EFFECT OF PARTIAL DISCHARGES ACTIVITY BY ARTIFICIAL FAILIURE ON COMPOSITE INSULATION SYSTEMS OF MINI-CABLE-SAMPLES IN LN_2

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ABSTRACT

The objective of the study is to investigate the effect of partial discharges on the wrapped, cryogenic composite insulation of HTS cables. The investigation is used to better understand the mechanisms around the potentially damaging effect of partial discharges to the insulation capability of HTS-Cold-Dielectric-Cables made from polymeric insulation tapes. Therefore an artificial failiure is inserted to the insulation of a mini-cable sample and the development of the breakdown channel through the insulating tape layers is investigated.

KEYWORDS

HTS-Cable, Breakdown-channel development, breakdown characteristics of wrapped isolation, partial discharges

INTRODUCTION

Power transmission and distribution grids must be continuously adjusted and optimised in order to ensure a secure energy supply in face of constantly increasing demands. Especially in metropolitan areas with dense building and high population density, the energy demand and thus the stress on the power distribution grids is continuously rising. This is caused by the increasing electrification of the private and industrial sectors. The population of booming cities and their surrounding areas is growing and in the same way the demand for heating, cooling, e-Mobility and process energy rises up. Moreover the transition from energy conversion from oil, gas, and coal to electrical energy, to eliminate the emission of CO_2, which is stated in the future plans of most european countries, leads to even higher electric energy demands and necessarily higher energy transfer performances. A good example is the number of electric cars replacing conventional cars. It is predicted that the number of electrically powered cars will be more than tenfold by 2030 compared to 2020 [1]. In addition, the registration of new cars with combustion engines will be banned throughout Europe from 2035, which could accelerate the development even further [2]. The associated increase in energy demand is synonymous with higher utilisation of the transmission grids. The higher demand for transmission power requires the expansion and reinforcement of cable networks. In addition, there is general pressure to renew the existing network, as the expected lifetime of the existing energy cable may be reached in the next few years or has already been reached in many cities.

All activities to reinforce, expand and extend the electrical network in urban regions must take into account that the dense construction, the costly surface and the presence of numerous supply systems and other infrastructure require a great construction effort and are very cost-intensive. Superconducting power cables (HTS-Cables), which are characterised by high transmission capacities and low civil engineering costs, can offer an alternative here compared to conventional XLPE cable systems [3]. The Technology Readiness Levels (TRLs), which indicates the level of technological development using a scale of 1 - 9, and describes the technology status from basic research to full-scale technology readiness, rates AC HTS cables with a TRL of 7 to 8, based on demo and pilot projects carried out. The rating equates to the transition from demonstration of the technology as an integrated pilot system to the ability of integration into a commercial design [4]. The system integrability of the technology has already been proven in several projects and several years of undisturbed operation. For the use of HTS cables in the high-voltage level, the reliability and durability of the electrical insulation is of particular importance. Damage effects, e.g. due to thermal aging effects of the insulation material, are rather unlikely at temperatures around minus 190°C. But the effect of partial discharges to the insulation capability and ageing effects is not further investigated yet.

HTS cables generally consist of wound insulating tapes or foils, similar to oil-paper-cables, which are impregnated with liquid nitrogen (LN_2), which defines them as a composite insulation system [5]. Partial discharges in this system may lead to dielectric strength degradation and may ultimately introduce the breakdown of the insulation. To investigate the effect of partial discharges on insulation in high-voltage cryogenic cables, an artificial defect was injected into a coaxial cylindrical cable sample. The artificial defect enables the reproducible generation of partial discharges in the composite system. Due to the insulation mixture of LN_2 and wrapped foil or paper tapes with thicknesses of 100-150 µm each, no treeing process as in XLPE insulation is to be expected. It can be assumed that there will be an erosion process caused by surface discharge in gap areas and the LN_2-filled areas with lower permeability, which lead to insulation deterioration and breakdown by time.

METHODOLOGY

Test Setup

A cable section of a 110-kV-HTS-cable was used for the investigations. The former with the HTS tapes and the inner conductive layer has a diameter of 17.0 mm, the insulation consists of Cryoflex, a polymeric insulating film, with a insulation thickness of 9.0 mm. The nominal operating field strength (NOE) is 14.63 kV/mm according to Formula 1.

$$\hat{E}(R_1) = \frac{U \cdot \frac{1}{\sqrt{3}} \cdot \sqrt{2}}{\ln\left(\frac{R_2}{R_1}\right)} \cdot \frac{1}{R_1} \qquad [1]$$