THE ELIMINATION OF POLLUTION FLASHOVERS IN SUBSTATIONS

R E Macey and *W L Vosloo

Mace Electrical Technologies cc.
P O Box 739, Lonehill 2062, South Africa

*Eskom Holdings Ltd., Resources & Strategy Group
Private Bag 40175, Cleveland 2022, South Africa

SUMMARY

This paper serves to examine the experience gained over the past fourteen years with the application of silicone rubber coatings to the insulation of substation equipment located in severely contaminated areas.

In the specification of outdoor apparatus, often little attention was paid to the insulating bushings and housings and their suitability to the operating environment. Consequently, pollution flashovers cause serious disruption of supply. Insulator washing is not very effective as climatic variables make the correct timing and frequency of the wash impossible to judge. In addition, the occurrence of conductive fogs can cause the rapid breakdown of porcelains even if recently cleaned. Greasing offers better protection but the unpleasant nature of the regular replacement task, and the high labour, material and outage costs, make it unattractive. Silicone rubber coating, with its inherent hydrophobicity preventing the formation of continuous conductive layers on the insulator surfaces, has thus gained in popularity and its use is now widespread. .

An evaluation of coatings at the Koeberg natural insulator test facility and the performance of several substations operating at different voltages and subjected to various types of pollutants, before and after coating, indicates that, even when the insulators are exposed to extreme marine, industrial and agricultural contamination, flashovers can be eliminated and system security considerably improved at reasonable cost.

R E Macey   macetech@icon.co.za

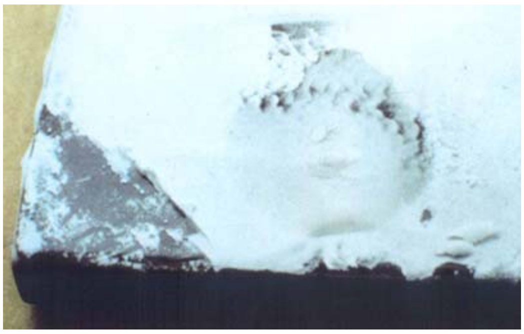
INTRODUCTION

In South Africa, the problem of the flashover of overhead line insulators in polluted environments has been largely solved by the replacement of the existing glass disc strings with appropriately dimensioned silicone rubber composite long rods. These not only provide flexibility in shed and profile design to achieve long creepage distances of high quality, but the hydrophobicity of the material prevents the formation of continuous wet conductive contaminating layers. In substations, however, with the multitude of different ceramic post, bushing and housing types present, general replacement of the insulation is not possible - yet the need for a permanent, maintenance-free solution to pollution flashover remains.

Washing of the insulators can remove the contaminants but it needs to be done frequently. The timing of the cleaning is critical and often outages are still experienced when unseasonal mists or rains occur unexpectedly. Moreover, in areas subjected to "instantaneous" pollution by conductive marine or industrial fogs, washing is totally ineffective.

The application of silicone grease, with its water-repellent properties and ability to encapsulate contaminants, can permit a longer maintenance interval than washing. The highly labour intensive and expensive task of replacing the grease on a regular basis, though, makes this by far the most costly option. Add to this the associated long outages required, possible insulator flashover or damage if the layer is not renewed in time, potential health risks and environmental disposal problems, and greasing is not at all attractive.

In view of the above, the coating of the insulators with room temperature vulcanising (rtv) silicone rubber, has rapidly gained in popularity. Owing to its hydrophobic nature, the superior performance of silicone rubber over other insulating materials in polluted environments is well proven. What makes silicone unique is the fact that, because of the migration of low molecular weight silanes that exist within the elastomer into the pollution layer, the water repellent properties are imparted to contaminants which land on the surface.



Uncoated porcelain – the pollution wets and forms a conductive layer

On a silicone surface, the pollution becomes hydrophobic

Figure 1

This hydrophobicity transfer characteristic, coupled with silicone's inherent resistance to degradation by ultra-violet radiation, ozone and most chemicals, combined with the use of specialised fillers to combat power arc and spark damage, enables the material to provide protection against pollution flashover over a period of many years.

In South Africa to date, over 125 substations, ranging in voltage from 11kVAC to 400kVAC, and up to 533kVDC, have been silicone rubber coated. The total material applied exceeds 25 000 litres. With the first coating having been undertaken in 1991, this paper reviews the performance in natural tests and in service over the past 14 years.

COATING EVALUATION

The national utility, Eskom, has undertaken comprehensive testing of coating materials at their Koeberg Insulator Pollution Testing Station (KIPTS). [1]. Situated on the west coast of the country, the various energised samples are exposed to the extreme marine conditions characteristic of the site. Physical degradation, leakage current amplitudes and flashover occurrence are closely monitored. Figure 2 shows the relative cumulative leakage current flow on three identical insulators – two of which are coated with different brands of silicone rubber and the third left uncoated. It is evident that the silicone rubber significantly improves the insulator performance and, further, that the extent of the improvement is dependent on the type of rubber used.

