Chapter 10

Polymer Insulation for Superconductive Application

ABSTRACT

With the research and development of high temperature superconducting technology, superconducting insulating materials under liquid helium and nitrogen temperature have been gradually taken seriously. Considering the unique operating environment, epoxy resin and PI face the challenge of low temperature. Electrical tree is one of the aging failure phenomena occurring in solid dielectrics. These imperfections could cause the field concentration with the application of high voltage, which results in partial discharges (PD). PD testing is an important quality check for the insulation of HTS cable. This chapter presents a study aimed at clarifying the influence of low temperature, pulse frequency and pulse duration on the electrical tree characteristics in epoxy resin, as well as PD characterization of PI film in LN2. The results show that the number of discharges and the discharge quantity in PI films increase with the increasing of the applied voltage and the defect size. The PD inception voltage decreases when the void defect diameter in PI enlarged and it is higher in LN2 than that at room temperature.

INTRODUCTION

With the research and development of high temperature superconducting technology, superconducting insulating materials under liquid helium and nitrogen temperature have been gradually taken seriously (Ivanov et al., 2017).
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2013). The international thermonuclear experimental reactor (ITER) project and High temperature superconducting (HTS) cable develop very fast. Since the device operates in the liquid He environment insulating materials in the superconducting magnet system and HTS cable endure the extremely low temperature.

Considering the no-polluting and high-energy characteristics of nuclear fusion energy, the international thermonuclear experimental reactor (ITER) project has attracted much attention in China, India, EU, USA, Japan, Russian Federation and South Korea (Hong et al., 2014). During the operation of ITER, superconducting magnet insulators take the responsibility of the insulation for the liquid helium and nitrogen channels (Boyer et al., 2014). Moreover, fusion process is driven by radio frequency (RF) and pulse power. ITER superconducting coils face the challenge of pulse voltage during superconducting coil current quench, plasma startup and disruption. Epoxy resin is used as the adhesives and electrical insulation in the superconducting magnet system because of its excellent performance in many aspects (Bittner-Rohrhofer et al., 2003). However, in the fabricated process, it is inevitable to bring some defects into the insulating materials, such as voids and impurities, which result in the uneven electrical field strength. The defect regions may cause the stress concentration and become the weak points for partial discharges (Danikas et al., 1997). Therefore, the defects have a close connection with the electrical tree initiation and breakdown process of electrical insulation systems (Li et al., 2012). From the view of reliability of ITER system, it is very important to investigate the treeing mechanism in epoxy resin under the low temperature.

Many researches have been carried out to investigate the tree growth mechanism in epoxy resin. Bahadoorsingh et al researched the relation between the harmonics and the electrical tree growth in epoxy resin. It was indicated that electrical trees in a harmonic distortion environment would reduce the lifetime of electrical insulation (Bahadoorsingh et al., 2010). Chen et al investigated the tree initiation time of pure epoxy resins and found that partial discharge processes are involved in tree initiation, especially at low electrical field strength (Chen et al., 2010). Stone et al studied the effect of pulse voltage on epoxy resin and revealed that the lifetime of epoxy resin decreased with the increase of pulse voltage, and that the insulator had a shorter lifetime with positive pulse than with negative pulse voltage (Stone, 1992). These experiments were carried out above the room temperature. Tree
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