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AC and DC pollution testing methods: accuracy and limitations

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SEDIVER

The pollution performance of insulator strings is a center piece in the design of towers for overhead lines. It is even becoming a more pressing question with silicone hydrophobic surfaces which properties are dynamic and respond differently in various service conditions.

The following note gives summarizes some observations and test details which can be of interest in the evaluation of insulator strings in such conditions.

On one side testing hydrophobic surfaces need more work as already engaged in IEC and already summarized in [9], but the question of heavy and very heavy pollution conditions remains an open question.

More generally speaking it is crucial to avoid over-pessimistic or over-optimistic scenarios through the interpretation of results from a withstand test compared to results from a rapid flashover test.

A particular point of interest is DC where IEC TS 60815-part 4 [3] used data for ceramic insulators which are by far too pessimistic and therefore lead to longer than necessary string designs. It is clearly demonstrated in this document that DC glass insulators (with the appropriate shape for DC applications) outperform largely the USCD expected from the IEC guide.

1. Particularities to consider for solid layer pollution testing with heavy and very heavy deposits on silicone surfaces

Silicone surfaces are hydrophobic. This property is very desirable for polluted environments since the hydrophobicity is transferred to the layer of contaminants which therefore remains dry limiting leakage currents despite the presence of the surface deposits. The difficulty for testing such products is not only in the application of the deposit on the surface of the insulator (which can be inspired from [4] so far only used for light and medium pollution class) but more specifically the time required for allowing a reasonable transfer time when heavy or very heavy pollution criteria are required. The representativeness of the method needs to be challenged as well.

The application process commonly used is to dip the insulators in a slurry adjusted at the correct ESDD values. Most tests are performed at NSDD=0.1mg/cm² using correction factors to evaluate their expected performance at higher NSDD values. The amount of deposits between top and bottom (the CUR ratio) is also usually taken at a standard value of 1.

Sediver has developed a deposit method (called SDAM Spray Deposit Airborne Method, figure 1) by which the solid layer is built on the insulator from airborne dust in a controlled spray process, method also mentioned in IEC 60507 [1]. This allows for a deposit which is more representative of actual field conditions compared to the dipping method, with also the possibility to achieve uneven CUR ratios. Unlike for dipping where thickness is often not homogeneous, SDAM ensures a very good homogeneity all along the surface.

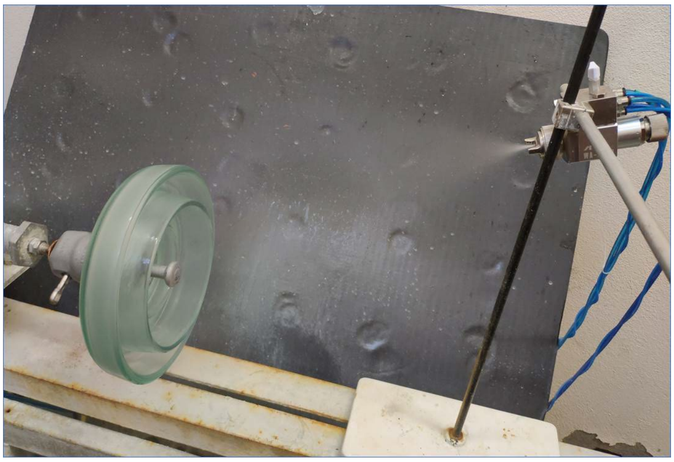


Figure 1: SDAM technique producing consistent pollution layers with possible different CUR levels

Either dipping or SDAM ends up with the same question of transfer time prior to testing when the layers correspond to heavy or very heavy pollution for which the NSDD level exceeds 0.2mg/cm². An accepted practice today is to wait for 48 hours or 72 hours between the application and the pollution test but for very heavy conditions the transfer is not at all in place. Figure 2 shows the average transfer time under high pollution conditions. In fact, the real question is to decide between a standard "rest time" or a defined hydrophobicity status. Most likely an HTM insulator does not need to be HC1 (the most hydrophobic status) to perform well, but in that case, what is acceptable keeping in mind that in "the real world" insulators have hydrophobicity levels which are not uniform along their surface, and likewise are not uniform along the string (or unit in the case of a polymer) This topic needs to be addressed by expert groups for future standardization keeping also in mind that "in the real world" such levels do not accumulate at once but progressively for most cases. As a result, the low molecular weight species (LMW) had time to transfer progressively through the deposit which creates a completely different condition than an artificial test where the entire pollution is applied in one operation. Figure 3 shows the difference in transfer time between a dipping deposit and a SDAM deposit. Because in natural conditions the deposit is airborne it is interesting to note that while SDAM is more representative it leads to a different dynamic in the transfer of the LMW. The findings shown here open the question of practicality in testing very heavy polluted conditions. It can be noted that transfer time varies with the chemistry of the silicone itself but also with the temperature at which the samples are subjected after application of the pollutant.