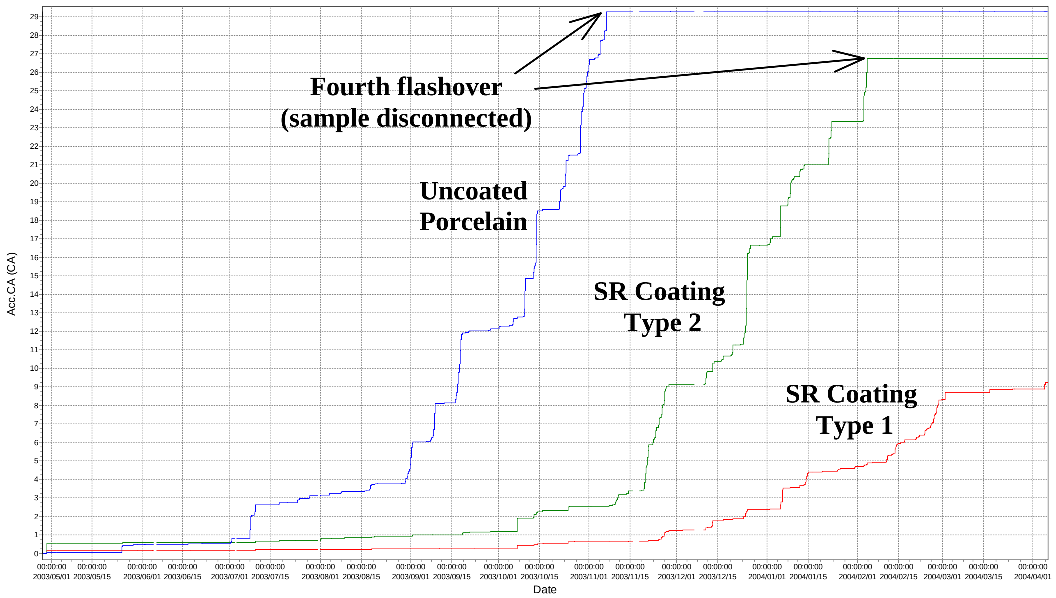


Figure 2: Accumulated coulomb ampere leakage currents measured on coated and uncoated porcelain insulators over a period of one year.

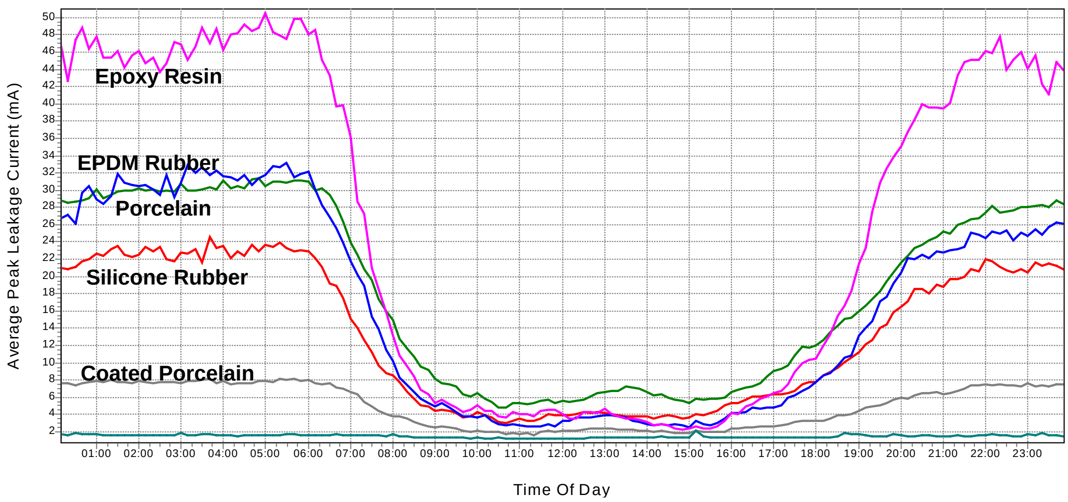


Figure 3: Average leakage current amplitudes in relation to time-of-day, measured on various insulator materials over a one year period.

R E Macey macetech@icon.co.za

The performance of a porcelain insulators coated with silicone rubber (Type 1) compared to units of identical design but of different materials, is illustrated in Figure 3.[2]. It is interesting to note that the leakage currents on the coated porcelain are significantly less than even the silicone rubber composite unit. This is possibly due to differences in the composition of the rubbers, but the ability of the ceramic substrate to dissipate the heat of surface discharges more quickly than the solid silicone may also play an important role.

COATING LIFE

The first coating was undertaken at a 132kV substation feeding a large aluminium smelter in Richards Bay – an area subjected to extreme marine, agricultural and industrial pollution. After fourteen years, no flashovers have been experienced but the coating has now lost its hydrophobicity on the sides of the insulators facing the smelter. On the units closest to the plant there is mainly only filler left. The condition of the coating is illustrated in Figure 4. The general pollutants of the area have had little adverse effect but the emissions from the smelter seem particularly aggressive. The deterioration in the coating may be due to their high fluoride content. However, considering the severity of the site and the relatively low specific creepage distances of the insulators of around 20mm/kV, the material life has well exceeded initial expectations.

