Surface Hydrophobicity in Medium Voltage Terminations

K. Väkeväinen
Ensto Utility Networks, Ensto Finland Oy, Porvoo, Finland

Abstract

The surface hydrophobicity in medium voltage terminations is studied in this paper to see if the performance of aged heat shrink terminations could be improved. Terminations which are used inside of unheated outdoor enclosures can often be subjected to leakage currents and surface discharges along the insulating surface if the environmental conditions inside the enclosure become harsh. The discharge phenomena on the insulating surface is generally not critical but continuous electrical activity on the surface could eventually lead to a flashover or breakdown as the materials age. The effect of surface hydrophobicity was studied by comparing the performance of heat shrink terminations over a longer time in operation. Improvements were done to aged heat shrink indoor terminations which already had signs of discharge occurrence on the termination surfaces. The results indicate that the performance of these aged terminations improved simply by increasing the surface hydrophobicity of the original installation. The improvement can be done by applying a silicone coating on the termination surface. This solution offers a convenient method for improving the performance of aged heat shrink terminations used in unheated outdoor enclosures.

1. Introduction

The rapid increase of underground cabling within the recent years has led to an increasing amount of secondary outdoor substations in the network. The typical structure of a secondary outdoor substation consists of separate compartments for low voltage, medium voltage and the transformer. Condensed water droplets are commonly found inside these type of enclosures since the heat from the transformer is not circulating well between the different substation compartments and the loading of the cables can be very low, especially in rural areas. The medium voltage terminations used inside these unheated outdoor enclosures are not subjected to the natural washing effect of rain and are therefore prone to surface discharges and dry band arcing if significant amount of conducting particles and moisture accumulate on the termination surface.

This investigation was performed by studying the performance of aged terminations in operation. The surface hydrophobicity was improved with a silicone coating on terminations that had clear indication of discharge occurrence on the surface. Also the creeping distance was increased by rain sheds on some of the terminations included in this study. The performance of the terminations was then followed over several years after the modifications were made to see how well these improvements would eventually last in normal operation.

2. Surface discharge occurence

Surface discharges can occur on medium voltage terminations when sufficient amount of conducting particles and moisture accumulated on the insulating termination surface. The operating conditions inside of unheated outdoor enclosures have proved to be challenging for the terminations and insulators used inside of these structures. Typical substation installations are shown in Figure 1 with dust accumulation on the termination surface and water level close to the bottom of the enclosure. The problems with surface discharges can be hard to identify, since it can take years before the first signs of discharges are visible on the insulating surfaces. Several methods are available for detecting discharge occurrence on medium voltage terminations, but a visual inspection combined with thermal imaging offers an easy and effective way to identify discharge occurrence on termination surfaces. The main advantage of this method is that it can done without outages in most substation models. The use of thermal imaging also gives good indication of discharge occurrence on termination or insulator surfaces before the actual discharge occurrence can be seen or heard. A thermal image of a heat shrink indoor termination with surface discharges is presented in Figure 2.

Figure 1. Typical installations sites with dust accumulating on the termination surfaces and water level close to the bottom of the secondary outdoor substation.

The surface discharges occurrence is not only limited to the medium voltage terminations used inside of unheated outdoor enclosures. Discharges have also been noticed on insulators in the medium voltage switchgear when terminations used in secondary outdoor substations were inspected. The terminations are generally located closest to the open ground underneath the substation and are therefore subjected to bigger temperature variations between the termination surface and the surrounding air, which generate more condensed water on the surface.

Previous field inspections indicate that the creeping distance of the termination and the surface hydrophobicity of the material have an effect on the occurrence of surface discharges on terminations that are used in unheated outdoor enclosures. Outdoor terminations with longer creeping distances have less traces of discharges when compared to indoor terminations of same type but with a shorter creeping distance. Cold shrink terminations with silicone insulation have had no traces of surface discharges when used in the same unheated outdoor enclosures. The naturally hydrophobic silicone insulation does not allow wetting of the surface similarly as the materials used in heat shrink terminations. Since the cold shrink terminations still represent a newer generation of cable accessories, the majority of the existing installations have been done using traditional heat shrink terminations. [1]

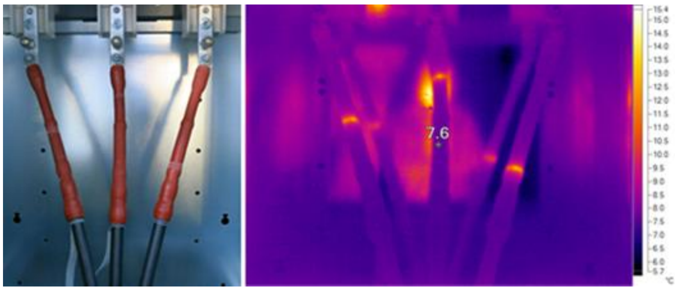

Figure 2. Identification of discharge occurrence on terminations by thermal imaging.

