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Volume effect of partial discharge inception characteristics in high temperature superconducting cable

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In recent years, high temperature superconducting (HTS) cables have been developed and tested for more compact, more efficient and more environmentally-benign electric power transmission. Although the operating voltage of the HTS cables is supposed to be as high as 66 kV, 154 kV and the higher level, electrical insulation techniques at cryogenic temperature have not yet been established. Especially, liquid nitrogen (LN_2)/polypropylene (PP) laminated paper composite insulation system is expected to be the most promising system for the cold dielectric type of HTS cables, where butt gaps between the laminated papers can be regarded as the weak points on the partial discharge (PD) leading to the insulation degradation and final breakdown. Furthermore, since the longer HTS cable has the more weak points, the size effect or the volume effect of PD inception characteristics should be taken into account for the practical insulation design of the HTS cable.

From the above background, this paper discussed the PD inception characteristics of LN_2/PP laminated paper composite insulation system and evaluated the volume effect of PD inception field strength (PDIE). Two types of model electrodes were used in this experiment; sheet model and coaxial cylindrical model. The sheet model consisted of PP laminated paper with different layers and butt gap numbers between parallel plane electrodes with different diameters. The coaxial cylindrical model was composed of 3-layer PP laminated paper with the effective length of 100 mm around a copper pipe with the diameter of 20 mm. The model electrode was immersed in LN_2 at the atmospheric pressure and exposed to ac 60 Hz high electric field stress. PD signal was detected with the sensitivity of 1 pC. PDIE was measured repeatedly and analyzed by Weibull statistics.

Experimental results revealed that PDIE decreased with increasing the butt gap number under a fixed condition of the PP laminated paper layer and the electrode size. PDIE also decreased with increasing the PP laminated paper layer and the electrode size under a fixed butt gap number. These results suggest that PDIE cannot be evaluated by only the butt gap volume with the high electric field stress. There could exist other weak points between the laminated papers associated with the surface roughness. Statistical stressed liquid volume (SSLV) was defined with consideration of the discharge probability based on the electric field distribution in each model electrode. As the result, PDIE decreased with increasing SSLV, as shown in Fig.1, for different butt gap numbers, PP laminated paper layers and electrode sizes, which shows the volume effect of PDIE. In Fig.1, we can find the PD inception probability at the interface of PP laminated layers. By the measurement of PD illumination at the interface using the transparent electrode system, we confirmed the PD generation both at the butt gap and the layer-interface. Such a general expression for the volume effect of PDIE for LN_2/PP laminated paper composite insulation system will contribute to the practical insulation design of HTS cables.

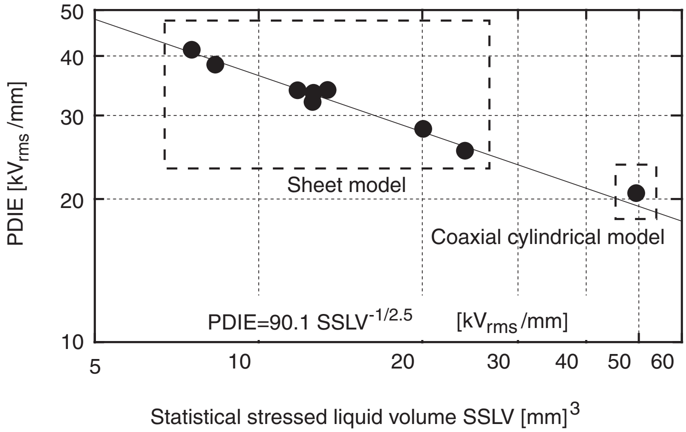

Fig.1. PDIE as a function of SSLV