Field Experience and Laboratory Investigation of Glass Insulators having a Factory-applied Silicone Rubber Coating

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ABSTRACT

This paper presents the results of studies carried out on RTV rubber pre-coated toughened glass insulators intended for use in polluted conditions. RTV pre-coated toughened glass insulators have been developed which are coated during manufacture to produce a highly adherent and uniform layer of hydrophobic RTV silicone rubber on the dielectric, vastly improving the lifetime and effectiveness of such a coating when compared to past practice of application of coatings on site or in-situ. Over the last 10 years a test program has been implemented with periodical sampling of RTV pre-coated insulator strings in service in difficult environmental conditions. The reported returns from the field highlight that the RTV pre-coated insulators are an excellent solution to solve very severe contamination flashovers. This behavior should be predicted by suitable procedures for laboratory testing of such insulators with a hydrophobic coating and the proposed Rapid Flashover test method is presented. Laboratory pollution tests showed a remarkable improvement in the pollution withstand performance of RTV pre-coated glass insulators, compared to their traditional counterparts.

Index Terms - **Silicone, coatings, glass, insulators, pollution, transmission lines.**

1 INTRODUCTION

THE application of silicone coatings to outdoor insulators has until now been mainly a palliative measure, used on existing insulation in the field to mitigate pollution-related outages. For many years the coating was viewed as a maintenance product and applied mainly to station insulators wherever greasing or water washing of insulators on a regular basis was necessary in order to prevent flashovers. For a silicone coating to be effective it must be applied to a scrupulously clean surface and in an even manner to ensure a long and effective life. The main experience with field-applied coatings has been with posts and bushings for which cleaning and application are eased by both their shape and accessibility; application of coatings to cap and pin units on transmission towers being much less practical due to working height and difficulty of access to the underside of the insulator units. More recently toughened glass cap and pin insulators have been developed which are coated during manufacture to produce a highly adherent and uniform layer of hydrophobic Room Temperature Vulcanizing (RTV) silicone rubber on the glass dielectric. This process can vastly improve the lifetime and effectiveness of such a coating.

Such RTV pre-coated insulators have been installed in large numbers on lines in heavily polluted conditions in the Americas, the Middle East, Africa and Europe, notably in Italy where TERNA started about ten years ago with the first trial installation of RTV pre-coated toughened glass insulators on a 380 kV AC line [1]. Since 2003 the tests are going on with periodical sampling of naturally polluted insulator strings. To gain the proper confidence in the performance of this solution, aging tests have been performed on new and field aged insulator strings. The positive results have led TERNA to install about 600,000 RTV

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pre-coated insulators between 2005 and 2013 in harsh and very harsh polluted environments (notably combined coastal and industrial areas). Additionally 2000 insulators have been installed on HVDC lines in Italy as part of an in-field investigation. The reported returns from the field presented in this paper highlight that the RTV pre-coated insulators are an excellent solution to solve very severe contamination flashovers.

Pollution testing of hydrophobic insulators presents a particular challenge compared to traditional materials, notably for the successful application of an artificial layer and for the testing of naturally polluted insulators without washing off the layer before a valid result has been obtained. The suitable preparation and testing procedures for insulators with a hydrophobic coating are presented in this paper with particular reference to Rapid Flashover methods. Laboratory pollution tests confirmed a remarkable improvement in the pollution withstand performance of RTV pre-coated toughened glass insulators, compared to their traditional counterparts, and good correlation with in-field experience. The artificial pollution tests have also determined the necessary parameters for inclusion of RTV pre-coated toughened glass insulators in insulation selection software tools.

The use of such factory RTV pre-coated insulators not only allows a reduction in initial line costs, compared to uncoated cap and pin insulators, due to avoidance of longer string lengths (and increased tower height) being required for polluted conditions, but also life-cycle costs are reduced with respect to equivalent composite insulators due to the far simpler inspection and condition monitoring procedures available with glass insulators. Additionally, traditional live-line working procedures are still valid without the need for specific insulation safety diagnostics associated with, for example, composite insulators. Furthermore, the ease of inspection associated with toughened glass cap and pin insulators is maintained [1].

2 INSULATOR COATING TECHNOLOGY

RTV pre-coated glass insulators have so far shown very good behavior when installed on HV lines under AC and DC [1], thanks to careful choice of the silicone coating material and an appropriate application process. The use of an in-factory process makes it possible to produce a consistent, high-quality layer, as opposed to previous post-production or on-site application methods. It is important to note that the coating materials and methods developed for post insulators and bushings may not be appropriate for cap and pin insulators where E-field distribution and magnitude can be greatly different.

