Central Power Research Institute
Vol. 17(1)/01-06, January-June 2021
ISSN (Print) : 0973-0338
DOI : 10.33686/pwj.v17i1.167352
Power Research

Field Coating of 765kV Transformer Bushings with RTV HVIC: Planning, Implementation and Results

Neelesh Arora

Epsilon Asia Group, New Delhi – 110024, India; neelesh.arora@epsilonasia.com

Abstract

This paper discusses the selection, planning, implementation and performance of RTV Coating on 765kV OIP transformer bushings that are part of a critical transmission grid requiring near-zero downtime performance. After several instances of pollution flashovers on bushings in foggy and humid conditions, various methods of reducing such outages were considered, including the application of two kinds of RTV Coatings – the first a Gen-3 coating and thereafter a Gen-4 RTV with Quartz Silica as the primary filler. Other than RTV Coating, no maintenance methods were successful or viable whereas after the application of RTV, the number of failures had dropped considerably with only one bushing failure reported on the Gen-3 coating and zero failures on the Gen-4 coating.

Keywords: Anti-tracking Coating, Dry Film Thickness (DFT), Epsilon G4, Fillers, Hydrophobicity, PowerGrid, Quartz Filler, RTV Silicone Insulator Coating, Transformer Bushings, Transmission Grid, Wet Film Thickness (WFT), CTU, Gen-3, Gen-4, HVIC, IEEE 1523, OIP, PGCIL, UHV, 765kV

1. Introduction

PGCIL is the national utility of India with assets including 163,282 circuit kms of lines and 248 substations with a transformation capacity of 409,899 MVA at the time of this paper going into publishing. The operating voltage class of a considerable number of recently commissioned lines has been of 765kV AC and 800kV HVDC for enhanced power transmission capacity and efficiency, making each piece of equipment in the network a critical link.

Transformer Bushings are a critical component to ensure the grid reliability of the high voltage transmission system especially as the repair and replacement of the same is a difficult and logistical challenge.

Instances of external flashovers were observed on some of the 765kV bushings across the Indian electrical grid within a short period of commissioning. Upon investigation it was found that these flashovers were due to environmental or pollution impact. Washing and greasing were not deemed to be modern, viable or long-term solutions to this type of problem. After much consideration of the possible technical solutions, RTV Coatings were considered as a most techno-economically viable option to reduce – or ideally eliminate – any pollution flashovers.

Of a total of 469 bushings (which were identified as being vulnerable to external flashover), 135 were coated a Gen-3 RTV Coating supplier-contractor and 334 were coated by M/s. Epsilon using Epsilon Gen-4 (G4) RTV Coating.

RTV Coatings were selected because of their expected long life and robustness, relative ease of deployment and 'one-size fits-all' universality that allows successful use on AC and DC systems, on BPIs, Circuit Breakers, CVTs, CTs, glass or porcelain discs and of course – on bushings, of all creepage lengths.

2. Planning

Obtaining shutdowns for a 765kV line is a complex task that requires multiple permissions, planning and can only be done with the direct involvement of the owner at all times. The approval of planned as well as emergency outages in the transmission network level in real time is coordinated by SLDC/ RLDCs based on several factors. Such shutdowns were obtained by PGCIL as per dates allocated in advance.

The importance of logistics, vendor reliability and the skill of the application team to execute planned work in the stipulated shutdown period cannot be overemphasized.

The initial work was executed by an international team in India, and on an average, 1-2 765kV bushings were being coated per day of planned shutdowns. This was inadequate to meet the challenges of required reliability and therefore it was decided that work must be expedited.

Thereafter, the selection of local RTV Coating suppliers and application contractors was conducted after a thorough examination of RTV coating performance, and an audit of application and safety procedures by means of a trial application at PGCIL Jhatikara 765kV station. A team of international specialists visited India for the assessment after which M/s. Epsilon was selected.

Quality Control is a critical factor and was examined in great detail. A system for field application of bushings (a) in erected state and (b) retained in inventory as spare was devised. Bushings in erected state were relatively easier to coat as compared with spare bushings due to the weight, size and post-coating handling of the equipment.

