

Mitigation of severe contamination problems on overhead lines
without the need for composite insulators

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Abstract

Today it is commonly understood that heavy or very heavy contamination problems of overhead lines are managed by using polymer insulators instead of classical porcelain or toughened glass insulators.

The many problems encountered in the field, the doubts and open questions with respect to durability, inspection, maintenance and live line work of composite insulators has opened new directions among which silicone coated toughened glass insulators. This technology is currently used worldwide with millions of insulators already in service for decades. The pollution conditions under which such insulators are being installed cover marine or desertic environments, industrial pollution or a combination of all the above.

This paper will describe the technology of silicone coated insulators from a material selection point of view to laboratory testing and performance evaluation. Field experience in AC and DC is presented under a large variety of environments. Among the very interesting information gathered between field and laboratory testing comparative results, ageing and inspection criteria are presented.

Introduction

Among the various options to fight contamination problems on overhead lines the choice today lies between using higher creepage distances on the insulators, and using silicone rubber housing materials...or both. The latter solution can be achieved through a silicone housing covering a composite insulator or by the application of a silicone coating over a ceramic (glass or porcelain) insulator.

The failures encountered by quite a number of utilities with composite insulators have considerably impacted the confidence in the technology while actually often used to solve contamination problems. The ageing mechanisms reported in the last decade are also an indication of the impact of harsh conditions on a component specifically installed there to sustain these very severe conditions.

Laboratory tests, field monitoring and performance of silicone coated toughened glass insulators are presented in this paper covering a variety of conditions.

1. Laboratory tests and selection of silicone coatings

Laboratory testing and field experience has been instrumental in the definition of the most appropriate material selection criteria. While it is important to have the best possible erosion performance, it must be noted that the degradation of a coating over toughened glass will never lead to the same catastrophic failure modes than for a composite insulator which fiberglass rod and

interfaces have to remain protected at all times from moisture ingress. Exposed glass under a silicone coating will have no adverse effect.

Qualification tests such as the 2000h cycle described in **figure 1** are considered to be a good screening tool for the selection of coatings. Optimum chemistries of silicone coatings have been defined through this test (among other qualification tests), and it was established that the most effective coating is one containing ATH (Alumina Tri Hydrate).

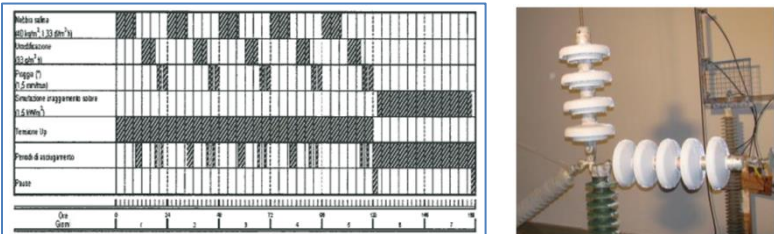


Figure 1: Typical 2000h multi-stress ageing test (TERN) performed in the Sediver Research Center (Saint-Yorre, France). The test combines UV, high humidity and salt fog, rain, USCD= 20mm/kV.

Figure 2 shows a variety of results in this test with different types of coatings. It can be noted that while some RTV coatings with no fillers are being used in substation with success, the same material would suffer extensive erosion in an electric field corresponding to the geometry of a suspension cap and pin insulator. This section of the insulator surface will be the most severely challenged during the life of the insulator, and hydrophobicity will decrease primarily there as shown in **figure 3**.



A: polymer 1 ATH type a B: polymer 2 ATH type b C: polymer 2 ATH type c D: polymer 2 quartz filler

Figure 2: Variety of erosion patterns as a function of chemistry of the silicone coating

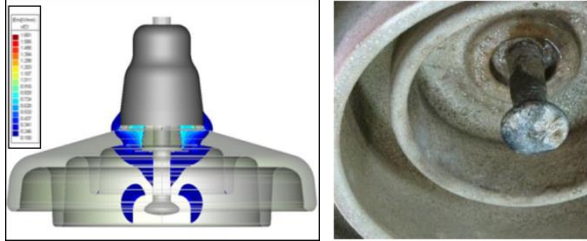


Figure 3: Electric field around the pin of a suspension cap and pin insulator

Different chemistries of silicone will display an ability to recover their hydrophobicity differently once inhibited by strong electric activity. This is a function of the material itself. Likewise the transfer of hydrophobicity across a layer of contaminant can fluctuate as well. Like for silicone composite

insulators is a tradeoff between the dynamics in these processes and the ability of a coating to sustain electric activity during the periods of time where the hydrophobicity is inhibited.