The common practice for many distribution network operators has been to use indoor terminations in their secondary outdoor substations. This situation is challenging since it can take years before the first traces of discharge occurrence are visible on the termination surface. The service intervals where these terminations could be cleaned to improve the performance are generally long and the expected lifetime for the equipment is still several decades. The challenges in repairing or re-installing terminations is not only limited to the time and cost of the installation work, but also the limited space inside of these enclosures makes the assembly work very challenging.

2.1 Surface hydrophobicity

The discharge occurrence on insulating materials requires moisture on the surface of the material, so the hydrophobicity of the material can affect the termination performance in an environment where water is condensed on its surface. The classification guide published by STRI provides a coarse classification for an insulators wetting status and is suitable for checking insulators used in in the field. Examples of typical hydrophobicity classes from 1 to 6 are shown in Figure 3. [2]

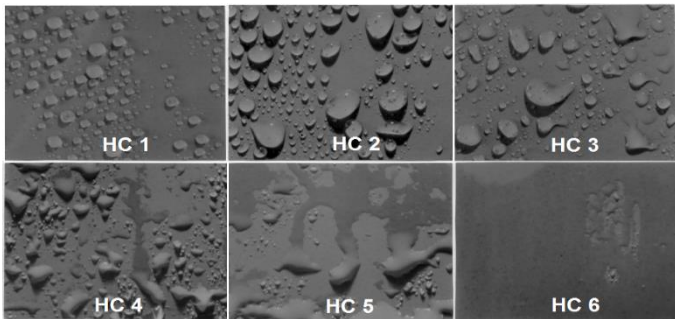

Figure 3. Hydrophobicity classes in STRI Guide 1.

The hydrophobicity of the material used in the studied heat shrink indoor terminations was compared to the hydrophobicity classes given in the STRI guide. An original material sample and a silicone coated sample was studied and compared to the classes given in the STRI guide. Water droplets on heat shrink material samples are shown in Figure 4. The hydrophobicity of the original sample corresponds to HC 2 and the silicone coating improves its hydrophobicity to HC 1. A fast test like this can easily indicate that the surface hydrophobicity of the material can be improved simply by applying a silicone coating, but the performance difference for this improvement on real terminations had to be studied on field installations to see if this improved hydrophobicity would actually last when the terminations are subjected to the real environmental conditions inside of a secondary outdoor substations.

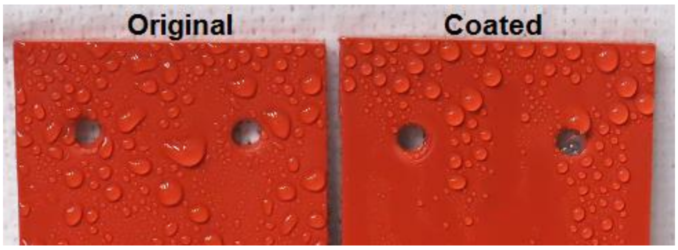

Figure 4. Hydrophobicity of original vs. coated surface.

3. Results

The field inspections and termination improvements were performed in Eastern Finland on a site with ten different secondary outdoor substations. A total number of 22 three-core medium voltage terminations were installed in these substations. All terminations were of the same heat shrink indoor termination type with no rain sheds. The inspections were performed at three different occasions over a six year period. The terminations were inspected after 24, 40 and 74 months in operation. The field inspections included a visual inspection and thermal imaging of the terminations.

The first termination inspections were performed for the originally installed terminations after two years in operation. Traces of surface discharge occurrence were noticed already in ten different terminations after a 24 month period in operation. Improvements were done to the terminations by improving the hydrophobicity of the termination surface and by both increasing the creeping distance and improving the hydrophobicity. The creeping distance was increased with rain sheds and the hydrophobicity by applying a silicone coating on the termination surface. The same improvement was performed for all three termination cores even if discharge traces were visible only in one single core of the termination.

The second inspection was performed when the terminations had been in operation for 40 months. Two more of the originally installed terminations had traces of surface discharges at this point but all terminations with improvements were in perfect condition. The two terminations that had discharge traces were improved by adding rain sheds and applying the silicone coating on the termination surface.

