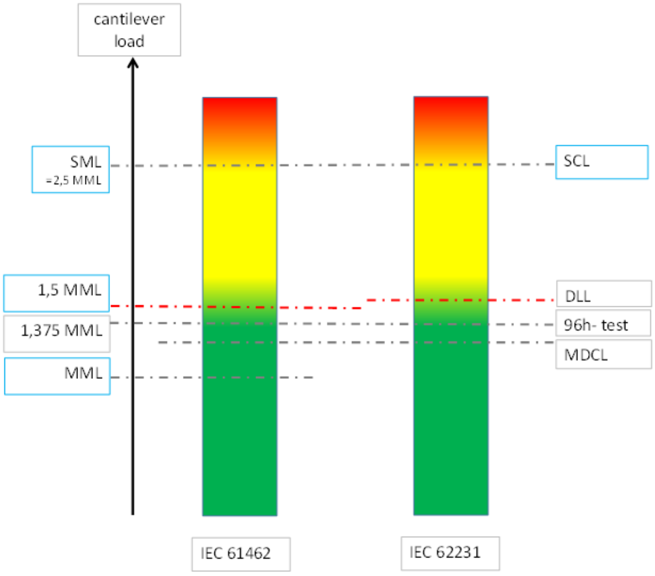


Figure 10. Comparison of definitions IEC 61462 vs. IEC 62231

In IEC 62231 however no clear relationship between the specified cantilever load (SCL) and the MDCL is given. Also the damage limit load (DLL) is not defined. However, from different literature (i.e. [5]) it is known that the usual relations from practice can be assumed as follows:

SCL ≈ 2 MDCL (= 2 x 1, 25 x MML = 2, 5 MML = SML)

DLL ≈ 1, 25 MDCL (= 1, 25 x 1, 25 x MML = 1, 56 x MML)

The values in brackets show the projection of the given to the newly aligned consideration.

In summary, the definition found builds a satisfying alignment between both the composite standards when applying them to the new one, which will be published as CCDV just those days.

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