As a benchmark, a comparison between silicone composite insulators and a string of Sediver silicone coated toughened glass insulators was made with the same creepage distance in the same location over a period of 5 years in the Koeberg test station in South Africa where the harsh local conditions are known for a strong acceleration of the ageing process of insulators. The results in **figure 4** show explicitly the benefits of a coated insulator which does not pose a threat to the reliability of the line compared to a polymer insulator which condition after 5 years would require an immediate replacement.



Figure 4: Comparative ageing pattern between a silicone coated composite insulator and an equivalent string of silicone coated toughened glass insulators.

2. Performance of silicone coated insulators under various polluted environments

SEDIVER silicone coated toughened glass insulators have been in service for almost 20 years in various countries around the world with impeccable performance and results. Experience is gaining progressively a large base including DC applications.

2.1 Field experience and results on AC lines

More than 1,5 million Sediver silicone coated toughened glass insulators are in service in more than 17 countries and systematically in harsh conditions where otherwise composite insulators would be installed. The main driver for the decision of utilities to engage into a coating solution instead of a composite insulator has always been long term reliability, capability of live line work and easy inspection methods. All these features represent a major attribute of toughened glass insulators especially when comparing with composite insulators or even porcelain discs.

In Italy, where coastal contamination is the dominant factor given the presence of thousands of miles of coastal lines, silicone coated toughened glass insulators have been used for about 10 years with excellent results, with so far a complete elimination of the need for washing. Approximately 700000 insulators are in service, and a periodic monitoring program is in place with TERNA, the local utility.

Figure 5 gives examples of the condition of the insulators in very harsh environments, mostly on the coast.

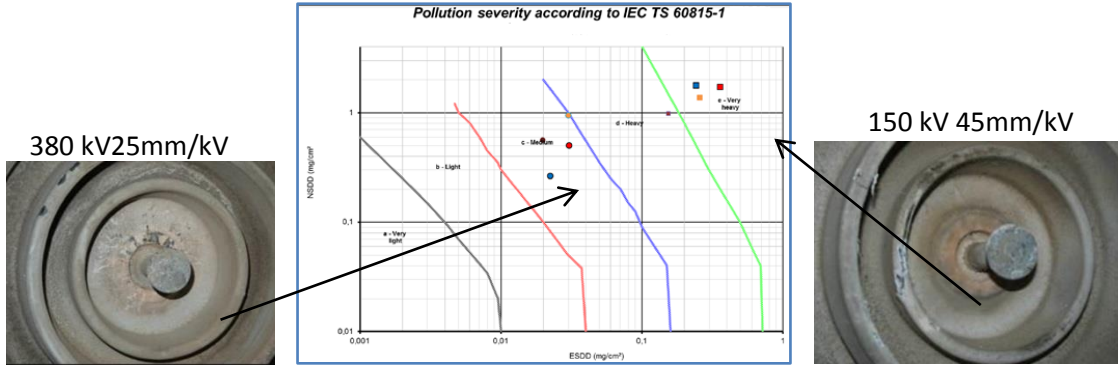


Figure 5: Example of condition of the silicone coated insulators with respect to their local environment determined from pollution measurements on site (ESDD/NSDD)

The evaluation criteria used by Sediver combine erosion (see the SEDIVER erosion chart in **figure 6**), hydrophobicity and location of the units which appear to be affected by electric activity along the string. The monitoring of the units retrieved from the Italian grid show a condition classified as CE3, with an average hydrophobicity of HC2 –HC3 limited to the first 3 units from the bottom of the string. The condition is quite good given the environment after about 10 years of service.