The final inspection was performed when the terminations had been for 74 months in operation. All ten of the originally installed terminations had traces of discharge occurrence on the termination surface after six years in operation. All terminations with improvements were still clear of discharge traces at this point. The ten original terminations with traces of discharges were improved by applying the silicone coating on the surface of the termination. The amount of different terminations in operation over the full six year period can be seen in Table 1.

Table 1. Terminations types in operation after each inspection.

Time in operation	Original	Coating only	Rain sheds + Coating
0 months	22	0	0
24 months	12	7	3
40 months	10	7	5
74 months	0	17	5

4. Discussion

The first ten of the originally installed terminations had traces of surface discharges already after 24 months in operation. This corresponds to 45 % of all the installed three-core terminations at this site. It can be assumed that these ten terminations were installed in the substations with the worst environmental conditions, because all the inspected terminations are of the same type. At the time of the second inspection, two more of the originally installed terminations had traces of surface discharge occurrence on the surface. This means that more than 50 % of the originally installed terminations had been subjected to surface discharges after 40 months in operation. Surface discharge occurrence on this many terminations clearly indicate that the originally installed heat shrink indoor terminations are not the correct accessories to be used in these secondary outdoor substations at this site. The discharge occurrence on these terminations at different inspections are shown in Figure 5.

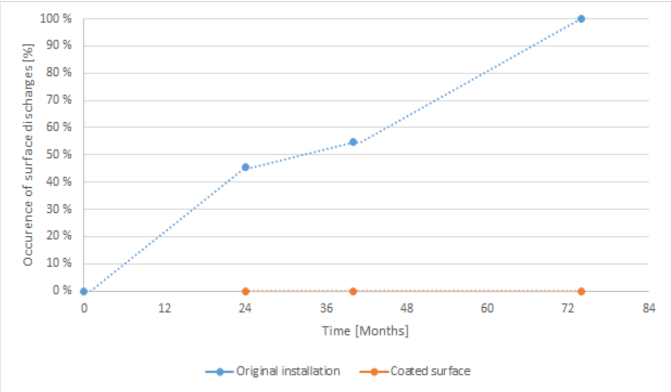

Figure 5. Occurrence of discharges versus termination age.

The improvements were done to the originally installed terminations by increasing the creeping distance and the surface hydrophobicity after 24 and 40 months from the original installation. The final inspection was done 74 months after the original installation, so the terminations with improvements were in operation for 50 and 34 months. This is a clear improvement to the performance of the originally installed terminations, especially since these improved terminations were installed in the secondary outdoor substations with the worst environmental conditions.

All improved terminations were free of surface discharge traces at the time of the final field inspection, so no performance difference could be seen between these two improvement methods during a 50 month inspection period. A longer inspection period would be needed to study the difference between these two methods further. The additional benefit which the increased creeping distance could provide in these installations is however not seen beneficial because of practical reasons. The installation of rain sheds requires that the termination is first disconnected from the busbar and the assembly work inside of cramped enclosures is still challenging. Poorly installed rain sheds could eventually result in a worse situation than before the improvement when discharges start to erode the insulation under a loose rain shed.

The application of a silicone coating on the termination surface provides a fast and convenient improvement without the need of disconnecting the terminations from the busbars. The performance improvement gained by this increased surface hydrophobicity is sufficient to guarantee a service and cleaning interval of at least five for these aged heat shrink terminations. Longer service intervals need to be verified by the distribution network operator during future inspections if they wish to extend the intervals further.

5. Conclusions

The surface discharges that can occur on medium voltage terminations are affected by the accumulation of conducting particles and moisture on the surface of the terminations. The constantly changing environmental conditions inside of unheated outdoor enclosures makes it hard to simulate real life conditions in a laboratory environment, so field inspection offer the definite solution for termination comparison. Experimental termination improvements have been studied over several years to find a working solution for improving the performance of existing heat shrink terminations that are already in operation.

Improvements were made to terminations by increasing the creeping distance with rain sheds and by increasing the surface hydrophobicity by applying a silicone coating on the termination surface. The silicone coating was used on terminations with and without rain sheds to see if this improvement alone would increase the performance of the terminations sufficiently. Based on these results it can be seen that the increased surface hydrophobicity alone improved the performance of the studied heat shrink terminations significantly. The application of the silicone coating provides a convenient improvement for aged heat shrink terminations used in secondary outdoor substations or similar unheated outdoor enclosures.

6. References

[1] K. Väkeväinen. Surface Discharge Phenomena in Medium Voltage Terminations, Aalto University, 2015.

[2] STRI. *Guide 1, 92/1: Hydrophobicity Classification Guide*. Swedish Transmission Research Institute. 1992.