2.1 Safety

At all times, safety during the coating process was monitored at all sites by a method put in place by the coating contractor. No deviations in method were permitted.

2.2 Coating Grade

Commercially available RTV coatings most often contain fillers like Alumina Trihydrate (ATH), Quartz, or a blend of both and all have showed very good performance in the field. Credible research has demonstrated that there is a significant correlation in terms of pollution performance of different coatings in terms of ability to suppress the onset of leakage current as per IEC 62217 in different orientated insulators. Performance depends on (a) filler type (ATH or Quartz) and (b) orientation of the equipment. Quartz-dominated/Gen-4 coatings exhibited marginally better performance than ATH- dominated coatings on vertically aligned coated insulators perpendicular to the ground (90^o) but showed significantly better performance in tension/horizontal insulators, parallel to the ground (180^o). However, in the instant case, erected bushings were to be near-perpendicular and this parameter was not a contributory factor in the selection of the RTV Coating.

A key parameter for the selection of coating was the demonstrated ability and record of the applicator to conduct such work with precision, as per a tight schedule and while maintaining high quality.

2.3 Target Thickness and Method of Measurement

Thickness of an RTV Coating is considered critical and often there is a lot of emphasis on this aspect, including in many instances, the primary criterion for acceptance of field coating work. However, there is adequate evidence from the field, empirical data and confirmation provided in IEEE 1523: 2018[7] that thickness in the range of 125µ to 700µ (dry) have been applied in the field with equal success.

2.4 Reproduced herein from IS: 11310 (that is based on IEEE 1523: 2018)

Manufacturer's recommendations vary a little, but the thickness range specified is 250 µm to 500 µm. This thickness is a practical rule of thumb guide that has been used for years in the coating industry and as such has little significance to coating of electrical insulators. The experience to date suggests that coating thickness is not a factor in either the performance or the life of the coating. Coating thickness (dry) in the range of 125 µm to 700 µm have been applied in the field with equal success. Laboratory tests indicate that when leakage current of a damaging magnitude develops on coatings, then thickness plays a role in the coating life. Thick coatings provide increased thermal resistance to heat generated by dry band arcing and as such do not allow the heat to be conducted away to the coated insulator substrate as quickly as thinner coatings. Thick coatings can result in higher hot spot temperatures during dry band arcing, thereby causing thermal degradation of the coating sooner than thinner coatings. A coating that is too thin, however, may degrade quickly due to wearing from environmental forces.

For quality control purposes, there are two non-destructive tests that can be performed on RTV coatings to verify thickness. These are as follows:

a) Wet film gauge: Wet film gauges give a reading on Wet Film Thickness (WFT) as applied. To determine the dry film thickness (DFT), subtract the percentage of solvent. For example, 0.5 mm of wet material at 70% solids would provide 0.35 mm of cured coating. Applicators typically take frequent wet film readings

b) Ultrasonic thickness gauge: Ultrasonic thickness gauges will read the thickness of cured silicone coating on porcelain surfaces. These gauges must be calibrated and checked prior to use"

Therefore, IEEE 1523 (and consequently, Indian Standard IS 11310) make no preference between thickness as measured by WFT or DFT method. [ref.: E. A Cherney]

For the purpose of this coating application on 765kV bushings, a target thickness range of 450μ ± 10% was set with several measurements per coated unit being conducted by WFT method. To obtain DFT, a simple formula is used in accordance with IEEE 1523. This is an optimum band of thickness considering that field applications are conducted in environs with no control on wind, humidity and ambient temperature.

In order to obtain true DFT measurements, a minimum of 24-hours curing period would be required which would entail additional and repeated shutdowns of which the disadvantages largely outweigh the advantages, if any at all.

WFT measurement, as a quick and practical nondestructive test with several decades of proven results was planned upon.

3. Implementation

The implementation of RTV Coating on an operation network of 765kV equipment across 40 substations required exceptional precision and logistical reliability.

A core team under the aegis of the POWERGRID Asset Management team (PGCIL/AM) was constituted for implementation and coordination of this project. A core team under Epsilon was also constituted.

Shutdowns based on criticality of stations, expected weather conditions and geography were planned and permissions from Load Dispatch Centers were sought.

