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V-t characteristics at PD inception for LN<sub>2</sub> impregnated HTS cable insulation system  
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**Abstract:** In this paper, V-t characteristics at partial discharge (PD) inception were discussed for liquid nitrogen (LN<sub>2</sub>) / polypropylene (PP) laminated paper composite insulation system for high temperature superconducting (HTS) cables. Experimental results revealed that n values of V-t characteristics at PD inception were as high as 80~110. On the other hand, the lower n values of those obtained at breakdown were interpreted by the intensified PD development in thermal bubbles generated after the PD inception. Furthermore, V-t characteristics at PD inception were theoretically calculated in terms of the extended Weibull distribution with consideration of location parameter.

**Keywords:** High temperature superconducting cable, Partial discharge, V-t characteristics, Butt gap

## 1. Introduction

In the last ten years, high temperature superconducting (HTS) cables have been developed in the world from the viewpoints of compactness and environmental compatibility [1-2]. 3-phase 66 kV/1 kA HTS cable with the length of 100 m has successfully been developed by TEPCO, SEI and CRIEPI in 2002 [2]. Although the operating voltage of HTS cables is supposed to be 66kV, 154kV and the higher level, electrical insulation techniques at cryogenic temperature have not yet been established.

For the practical development of HTS cables, it is needed to establish the electrical insulation techniques in liquid nitrogen (LN<sub>2</sub>) / polypropylene (PP) laminated paper composite insulation system. Especially, V-t characteristics are quite important for the reliable insulation design and the testing for life-long operation of the HTS cables. V-t characteristics at breakdown in LN<sub>2</sub>/PP laminated paper composite insulation system have already been investigated [3-5]. However, few studies have so far focused on V-t characteristics at partial discharge (PD) inception as

**Résumé:** Dans ce papier, les caractéristiques V-t au début de décharge partielle (PD) sont étudiées pour le système isolateur composite au papier laminé d'azote liquide (LN<sub>2</sub>)/ polypropylène (PP) pour les câbles supraconducteurs à haute température (HTS). Les résultats d'expériences ont démontré que les valeurs n des caractéristiques V-t au début de décharge partielle étaient aussi élevées que 80 à 110 environ. D'autre part, les valeurs n plus basses au claquage sont interprétées par un développement plus important de PD dans les bulles thermiques produites après le début de PD. De plus, les caractéristiques V-t au début de PD sont théoriquement calculées selon la loi de Weibull en considération du paramètre de position.

**Mots clés:** Câble supraconducteur à haute température, décharge partielle, caractéristiques V-t, déjoint

the precursor of BD, which can be more crucial to understand the insulation deterioration mechanism of the HTS cables.

From the above background, we have been investigating the V-t characteristics at PD inception in LN<sub>2</sub>/PP laminated paper composite insulation system [6]. In this paper, we measured and theoretically calculated the V-t characteristics at PD inception for different electrode arrangements. We also discussed the difference in lifetime indices n of V-t characteristics between at PD inception and at breakdown, with consideration of PD inception and breakdown mechanisms.

## 2. Experimental setup

Figure 1 shows the LN<sub>2</sub>/PP laminated paper composite insulation system for the measurement of V-t characteristics. PP laminated papers with butt gaps were sandwiched between parallel plane electrodes. The butt gap was simulated as a circular shape with 5mm diameter, and the thickness of a PP laminated paper was 0.125mm. Upper and lower electrodes were made of aluminum, and the upper