Figure 4: Hydrophobicity of coating after 14 years of service

POWER STATION ENVIRONMENTS

In 1998, following several flashovers, the 132kV and 400kV yards of the coal-fired Hendrina Power Station were silicone rubber coated. At the same time, the glass disc strings of the strung busbars were replaced with new discs. The original discs had not given any problem in their 21 years of operation but were very dirty in appearance. In the spring of 1999, however, the new strings flashed over, resulting in the total shutdown of this 2000MW generation facility. This indicates that the coating prevented the flashover of the previously vulnerable post and apparatus porcelains but that the problem then manifested itself on the next weakest link - the busbar strings.

A flashover at this substation was again experienced in 2000. On investigation, it was found that a 132kV isolator (disconnector), installed 10 months previously but left un-coated, was the cause of the fault. This again demonstrated that new insulators can fail in under a year at this site. The coated porcelains have now displayed seven years of trouble-free service and show no signs of deterioration.

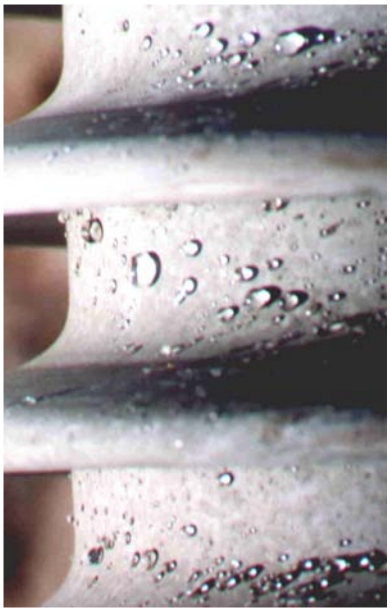


Figure 5: Surface characteristic after 4 years.

PERFORMANCE UNDER DC CONDITIONS

In 1997, the main apparatus bushings of the 533kVDC Apollo Converter Station were coated. The utility excluded the treatment of the bridge and capacitor bank support insulators as they considered these to be of adequate creepage distance. In July 2001, during the occurrence of a heavy mist, both the bridge and capacitor supports flashed over – even though they possessed considerably greater creepages than the coated bushings which did not flash or, in fact, show any signs of leakage current activity.

An inspection of the insulator surfaces in 2005 showed no significant ageing of the coating layer or any indication that degradation of the material is accelerated with the application of a DC voltage.

Figure 6: Coating condition at Apollo Converter Station after 8 years of service

PERFORMANCE WITH BULKY CONTAMINANTS

Whites North 88kV Substation in the town of Lichtenburg is located within the premises of an active cement works. As such, it is subjected to continual cement dust contamination which builds up and hardens on the surfaces of all apparatus, forming layers up to 4mm thick. Needless to say, flashover of the insulation was common.

Although concerned that the large amount of contamination present may overwhelm the beneficial properties of a silicone rubber coating in a fairly short period, it was decided to increase the specific creepage distance of the insulators to 31mm/kV by means of shed extenders followed by the application of silicone rubber coating. This was completed during the first quarter of the year 2000.

Figure 7: The cement dust laden environment of Whites North Substation

During October 2003, a transformer was replaced but the new bushings and associated surge arresters were left uncoated. In February 2004, two of the HV bushings and one of the arresters flashed over. The rest of the yard remained unaffected. The upgraded insulation had thus served for four years without problem whereas new untreated porcelains failed within four months of exposure at this site.

An examination of the coating in 2005 showed that, in spite of the thick contaminating layers, the surfaces were still hydrophobic and no peeling or deterioration of the coating was evident. The condition of the coating compared to uncoated glass disc units installed, unenergised, at the time for the purpose of pollution severity measurement is shown in Figure 8.

Figure 8: The hydrophilic dust-covered glass surface compared to the hydrophobicity of the coated ceramic.

CONCLUSIONS

Following the evaluation of silicone rubber coatings at a natural insulator testing facility and their consequent approval for use on the Eskom system, they have been applied to numerous substations in the country. Operating in a wide variety of severely contaminated environments, the ability of the coating to prevent pollution flashover has been well demonstrated.

Although a life of 5 to 7 years was initially envisaged, experience has shown that a replacement interval of over 10 years is feasible. The fitting of shed extenders prior to coating to increase the creepage distances of under-dimensioned insulators in severely contaminated areas can serve to further extend the life of the material.

Original costing studies, based on replacement intervals of 1 and 5 years for silicone greasing and rubber coating respectively, indicated that greasing was eight times the cost of coating. In a more recent exercise, the increase of the creepage distances to 25mm/kV by means of extenders and the coating of the insulators in seventeen 88kV substations which are currently greased, shows a reduction in maintenance costs over a ten year period from R13,7M to R2,2M.

The use of silicone rubber coating with, where considered necessary, shed extenders, thus represents an economical approach to eliminating the pollution flashover of substation apparatus.

R E Macey   macetech@icon.co.za

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R E Macey macetech@icon.co.za