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Laboratory Characterization of Material Interfaces Present in HVDC Joints

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The reporters for PS2 have recognized the importance of various material interfaces on the system performance. A statement is made that “material compatibility is assured through type-testing and pre-qualification testing for a new cable system,” and yet concern is expressed over consistency of workmanship during installations, aging of joints, and the introduction of new materials. The resulting question 2.06 poses the challenge of how to better understand the material interfaces within HVDC joints in ‘real world’ conditions through laboratory studies.

A review of relevant influential factors associated with material interfaces can be found within *CIGRE TB 210 (2002) : Interfaces in Accessories of HV and EHV cables.* The factors include interfacial roughness, contact pressure, lubricant, temperature and changes in temperature, quality of the installation, electrical field distribution, and so-called “long-term performance” aspects of aging such as material relaxation and lubricant migration. Most laboratory material evaluations are of individual materials for purposes of bulk property characterizations to facilitate modeling approximations of idealized interfaces, and thus we must rely upon the full-scale evaluations to validate performance of a material system inclusive of imperfect or non-ideal interfaces.

An opportunity exists for an improved laboratory evaluation which can account for as many real-world factors as possible. While one could conceive of many different evaluation schemes, the approach taken within our laboratory is provided for illustration. Here, the bottom portion of the sample consists of a compression molded insulation with embedded semiconductive electrodes with metal foil contacts. In this example the semicon electrodes are semi-circular. Interfacial roughness of the insulation layer can be controlled through sanding or molding against a fine grit sandpaper. An upper insulating layer forms a laminate, which may optionally contain a gap-filling fluid such as a grease or lubricant between the insulating layers. The laminate structure is held under controlled interfacial pressure within a spring-loaded assembly. The structure can experience elements of aging through control of time and temperature, and can also incorporate other aspects of material relaxation through adjustments of interfacial pressure. The diagnostic measure is that of an interfacial breakdown voltage or apparent breakdown stress. Modeling can be a useful tool to complement the evaluations to provide an estimate of the field and to better understand the impact of geometric modifications, such as electrode spacing.

The benefits of such an approach include the ability to evaluate the performance of a system which includes the cable insulation, accessory insulation, semiconductive compounds, and optionally lubricants. Aspects of the quality of the interface and aspects influenced by aging can also be investigated. The downsides of the approach include a relatively involved sample preparation process, and the requirement of a sufficient number of evaluations by which to generate statistical confidence in comparative results. As our laboratory continues to generate data using the apparatus described, we have been able to statistically differentiate performance due to factors including interfacial pressure, space-filling fluids, and aging. We believe that continuation with this approach will not only provide an improved understanding of non-ideal interfaces and the impact on system performance, but it will also provide baseline and direction for development of more robust material systems. Additional investigations and complimentary approaches of others in the industry will only improve this learning and accelerate the path to progress.