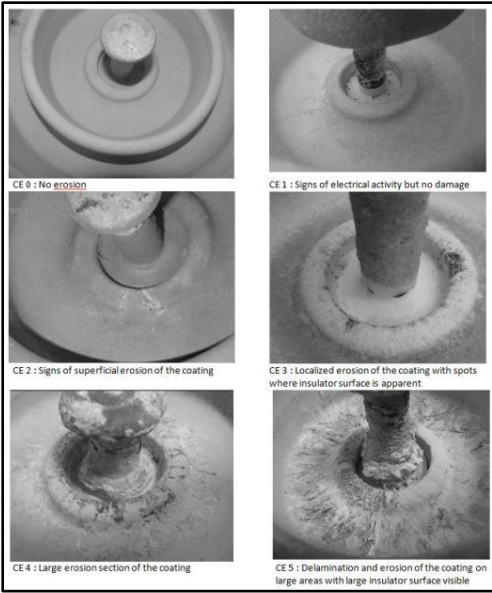


Figure 6: Classification as per Sediver erosion chart

Another example is coming from Qatar where silicone coated toughened glass insulators were installed in semi desertic conditions in 1996 on a 220 kV line. The local utility (Kahramaa) was facing flashovers on their old lines and regular washing was implemented until silicone coated glass insulators were installed. Samples have been removed for evaluation after 19 years in service and tested in the Sediver Reseach Center laboratories (St Yorre and Bazet laboratories, France). The level of pollution is given in **figure 7**, and the overall aspect of the units is shown in **figure 8**.

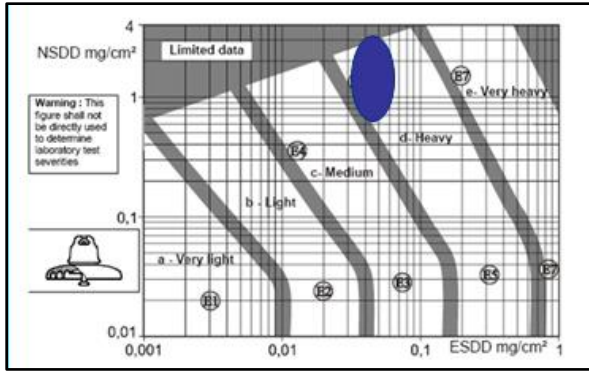


Figure 7: pollution chart



Figure 8: overall aspect of the insulators

It must be noted that the surface of the coating was damaged mostly because of handling during removal, but surface tears and damages were most likely existing in service, and it did not alter the performance of the insulators. **Figure 9** shows the hydrophobicity in some areas of the insulator surface, and the contact angle measured shows a super hydrophobic condition which is the result of the ageing of the polymer itself. This phenomenon (explained in an earlier publication at ISH 2015 by Sediver) is normally harmful for a composite insulator since this change will result in increased hardness and cracking of the housing to finally lead to moisture ingress. For a coated glass insulator this has no consequences other than increasing the hydrophobicity itself.

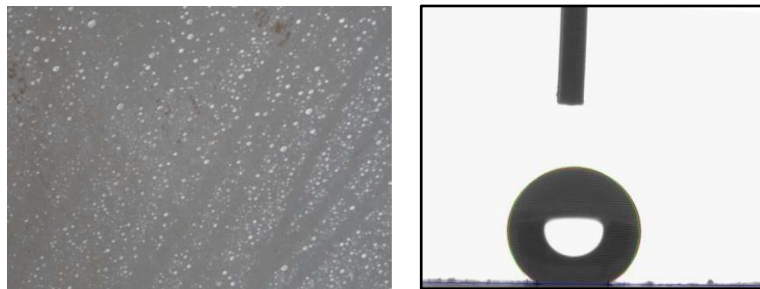
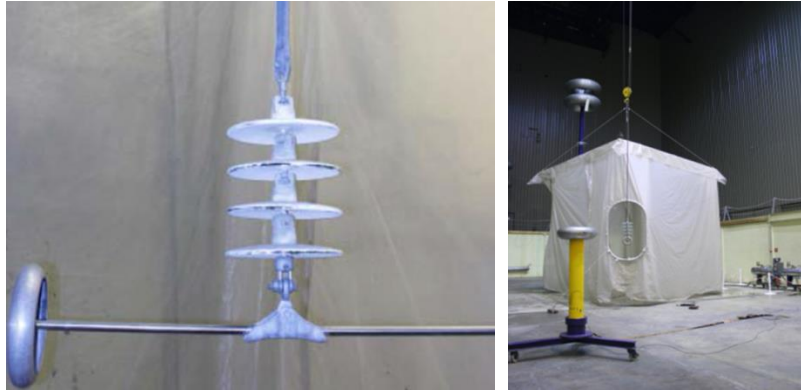


Figure 9 : super hydrophobic condition of the surface and contact angle (142°)

In addition to these observations, a comparative pollution test was performed on the samples removed from the line using a clean fog method and compared to non-coated new insulators on which a similar level of pollution (ESDD/NSDD) had been applied. The test method was a rapid flashover method, and the results are shown in **figure 10**.