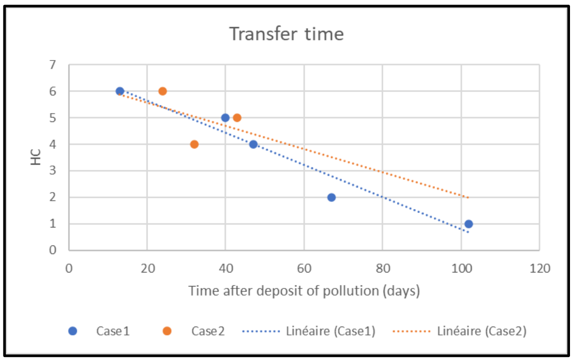


Figure 2: Transfer time for heavy and very heavy pollution layers on a silicone surface (Case 1 for NSDD=0.2mg/cm² and Case 2 for NSDD=1mg/cm²).

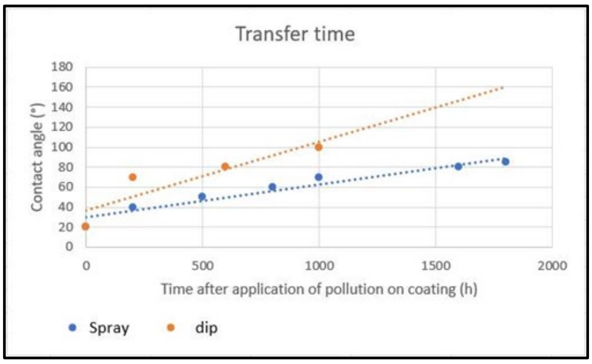


Figure 3 : Transfer time for NSDD= 0.2mg/cm² for dipping and SDAM application method

2. Rapid flashover method

The rapid flashover method is commonly used offering a valuable acceleration in the evaluation of the performance of a given string of insulators [5]. Nevertheless, the experience in pollution testing has pointed out the need to produce a withstand test around the values obtained in the rapid flashover method to validate the maximum withstand which typically will be higher than any calculated value based on the rapid flashover method. As shown below in figure 4 the actual withstand value is close to the value calculated as per [2] taking the average between the highest withstand and the lowest flashover result of the up and down method.

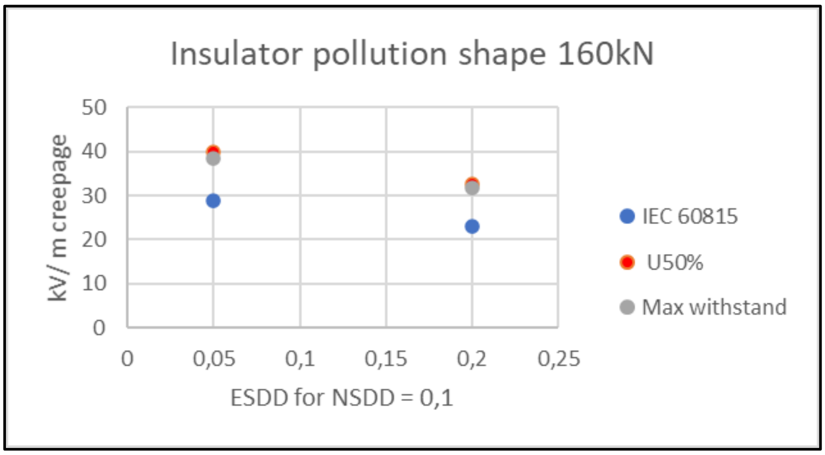


Figure 4: Withstand test results compared to the U50 obtained from a rapid flashover test.

3. Pollution performance under DC voltage

HVDC lines are used for long interconnexions between usually remote generation (hydraulic, renewable energy centers) and large consumer centers often located far away. DC lines have been built since the l960s in Europe but more largely in North America, Brazil, Africa India and finally China. Besides the specificities required in the insulator design to cope with the unidirectional electric field, pollution is a central topic in the dimensioning of the insulator strings. In a more recent past theoretical models and equations were crafted to assist in this task, leading to IEC TS60815-4 [3] recommendations. The definition of the necessary USCD as a function of the pollution conditions described in this guide tend to be over pessimistic for ceramic insulators (glass or porcelain) and over optimistic for polymers. This guide needs to be revised at least for two reasons:

- Revise the USCD requirements for ceramic insulators, but mostly for toughened glass insulators which performance is more than 30% better than the IEC curve.
- Include a safety buffer against early erosion for polymers when the design looks strictly at pollution performance and not early ageing. [6]

An extensive test program was initiated in the Sediver DC pollution laboratory with various solid layer pollution levels. Figure 5 shows the gap between the actual performance of a typical fog type glass insulator versus the USCD curve in IEC (dotted line), confirming earlier statements [8] already made on the DC performance under evaluation of ceramic insulators when using IEC TS60815-4 [3].