2.1 CHOICE OF THE RTV SILICONE COATING

The choice of the silicone material is essential and it is misleading to think that all silicone coating materials are equivalent, consequently it must be borne in mind that a silicone coating has to be considered as a compound with a specific recipe that is different for each manufacturer. In general, the silicone rubber coating compound should contain flame retardant filler, preferably alumina trihydrate (ATH), in a sufficient amount to provide good electrical tracking and erosion resistance [2]. The physical properties of the filler are also of importance. The quality of the coating itself is mainly evaluated by electrical measurements performed on samples of material (slabs).

It has been reported that the initial content of low molecular weight (LMW) silicones in the rubber will impact in-service behavior of the coating under climatic and electrical stresses by the imparted hydrophobic property of the coating [3]. Other properties are adjusted depending on the method of application, such as the viscosity, the specific gravity and the dry content of material. Figure 1 illustrates the difference in behavior of two coating materials with different ATH and LMW contents when subjected to a salt-fog aging test.

Figure 1. Example of the difference in behavior of two coating materials with different ATH and LMW contents when subjected to a salt-fog aging test.

2.2 APPLICATION PROCESS

In addition to the qualification of the silicone compound based on the previous requirements, the application onto the glass surface has to be under full control. The main concern is to provide very good cleanliness of the glass material before applying the silicone rubber, with a well-adjusted process and, last, but not least, special care must be paid to handling and packing.

The cleaning of the glass surface is ensured by the use of a precise solvent and, as for the choice of silicone, all the solvents are not equivalent in their performance. This cleanliness directly affects the quality of the adherence between glass and silicone and the choice of the good solvent allows excellent and consistent bonding of the layer to the insulator surface. Control of surface cleanliness is also aided by the fact that the process is applied in-house on recently manufactured insulators that have not been exposed to unknown environments and handling.

Another important topic regarding the application process is the final thickness of the RTV layer; all the insulators concerned in this study have a layer thickness greater than 280 μm on the bottom part of the glass shell and greater than 350 μm on the upper part. The coating is applied by spraying in multiple steps to achieve the required thickness. The spray parameters are directly dependent on the type of silicone and notably on its viscosity.

2.3 CURING AND PACKAGING

The main parameters influencing the quality and speed of curing are temperature and humidity. Humidity is necessary to initiate the chemical curing process of the RTV coating; higher temperatures help to provide good curing in a short time.

After complete curing of the RTV coating, one of the difficulties in handling pre-coated insulators is the risk to damage the silicone rubber layer either in the factory or during transportation and installation, for this reason, special protected packaging has been developed allowing safe handling. However, the extensive service experience gained by TERNA over more than ten years has shown that small scrapes have no impact on the coating performance or longevity. Figure 2 shows typical scrapes resulting from poor handling; while such a level of damage should always be avoided during installation, it does not adversely affect the service life or performance of the insulators.

Figure 2. Example of RTV coating surface scrapes resulting from poor handling.

2.3 VERIFICATION TESTS

At present there are no national or international standards for factory-pre-coated insulators. IEEE 1532 [4] proposes some possible tests for evaluation of coated insulators, but for the purposes of this study it was preferred to choose a set of tests that allowed some degree of reproduction of service conditions

2.3.1 TYPE/DESIGN TESTS

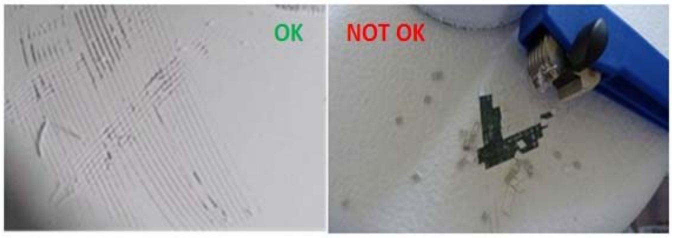
The following type/design tests are adopted based on a TERNA specification which describes in detail all the tests necessary to qualify a RTV pre-coated glass insulator [5]:

- control of the thickness and adherence of the coating,
- power arc test,
- salt fog withstand test,
- a newly developed ageing cycle test (2000 hours, consisting of 12 one week cycles) combining different stress parameters: voltage, salt fog, rain, humidity and UV [6].

