§15. "*Cryodielectrics*" – Electrical Insulation of Superconducting Power Equipment Based on Partial Discharge Measurements

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1. Introduction

Superconducting power equipment such as HTS power cables and magnets are expected to have higher power density and lower losses than conventional ones. However, electrical insulation technology of the superconducting power equipment, i.e. *Cryodielectrics*, has not yet been established. Partial discharge (PD) inception characteristics and mechanisms should be understood in order to prevent the degradation of insulation performance leading to breakdown (BD).

2. Partial Discharge Measurement of HTS Power Cables

Electrical insulation of HTS power cables consists of liquid nitrogen (LN_2) / polypropylene (PP) laminated paper composite insulation system as shown in Fig. 1. We have been investigating the PD inception and BD characteristics of HTS cable models. We have already evaluated the volume effect of PD inception strength (PDIE), as shown in Fig. 2, as a function of statistical stressed liquid volume (SSLV) defined by the following equation [1, 2]:

$$SSLV = \iiint \left(\frac{E_i}{E_m} \right)^m dv$$

where E_i is the electric field strength at a volume unit i, E_m is the maximum electric field strength, and m is the Weibull shape parameter for PDIE. $(E_i/E_m)^m$ corresponds to the relative PD probability at the volume unit i.

Electrical and optical PD measurements with statistical analyses revealed that, at the lower stress levels, PD was generated not only in butt gaps but also in micro gaps between PP laminated paper layers caused by its own surface roughness. After the PD inception, PD activity could be propagated in the butt gaps at the higher stress levels, finally leading to BD. A detailed observation of the test samples decomposed after the experiments confirmed discolored PD traces on the PP laminated paper layers as well as BD traces in the butt gap area [3]. The PD traces were distributed along the whole butt gap area on the paper layers. These results suggest that PD would be originated between the PP laminated paper layers and developed in the butt gaps before BD. Figure 2 also shows the volume effect on BD strength (BDE) as a function of SSLV [3]. The difference between PDIE and BDE can be recognized as the margin from PD inception to BD.

A novel PD measurement under ac and lightning impulse voltage applications has also been carried out by electrical, optical and acoustic methods [3, 4]. Such PD inception, propagation and BD characteristics together with their physical mechanisms are crucial for the reliable, efficient and practical electrical insulation design of HTS power cables.

3. Electrical Insulation Technologies for Superconducting Power Equipment

In order to review the state-of-the-art technologies on electrical insulation of superconducting power equipment, a seminar was organized and held in NIFS on November 17, 2005. The seminar consisted of 7 lectures focusing on fusion magnets, fault current limiters and power cables, and present status and future perspectives on *Cryodielectrics* were discussed. The details of the seminar can be found at http://www.istec.or.jp/Web21/PDF/06_5/J8.pdf.

References
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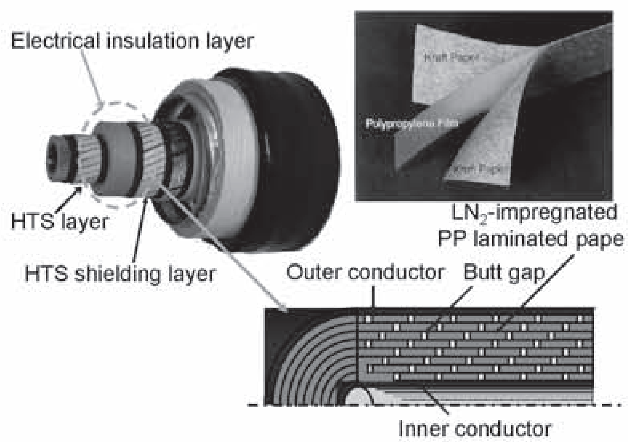

Fig.1. Electrical insulation structure of HTS power cables

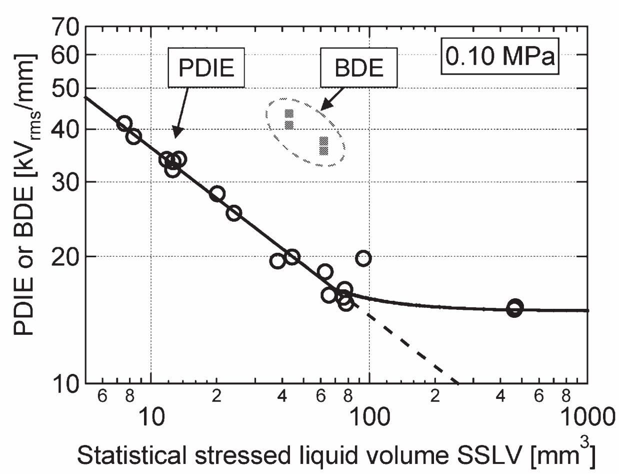

Fig.2. Volume effect on partial discharge inception strength (PDIE) and breakdown strength (BDE) as a function of SSLV for LN_2/PP laminated paper composite insulation system