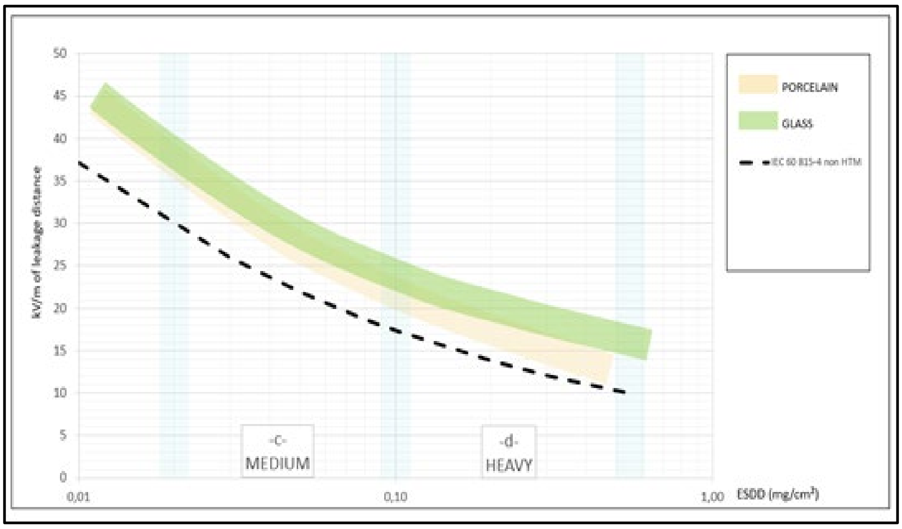


Figure 5: Actual pollution performance in DC under solid layer conditions compared to current IEC 60815-4

These results were calibrated against a reference pollution test performed in an independent international laboratory. This data corresponds to tests performed on DC insulators which are characterized by a specific shape for a DC application. This particularity has been largely documented in the past [10], [11] but probably forgotten. The dry band arcing activity in DC is different from what happens in AC and therefore real DC insulators (the only one to take into consideration for describing their pollution performance in DC) are designed with large inter rib distances and at least one long rib (figure 6) to mitigate arc development as shown in the still pictures from the observation with a high speed camera shown in figure7. It can be noted also that the making of a glass insulator allows for a better profile than porcelain (longer ribs and typically one rib less than porcelain for an identical leakage distance) which is also shown in figure 5