2.3.2 SAMPLE TESTS

These tests are performed in addition to the standard sample tests used for cap and pin insulators and include: control of the visual appearance, the adherence and the thickness of the RTV coating layer.

In these tests the thickness of the layer can be measured by ultrasound directly on the surface of the insulator or by micrometer or by magnetic methods on a peeled layer. The adherence is evaluated by a cross-cut test using a standard tool [7], see Figure 3.



a) Good result b) Bad result and tool

Figure 3. Typical a) good and b) bad adherence test results showing the cross-cut adherence test tool.

3 SERVICE EXPERIENCE AND MONITORING

It is estimated that there are several million silicone coated cap and pin insulators installed over the last 20 years, often coated at the foot of the pylon or in-situ as a palliative measure. Of these, over one million are RTV pre-coated insulators. When in-factory coating was developed in 2003 there was an opportunity to carry out close and frequent monitoring rather than relying on patchy field reports.

3.1 AC APPLICATIONS: SERVICE EXPERIENCE

The Italian transmission grid, with more than 63,500 km of overhead lines with a voltage rating higher or equal to 132 kV, is equipped mainly with glass insulators due to the positive experience gained with this technology over more than 50 years. Due to the geographic position of Italy, practically surrounded by the sea, sea salt is the typical type of pollution that stresses overhead lines insulators. However, in some cases the pollution is a mixture of both industrial and sea salt pollution which can be found in industrial areas by the sea. In areas where the pollution is particularly severe, insulator washing becomes an obligatory counter-measure with a washing frequency in some cases up to twice per year. In order to reduce as much as possible the risk of flashovers in harsh environments and to reduce the cost of line washing, TERNA started in the 1990's trial installations of RTV pre-coated insulators on some towers at sub-transmission levels (132 and 150 kV lines). Encouraging results were obtained in a short time, so the initial trial installation was extended to some sub-transmission line sections exposed to very heavy pollution (site equivalent salinity of about 160 kg/m³). The successful results pushed TERNA to extend the installation more and more and also to cover some line sections with a higher voltage rating. In 2003 TERNA started the installation of RTV pre-coated insulators on lines with voltage ratings higher than 150 kV, being the first TSO in the world at that time to have RTV pre-coated insulators installed at the 380 kV level [6], Figure 4 shows an example of such an installation in an area where the pollution severity was classified as "very heavy", i.e. corresponding to a site equivalent salinity higher than 160 kg/m³. No flashovers have been recorded in more than ten years. Similar very good results were achieved at all voltage levels and prompted TERNA to extend the installation of RTV pre-coated insulators even further. Today the RTV pre-coated insulator has become a standard at TERNA to be installed at all levels up to and including 380 kV at those sites ranked as "heavy" and "very heavy", i.e. with a site equivalent salinity higher than 56 kg/m³ and 160 kg/m³ respectively. Today TERNA has installed about 600,000 RTV pre-coated insulators and this number will increase in the coming years. At those sites where the RTV pre-coated insulators replaced the conventional glass insulators, where washing was necessary on a regular basis, no washing has been applied anymore.

The experience gained by TERNA over the years has been confirmed by a continuous monitoring procedure. The monitoring

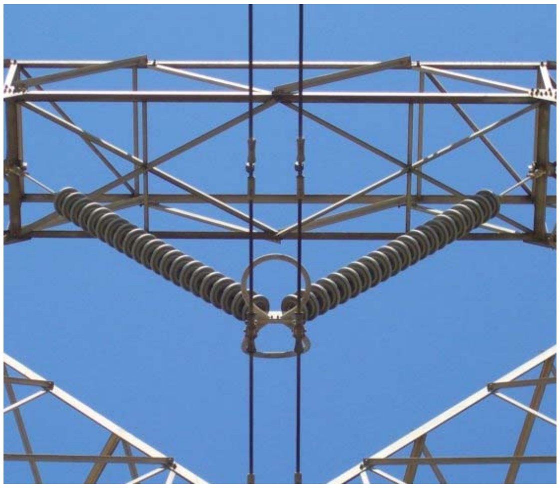


Figure 4. 380 kV line equipped with RTV pre-coated insulators: total creepage length 9345 mm 40.6 mm/kV) at pollution site with a severity greater than 160 kg/m³

program was established as a yearly sampling procedure from different sites in order to evaluate, through a proper sequence of laboratory tests, the degradation of the coating material and to make some estimation for the end-of-life of the insulator strings at different pollution levels. Such tests concern clean and salt fog tests both on strings "as received" from field and after cleaning [6].

