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Design of a high temperature superconducting cable termination

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Résumé

Cet article décrit certains aspects de la conception électrique et thermique d'une extrémité pour cable monophasé, supraconductrice haute température. Cette étude fait appel a la modélisation de l'extrémité par la méthode des éléments finis avec itération thermique et électrique. L'extrémité a été modélisée à pleine charge (4kA) et à charge nulle avec les propriétés du matériau dépendant de la température.
Au cours de l'étude les effets du modèle thermique sur le champ disruptif de l'extrémité ont été considérés. Des expériences ont aussi été menées afin de déterminer la contrainte seuil d'apparition des décharges partielles, l'amplitude des décharges, et les caractéristiques de durée de vie d'un système laminé polypropylène-papier imprégné d'azote liquide; résultats qui ont été utilisés dans cette étude.

Abstract

This paper describes aspects of the electrical and thermal design of a single-phase conceptual high temperature superconducting cable termination. The work includes iterative thermal and electrical finite element modelling of the termination which was modelled at both full load (4kA) and no load operating conditions with temperature dependant material properties.
Throughout the design, the effects of the thermal design of the electric strength of the termination were considered. Experimental work was also carried out to determine the partial discharge inception stress, discharge magnitude and life characteristics of liquid nitrogen impregnated polypropylene-paper laminate (PPL), and the results used in the conceptual design.

Introduction

A high temperature superconducting (HTS) power cable transmission system where the losses due to an alternating current are significantly reduced may appear to be an attractive option. Operating at liquid nitrogen temperatures, the use of such a system would result in an increase in power transfer for a given voltage. However, there remain many technical issues to be addressed before a transmission utility would install this technology.
An important piece of equipment which is vital to the secure transmission of power from the cryogenic to ambient environment is the cable termination. Under steady state conditions, this must be capable of carrying from no load to full load current from liquid nitrogen temperatures to ambient in the presence of high voltage such that security of supply is maintained.

The work presented in this paper forms part of a project looking at several key aspects of a conceptual HTS cable termination rated at 132 kV, 4 kA. This includes aspects of the thermal design, including consideration of the current lead, and the central region of transition between the cold and warm ends of the termination, and the design of electric stress control which must operate through the entire temperature range. Finite element (FE) modelling was used extensively throughout this work, and accuracy and validity was checked with appropriate benchmark cases. To take account of variations in material properties with temperature and boundary conditions, several iterative procedures were necessary. Owing to the cylindrical geometry of the termination, the FE modelling was implemented on an axisymmetric basis.

Development of Conceptual Design

A preliminary design was based on the concept of three regions: the low temperature, transition and ambient

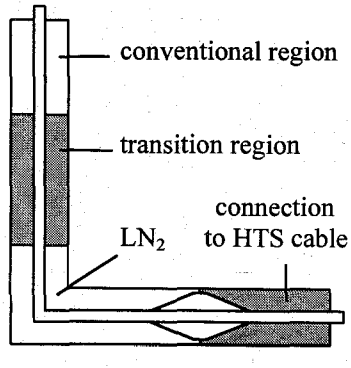

Figure 1 HTS Termination Concept

regions. Conventional terminations are normally designed to be vertical because the cable enters from below ground,