Other similar examples of silicone coated toughened glass insulators used instead of composite insulators can be found from Peru to California, Canada, Europe, North Africa or Asia. The trend is a strong growth in this technology, despite a procurement cost higher than for composite insulators. It is also the evidence that utilities are progressively becoming more sensitive to full cost of ownership and operating, maintenance costs rather than a simple initial purchasing cost.



ESDD=0,1 mg/cm² NSDD=0,1 mg/cm² (string of 4 units)	U50 (kV)
Actual units with pollution from site on coated units after 19 years	210 kV
Artificial pollution on non-coated string	72 kV

Figure 10: pollution test and results

2.2 Field experience and results on DC lines

DC overhead lines are dominantly using toughened glass worldwide. However, experience gained with silicone coated cap and pin insulators is providing alternate solutions when very severe contamination is encountered. In China, for instance, SGCC has decided to use hundreds of thousands of silicone coated toughened glass insulators on their next 800kVDC line. In this case, and for the first time in China the coating will be applied in the factory (in line with the Sediver technological choice implemented more than a decade ago) and not in the field as done in the past by Chinese utilities. The performance of silicone coated toughened glass insulator was established in the Sediver Research Center (St Yorre, France) using the salt fog withstand procedure as per IEC 61245 at 80g/l (**figure 11**). The results have shown a significant advantage for the silicone coated glass insulators.



	<i>Composite insulator</i>	<i>Silicone coated toughened glass</i>
<i>String leakage distance</i>	2560mm(100")	2090mm (82,2")
<i>U50 flashover voltage</i>	-70 kV	>-90 kV

Figure 11: comparative DC pollution test

Silicone DC toughened glass insulators have been successfully in service in harsh coastal conditions on the DC link between Italy and France and a sample removed from a string after 18 years in service in Corsica is shown in **figure 12**. While wear and tear is visible on the surface of the coating, the performance was still good and hydrophobicity while fluctuating along the surface depending where it was measured was found HC2 to HC5.



Figure 12: Silicone coated toughened glass insulator after 18 years in service

A trial with silicone coated toughened glass insulators gave also very positive results in Italy on the continental side of the same 200 kV DC link in Tuscany. **Figure 13** shows the level of pollution measured on samples from this line which will be equipped at larger scale with this technology in the coming future.

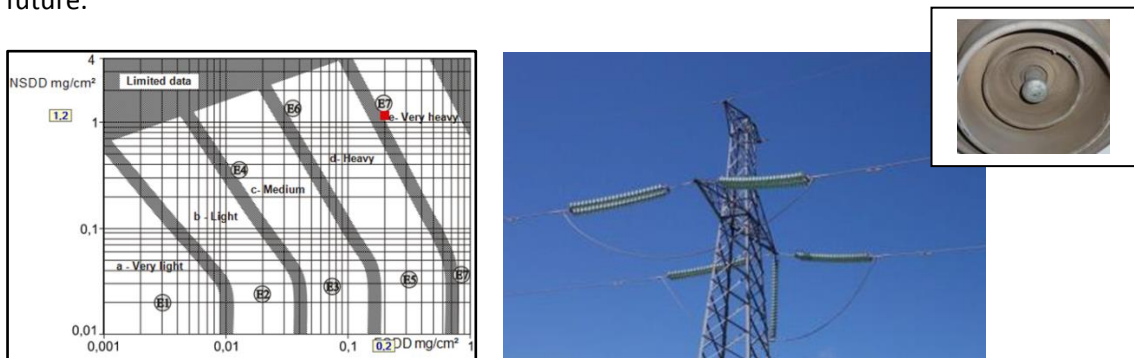


Figure 13: Pollution conditions at the 200kV DC link in Italy

3. Development of under-coated applications

In more recent work Sediver has initiated the development of silicone coated toughened glass insulators where only the bottom side of the insulator was coated (**figure 14**). This was suggested to produce favorable conditions of handling and installation, preventing damages which can occur on the surface of the coating during transportation or by the crews at the time of installation. Several applications are already operating with this solution.