Coating thickness and adherence, pollution level, hydrophobicity and recovery measurements and visual inspection (specially looking for traces of erosion or tracking) were included in the diagnostics. Today, after over more than ten years of experience, much data has been collected and their analysis has been helpful to better understand the behavior of RTV pre-coated insulators under different field conditions.

Some laboratory tests on six year aged insulator strings where the standard IEC 60507 salt-fog tests were applied revealed some flashovers in salt fog tests [8] but on the other hand no flashovers in the field have ever been recorded to date. This fact points out that the standard sequence of laboratory tests used in the monitoring process could be more stressful than the field conditions, this supports the investigation of the use of the rapid flashover test reported below.

Hydrophobicity recovery measurements have shown that a six year aged string installed in a very harsh environment with a site equivalent salinity higher than 160 kg/m³ completely recovers, after washing, to a hydrophobic class WC1 in about 50/60 hours and in about 140/150 hours for the bottom and upper surface respectively [8] highlighting that the rule of thumb of a hydrophobicity recovery in 24 hours represents a too conservative limit for insulators after some time of exposure to severe environments. To date TERNA has never performed insulator washing on installed RTV pre-coated insulator strings; nevertheless TERNA is examining potential water washing methods specific to RTV pre-coated insulators.

3.2 AC APPLICATIONS: DIAGNOSTICS

Insulators were returned regularly for analysis from two Italian locations, Villasor (150 kV, USCD = 59 mm/kV) and Brindisi (380 kV, USCD = 38 mm/kV). In all cases the insulators were removed from the HV end of the string where stress is the highest; inspection of the remaining insulators in typical strings confirmed this approach.

The main points which were investigated are coating thickness and adherence, pollution level, hydrophobicity and visual inspection for erosion or tracking.

After nearly 8 years of diagnostics no flashovers have been noticed on these lines and all the results are satisfactory: adherence remains satisfactory with no peeling, cracking, crazing or tracking. The thickness of the RTV coating has remained constant, and no abrasion has been found. Some slight traces of erosion of the RTV coating have been detected (see Figure 5) on the first two insulators at the high voltage end of the strings (they are the ones more stressed by the electric field), although such marking is not systematic.

Figure 5. Heavily polluted insulator after 7 ½ years showing very light surface erosion on the HV end unit: Brindisi 380 kV line, USCD: 38 mm/kV. Inset: Close-up of the first under-rib.

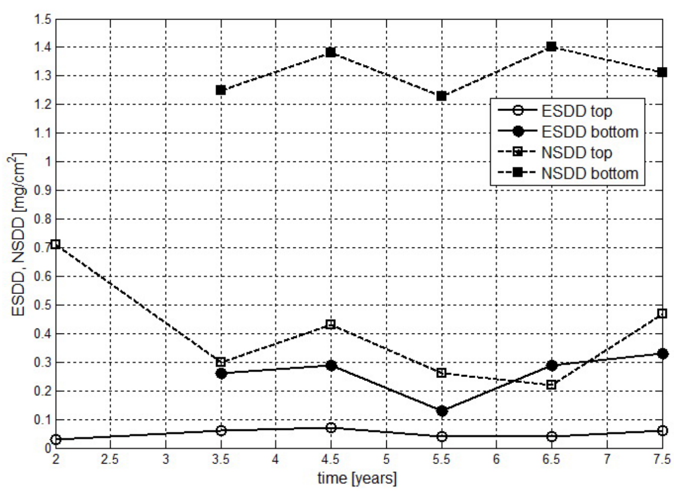


Figure 6. Pollution measurements over 7 ½ years at the Villasor (150 kV) site.

Pollution measurements included Equivalent Salt Deposit Density (ESDD), Non-Soluble Deposit Density (NSDD) and surface conductance. Figure 6 shows the yearly pollution measurements for the Villasor (150 kV) site. It can be seen that the levels are extremely high, notably the NSDD on the lower surface which reaches 1.4 mg/cm². Despite these high values there is no trend of increase in pollution with time, indicating that natural cleaning is still effective.