It was decided that all erected bushings would be erected on priority and thereafter bushings in spare would be coated.

3.1 Coating of Erected Bushings

It was imperative that skilled application teams were mobilized the sites without delay – ideally at both ends of the 765kV intertie at the to perform the coating on phases of transformer bushings at the same time.

Coating of erected bushings required man-lift access and shutdowns as work at 765kV cannot be done online – and moreover, live line coating work can only be done using special grade solvents that are nonflammable.

Insulators were cleaned and prepared for coating based on a proprietary sequenced procedure that entailed use of special permitted solvents and water.

In some instances, shutdown permissions were not obtained during working hours in which case coating was conducted after dark. This increases challenges to

Figure 1. In-situ cleaning of the bushing.

Figure 2. Coating of the bushings.

maintain safety and quality and therefore at least 30% extra time is required to ensure no safety or quality violations.

3.2 Coating Spare Bushings

Specific procedures for coating bushings in spare were designed. It was planned that two cranes/hydras would be operating, and both the crane controllers should coordinate with each other during the operation.

Rope slings by means of shackles were fitted into the holes provided in the lifting lugs on the metal flanges. Slings of suitable mechanical strength were attached to a spreader; when in horizontal position, the spreader should be at least 60 cm above the top of the bushing.

The unpacked bushings were then coated and upon drying, repacked using special padding materials to ensure scratches would be minimized – even though such minor scratches nicks and cuts pose no performance risks to the coating.

While bushings were repacked, it was mandatory to follow procedure which required the Oil Gauge to be on the underside of the bushing during storage and handling.

Figure 3. Unpacking the bushing.

Figure 4. Bushing being coated.

Figure 5. Handling coated bushing.

4. Performance after Coating

Of the 135 coated with GEN-3 coating, one insulator flashover was reported at Bareilly substation. Upon a cursory visual assessment, the hydrophobicity of the coating may be diminished and requires rechecking to ascertain the residual life of the coating.

Of the 334 bushings coated with Epsilon brand RTV Coating no flashovers were reported and the hydrophobicity observed (albeit, from a distance) appears to be satisfactory.

Further assessment of the coating (to check for hydrophobicity) in (a) randomly selected locations and (b) areas with high pollution should be conducted once in 2 years.

Along with the cost saving on account of prevented flashovers, additional cost savings on account of reduce leakage current would be there but are not quantified or considered herein as the primary intention of the application of RTV Coating was to mitigate the risk of flashovers.

Table 1. Flash over performance after coating

Coating Type	Qty.	Flash-overs F/O	F/O %
Uncoated Bushing	469	20	**4.26%** *Over a 2-year period*
After RTV Coating (*Over a 5-year Period)*			
Coating Type			
Gen-3 RTV	135	1	0.74%
Gen-4 RTV Epsilon	334	0	0%
	469	**1/469**	**0.21%**

4.1 Assessing Hydrophobicity

Hydrophobicity is a key performance indicator of an RTV coating. A loss of hydrophobicity along a significant and substantial section of the full creepage path of a coated insulator could result in flashover, though this is extremely rare with a good RTV coating and usually only achievable in laboratory conditions.

A yard inspection for visual and audible checks after an RTV coating application would reveal a considerable reduction of audible noise which is attributable to the (a) elimination of dry band activity and (b) a reduction in corona - both phenomena being a direct consequence of the hydrophobicity of the silicone coating. Over the years, an increase in audible noise in humid conditions would be expected and could an indicator of degraded hydrophobicity, requiring a subsequent visual inspection of the coating.

Hydrophobicity can be evaluated as per IEC 62073[6]; it is imperative that the whole insulator be assessed for hydrophobicity which could considerably vary along the creepage path.

Long distance visual observation of hydrophobicity may be considered using a binocular/zoom lens, but it is usually not possible to observe all portions of an insulator. Also, as hydrophobicity along the entire creepage path needs to be assessed this method cannot be relied upon as it is highly dependent on the observer's ability to view the entire creepage path.