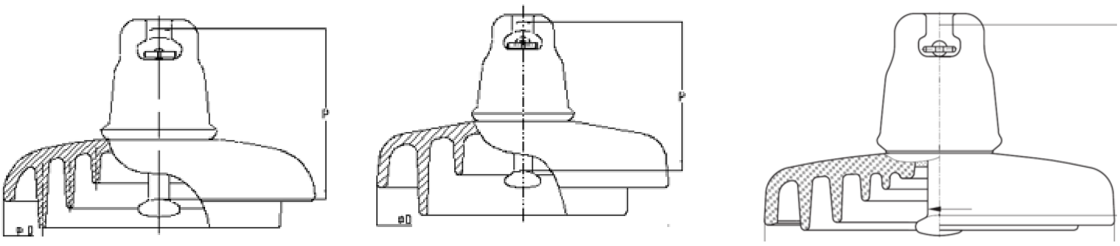
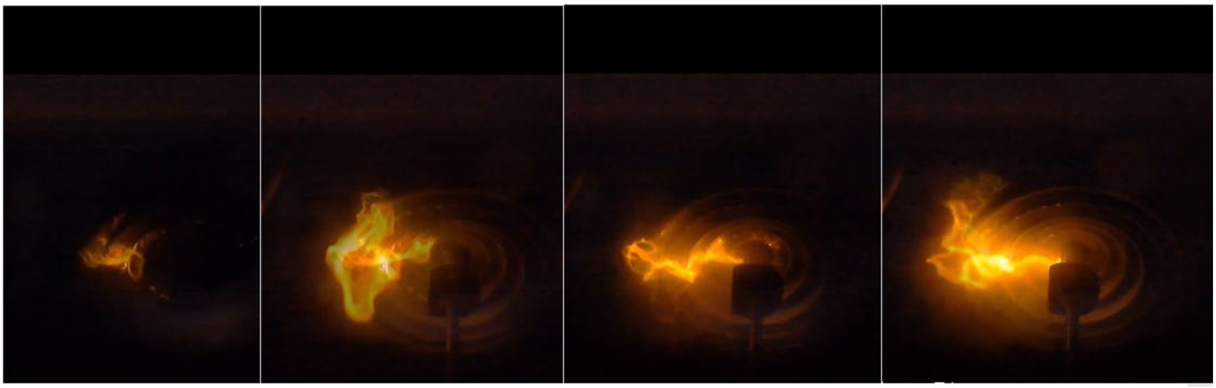
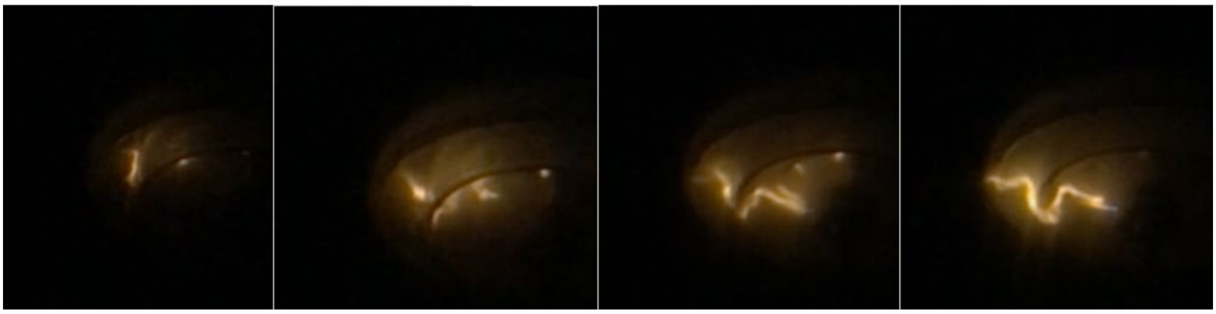


Figure 6: typical sketch of a DC glass profile (left and center) and profile not adapted to DC (right)



Arc development in DC over a glass insulator not specifically designed for a DC application. The arc is bridging the ribs eliminating largely the benefit of the leakage distance



Arc development in DC over a DC shape glass insulator. The arc follows better the profile taking a real benefit of the leakage distance.

Figure 7 comparison of the development of arcing activity in DC between a regular AC type insulator and a real DC glass insulator

It is interesting also to note that a similar test was performed with various lengths of strings. Some laboratories with limited resources would establish the DC performance on short strings and extrapolate to longer strings. It was shown in this program that a test performed on a few units (3 to 5 units) is over optimistic compared to longer strings. It seems adequate to consider that a minimum of 3m string length is required to obtain a representative test result which can be safely extrapolated to longer strings. For instance, the performance of a typical 500kV string can be correctly established with a half string sample. Figure 8 shows a summary of this test program performed in 3 laboratories.

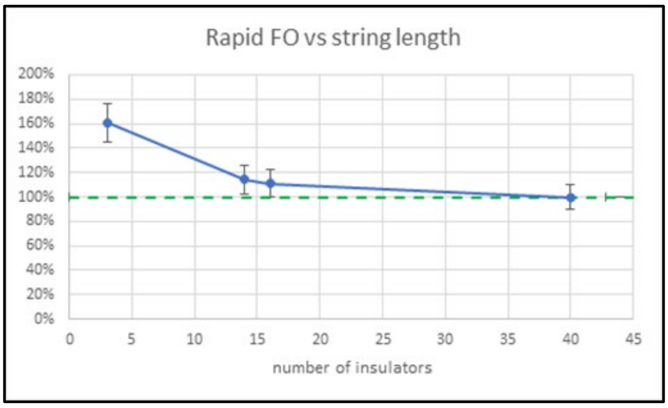


Figure 8: Comparison of test results between various string lengths under the same pollution conditions in a DC solid layer test using fog type insulators (values normalized at 100% for a long string)

Conclusion

More work is needed to establish commonly accepted testing techniques for the definition of the performance under solid layer pollution conditions on insulators made with hydrophobic surfaces and more so when pollution levels are heavy or very heavy.

The actual pollution performance needs to be challenged to avoid unnecessary string length designs especially in DC for which the data used for the theoretical evaluation of USCD needs to concentrate on real DC profiles.

Insulator profile matters in DC and generic performance curves can be highly misleading when disconnected from the proper product characteristics. It is worrisome to see some projects in which shape is ignored and offers submitted with classical AC shapes. This technical aspect should be kept in mind with string optimizations made possible through string testing in laboratories.

References

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