Layer conductivity measurements were carried out over 4 hours (in clean fog according to IEC 60507 [10] - solid layer method). The results showed very low values compared to the actual ESDD measurements, typically in the range of 0.1 µS to 0.5 µS. These values are in the order of two decades lower than would be expected for the ESDD values (there is a factor of about 150 between the ESDD and layer conductivity), indicating that there is encapsulation of the salts in the pollution layer by LMW silicone. This also indicates that the measurements of ESDD on silicone rubber surfaces seem to be not entirely correct in relation to actual pollution performance of such insulators in service. Nevertheless, it is important to say that no washing has been done since the installation of these insulators and no flashover has occurred despite the extreme ESDD/NSDD levels.

Since hydrophobicity of the coating is an indication of the status of the insulator, this property was evaluated on all the insulators returned from HV lines. The hydrophobicity was measured by using the IEC 62073 method [11] which gives a classification from Wettability Class WC1 (hydrophobic) to WC7 (hydrophilic) based on the observation of the pattern of water droplets sprayed at the surface of the coating.

Examples of WC measurements for both HV sites are given in Table 1.

Table 1. Hydrophobicity measurements for Villasor and Brindisi.

Villasor (years)	2	3,5	4,5	5,5	6,5	7,5
Top	WC1	WC1	WC1	WC1-WC2	WC1-WC2	WC2-WC3
Bottom	WC2-WC4	WC1-WC2	WC2-WC5	WC2-WC5	WC1-WC3	WC2-WC3
Brindisi (years)	2	1,33	3,66	4,66	4,33	7,25
Top	WC1	WC1	WC1	WC1-WC2	WC1-WC2	WC1-WC2
Bottom	WC2-WC5	WC3-WC4	WC2-WC5	WC2-WC5	WC2-WC4	WC2-WC5

Table 1 shows a slight decrease in the hydrophobicity status of the upper surface over time. On the bottom side, which consistently has a higher level of pollution, the hydrophobicity is always lower than the top side. Experience shows that natural washing helps to remove pollution giving rise to hydrophobicity being maintained in good condition for over 7 years. Some isolated patches on the bottom sides are no longer hydrophobic, but the overall hydrophobicity of the units is essentially constant over time after an initial slight reduction.

3.3 DC APPLICATIONS

In 2009, based on the positive experience gained on AC lines, TERNA started a trial installation of RTV pre-coated insulators on a 200 kV DC line. At present, after continual monitoring by yearly laboratory tests on strings removed from the line, TERNA became confident to extend the installation to about 20 km of the line. Today the number of RTV pre-coated insulator units installed in DC is about 2000 units and this number is expected to increase in the next years since laboratory diagnostic tests are giving encouraging results [9]. The selected overhead line is a section of the SACOI DC intertie which is frequently exposed to a heavy contamination in the form of combined sea salt and industrial pollution. This 20 km long section of the line was subject to frequent flashovers in specific periods of the year due to heavy contamination. Since the installation of the RTV pre-coated insulators no flashovers have been recorded. Table 2 shows typical pollution measurements on a sample string taken from this line, illustrating the very heavy pollution conditions. TERNA is continuing the investigation through sampling and laboratory tests.

Table 2. DC pollution measurements from a string after 4 year on SACOI intertie (insulators numbered from the earth end).

Sample	Exposure time	ESDD (mg/cm²)	NSDD (mg/cm²)	IEC 60815 Pollution level
Insulator 1	4 years 4 months	0.214	1.21	Very Heavy
Insulator 4 (top)		0.017	0.11	Medium
Insulator 4 (Bottom)		0.222	1.25	Very Heavy
Insulator 15 (top)		0.017	0.13	Medium
Insulator 15 (Bottom)		0.222	1.22	Very Heavy
Insulator 18		0.256	0.84	Very Heavy

4 LABORATORY POLLUTION TESTING

Laboratory pollution tests were used to obtain comparative results for glass cap-and-pin insulators and RTV-coated glass cap-and-pin insulators. The test objects were SEDIVER insulators F 120P/146 with the creepage distance 445 mm and the spacing 146 mm, see Figure 7. A string of five units was used for the tests.

It is generally agreed that the standardized laboratory pollution test methods are not applicable for composite (polymeric) or RTV-coated insulators. Therefore, a special procedure according to the recently published CIGRE Brochure was used [12]. The contamination procedure for RTV-coated insulators included four phases: (1) Gentle cleaning; (2) Pre-conditioning; (3) Application of the pollution layer; (4) Recovery phase (specific period of elapsed time between the contamination and voltage testing). For glass insulators only phases (1) and (3) were applied.