Audible noise in inclement weather comes about from corona from hardware and from dry band arcing. Corona noise from insulator hardware is heard as a constant "hiss" (2x power frequency) and is often suppressed by coating the hardware, but it is the first noise that is heard with age as the coating is starts to be affected by voltage stresses. Dry band arcing is distinct as a sharp cracking sound, heard below 2x of power frequency. This is a better indicator of a loss of hydrophobicity along the entire creepage path, but the technique is too dependent on the degree of natural wetting and pollutant mix which is not easy to quantify in outdoor conditions.

Figure 6. Retained hydrophobicity of Epsilon RTV.

5. Discussion

1. WFT measurements have proven to be successful for decades globally and in India as they allow for thickness errors to be rectified almost immediately and show no technical disadvantage vis-à-vis DFT coatings. Therefore, stipulating of DFT readings – especially on operational switchyard equipment that hampers project execution and requires multiple shut-downs a correct approach?
2. As global trends and data suggest that moving towards thickness in the range of 350µ to 450µ DFT is technically more suitable in terms of optimizing coating life and reducing hotspots, should utilities consider changing specifications that call for a 500µ t0 550µ DFT?
3. The number of factory-coated disc insulators in use globally is set to increase by 1,000% within 10 years with an estimated 100 million discs expected to be in service worldwide by the year 2030. This is part of a larger global trend where RTV coatings are gradually shifting from a 'Maintenance Tool' to being incorporated in the design phase itself. This helps with reduced insulator sizing, better coating quality, longer insulator life and capitalization of spends on coating. How can this technology be deployed for greater grid stability and lower Insulator TCO?

6. Conclusions

The RTV Coating brands selected and deployed were found to generally serve the needs of the owner with only one flashover on a GEN-3 coating and no flashovers reported on a Gen-4 RTV Coating; there were no required instances of insulator cleaning.

A key difference in the speed of deployment workmanship came down to logistical planning and applicator capability – factors that cannot and should not be ignored, as the material cost of RTV coating is miniscule compared to the cost of outages and wasted or sub-optimally utilized shutdowns.

With the planning of PGCIL and contractor working as per schedule, no shutdown was under- utilized and not a single pollution flashover has resulted after coating which is considered a successful project thus far.

The application of RTV Coating in a challenging logistical scenario on a pan-India basis with tight schedules was executed smoothly, without safety or quality issues and has been performing well thus far. However, the coating should continue to be observed for further learning about the role of thickness - if any, performance of different filler types and field performance.

7. References

1. Cherney EA. RTV Silicone - A high tech solution for a dirty insulator problem. IEEE Electrical Insulation Magazine. 1995; 11(6):8–14. https://doi.org/10.1109/57.475903
2. Meyer LH, Cherney EA, Jayaram SH. The role of inorganic fillers in silicone rubber for outdoor insulation-alumina tri-hydrate or quartz. IEEE Electrical Insulation Magazine. 2004; 20(4):13–21. https://doi.org/10.1109/MEI.2004.1318835
3. Ilhan S, Cherney EA. Comparative tests on RTV silicone rubber coated porcelain suspension insulator in a salt-fog chamber. IEEE Transactions on Dielectrics and Electrical Insulation. 2018; 25(3):947–53. https://doi.org/10.1109/TDEI.2018.006968
4. El-Hag AH, Jayaram S, Cherney EA. Fundamental and low frequency harmonic components of leakage current as a diagnostic tool to study aging of RTV and HTV silicone rubber in salt-fog. IEEE Transactions on Dielectrics and Electrical Insulation. 2003; 10:128–36. https://doi.org/10.1109/TDEI.2003.1176575
5. Naderian A, Cherney EA, Jayaram SH, Simon LC. Aging characteristics of RTV silicone rubber insulator coatings. IEEE Transactions on Dielectrics and Electrical Insulation. 2008; 15:444–52. https://doi.org/10.1109/TDEI.2008.4483463
6. IEC-TS-62073. Guidance on the measurement of hydrophobicity of insulator surfaces; 2016.
7. IEEE 1523:2018 Guide for the Application, Maintenance, and Evaluation of Room- Temperature Vulcanizing (RTV) silicone rubber coatings for outdoor ceramic insulators sponsored by standards committee of the IEEE Dielectrics and Electrical Insulation Society.