Figure 14: Under-coated toughened glass insulator

The first trial started in Peru with ISA in 2010 with very good results (**figure 15**). Today other utilities are starting using this technology offered by Sediver, including in the USA.



Figure 15: Under-coating toughened glass insulators in Peru (Chiclayo area)

The evaluation of the performance of fully coated versus under-coated insulators was made in the Sediver Research Center laboratories (Saint-Yorre and Bazet laboratories, France), as well as in STRI laboratory, Sweden.

The results of a solid pollution artificial test according to CIGRE document WG C4 303 using the rapid flashover method have led to the results shown in **figure 16** on short strings of 5 units for a contamination level set at an ESDD=0,1mg/cm² and NSDD=0,1mg/cm².

There is an improvement of performance when using a silicone coating estimated between 50% for the under-coating version and up to 70% when fully coated.

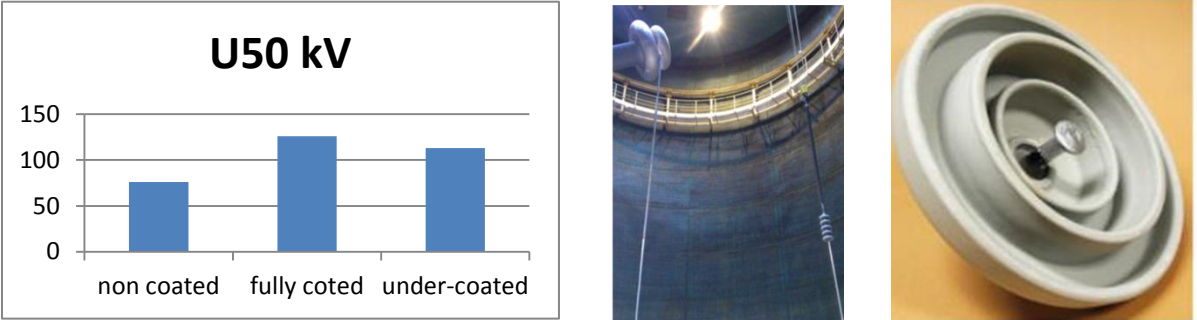


Figure 16: Artificial solid layer pollution test results on fully and under-coated toughened glass insulators (SEDIVER Research Center and STRI laboratories).

Salt fog withstand test were also performed on both options and the results show an equivalent (if not better) performance of under-coated toughened glass insulators. The test results in **figure 17** show an improvement of about 20% for an under-coated silicone glass insulator compared to a non-coated unit (salt fog test according to IEC 61507 at 40g/l).

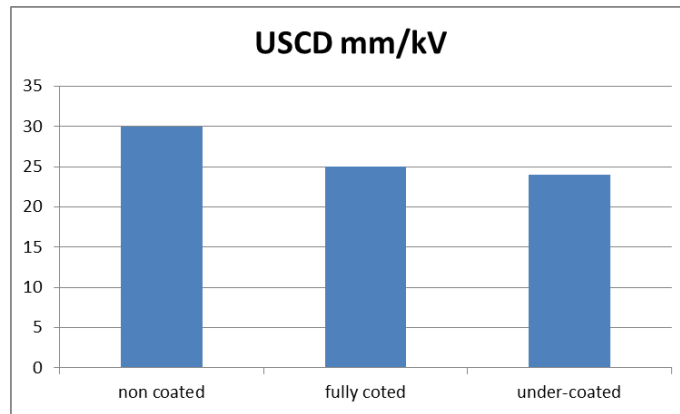


Figure 17: Salt fog test results showing an improvement of 20% of USCD (mm/kV phase/ground) with coated or under-coated (Sediver Research Center).

Take aways and conclusions

Sediver has acquired substantial R&D and field knowledge to offer a unique silicone coated toughened glass solution in substitution to traditional composite insulators for harsh environments. The benefits are numerous:

- Contamination performance in AC and DC which is compatible with the most severe pollution conditions
- Combination of the advantages of the hydrophobicity of silicone rubber together with the reliability, ease of inspection and safety for live line work of toughened glass.

While more expensive than composite insulators, this solution is more and more the preferred choice of utilities sensitive to full cost of ownership, reliability, inspection and live line work