Figure 7. RTV-coated glass cap-and-pin insulator.

The pre-conditioning was performed according to [12] by applying of dry kaolin powder to the clean and dry insulator surface by a brush. After the application, most of the powder was blown off by compressed air until only a very thin layer remained on the insulator surface. This layer provided uniform contamination while using standard dipping technique according to [10], see Figure 8. The insulators were dipped and twisted in the slurry for approximately 20 seconds to make sure that they get an even pollution layer. The RTV-coated insulators were then left to dry at room temperature before being tested after two days of recovery of hydrophobicity (maximum 16+48 hours in total according to the recommendations from CIGRE [12]).

Figure 8. Example of contamination procedure by dipping of RTV-coated insulators: the insulator is manually rotated in the slurry to obtain uniform pollution layer

The target SDD/NSDD levels were of 0.1/0.1-0.2 mg/cm^2 and 0.3/0.1-0.2 mg/cm^2. The final actual average pollution levels obtained during the tests on the RTV-coated insulators were 0.09/0.19 mg/cm^2 and 0.31/0.19 mg/cm^2, while for glass insulators they were 0.1/0.19 mg/cm^2. The top and bottom surfaces were measured separately and the SDD Contamination Uniformity Ratio (bottom/top) was about 0.9 for RTV-coated insulators and about 0.7 for glass insulators. Thus, using the pre-conditioning procedure according to [12] and the standard IEC procedure for contamination provides excellent repeatability.

Voltage tests were performed in accordance with the Rapid Flashover Solid Layer Pollution Test Method [15]. This method proposes to vary the applied voltage upwards or downwards in relatively small voltage steps with the time at each level that varies as a function of whether the insulator withstands or flashes over. With the Rapid Flashover (RFO) method the $U_{50\%}$ at a given pollution level can be estimated by two hours of testing which, if representative could lead to economic saving in pollution testing [16]. Primarily this diagnostic method could be of interest for investigation of the performance of naturally polluted insulators [13, 14] but could be standardized and verified for reproducibility with artificial pollution. This method has been already used for line glass cap-and-pin and composite insulators [15], and very recent results showed its feasibility for station insulators made of different materials [16]. However, this method was for the first time applied for RTV-coated insulators, which is described in this paper.

The polluted and dried insulators were placed into the climate test hall as shown in Figure 9. The insulators were wetted by steam fog of standard intensity according to the IEC 60507 [9]. After 15 minutes of wetting the voltage was applied.

Figure 9. Example of the set-up in the climate test hall.

The starting voltage level was estimated based on general insulator knowledge. Every five minutes the voltage was then increased in steps of 4 kV, which was roughly 5% of estimated flashover voltage. The speed of voltage ramping was about 6 kV/s. In case of a flashover the voltage was tripped and then immediately applied at a level decreased by one step (4 kV). The test was continued until the flashover level started to increase, indicating cleaning of the insulators. The total test duration was about 100 minutes. Two voltage tests per type and pollution level were performed according to the procedure described above. The $U_{50\%}$ in test 1 and 2 are calculated as the average value of the minimum flashover voltage and half a voltage step. Examples of the sequence of voltage application are shown in Figure 10 for glass insulators and in Figure 11 for RTV-coated insulators.

The comparative results of pollution testing are presented in Table 3. For the same pollution level the flashover performance of RTV-coated insulators is about 70% higher compared to the uncoated glass insulators. Because the tested insulators are identical in profile, the only difference between them is the RTV rubber coating and such a difference in flashover voltage indicates a very high speed of recovery of hydrophobicity after 64 hours. In comparison, similar tests performed on different silicone rubber long rod insulators revealed an increase in flashover voltage after recovery of 9-23% [12], [18]. The results also indicate high repeatability of the test method.

Table 3. Flashover voltages (U_{50}) for different glass insulators

	Test 1	Test 2	Average
RTV-coated, SDD 0.3 mg/cm^2	88 kV	80 kV	84 kV
RTV-coated, SDD 0.1 mg/cm^2	128 kV	136 kV	132 kV
Uncoated glass, SDD 0.1 mg/cm^2	76 kV	76 kV	76 kV

Test voltage (kV)	Rapid flashover test results																			
102																				X
98					X												X		O	
94				O		X		X				X				O		O		
90			O				O		X		O		X		O					
86		O								O				O						
82	O																			

Figure 10. Example of sequence from test for uncoated glass insulators for SDD=0,1, mg/cm². O = withstand. X=flashover.

Test voltage (kV)	Rapid flashover test results																								
142																X									
138															O		X								
134														O				X						X	
130													O						X		X		O		O
126												O								O		O			

Figure 11. Example of sequence from test for RTV-coated glass insulators for SDD=0,1, mg/cm2. O = withstand. X=flashover

The presented pollution test results were used for the creation of pollution performance curves directly applicable for implementation in the STRI-developed software Insulator Selection Tool (IST) [17]. The IST program follows principles of statistical dimensioning according to IEC 60815-1 and is applicable for both AC and DC applications. A number of power utilities and manufacturers (including SEDIVER) started to use this program for practical applications. Rough estimation in the IST program (see Figure 12) shows that RTV-coated insulators in a "shortly-recovered" (in 2 days) condition can reduce significantly the required length of insulator strings compared to non-coated glass insulators. In the example in Figure 12 a reduction of 30% is indicated at an ESDD level of 0.3 mg/cm². This improvement in pollution performance is comparable to the advantage often attributed to silicone rubber composite long rod insulators with respect to conventional insulators in polluted conditions.

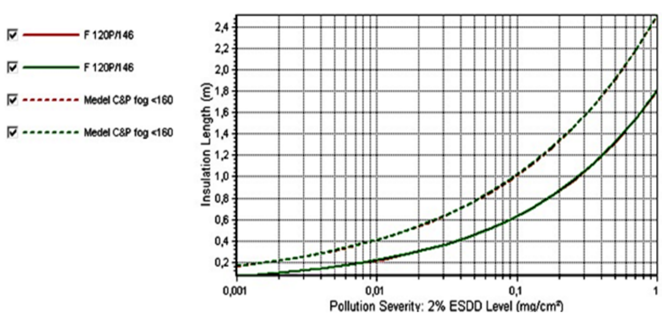


Figure 12. Comparison of required insulation length over pollution level for the tested RTV-coated insulator and a generic ceramic cap-and-pin insulator.

5 CONCLUSION

The development of in-factory pre-coating of toughened glass insulators with RTV has led to a reliable insulating solution that can improve insulation performance in polluted conditions compared to conventional cap and pin insulators. The in-factory process ensures excellent adherence of the coating and a constant quality.

A matrix of tests has been established to not only evaluate coating material and process suitability but also to diagnose coated insulators after field exposure.

Diagnostics of RTV pre-coated toughened glass insulators after up to 7 ½ years in service in difficult polluted conditions show a good adherence and resistance of the coating to erosion, good hydrophobic behavior, and no trend of pollution build-up.

Trial installations in service and a monitoring program started in 2003 in Italy on AC lines, and later on a DC line, have given very encouraging results which have led a TSO (TERNA) to extend the installation of RTV pre-coated glass insulators to extensive sections of transmission lines. The immediate benefits have been felt by the removal of any need for washing and a total absence of flashovers.

Comparative pollution performance data for glass insulators and RTV-coated glass insulators were obtained by appropriate testing. These tests included contamination application according the latest CIGRE recommendations for hydrophobic insulators [12] and a Rapid Flashover procedure earlier verified by SEDIVER/STRI for glass insulators. The results are repeatable and are in line with the results from previous tests, which indicate that the method has good repeatability. For a medium pollution level of ESDD/NSDD 0.1/0.1 mg/cm² the flashover voltage of RTV-coated insulators after a short hydrophobicity recovery period of 2 days between the contamination and voltage tests is about 70% higher compared to glass insulators and this is an indication that the hydrophobicity recovery of the RTV-coating may in general be faster than for silicone rubber composite insulators submitted to the same pollution application procedure [12].

If the RTV-coating keeps its high hydrophobic properties in service as is suggested by the results of 7 ½ years monitoring in very heavy pollution conditions in Italy, then new and existing installations can achieve greatly improved pollution performance, compared to glass and other ceramic insulators, without any increase in string length. Alternatively, in specific cases, the reduction of insulator string length can be considered.

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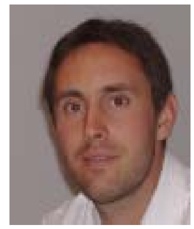

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