The Effect of Short-Term Cyclic Thermal Stress on Dielectric Parameters on Low Voltage Distribution Cables with Different Structure in Smart Grid Related Environment

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ABSTRACT

The distribution grid contains different cables with different construction. However, the used insulating material is exclusively PVC in low voltage (LV) distribution cables. The degradation of the insulating material depends on many factors, such as temperature and explosion to oxygen. Moreover, having cables with various structures in the grid makes it difficult to detect ageing on the cable network. The ageing factors also rely on the cable structure. It is aimed to compare the thermal ageing behaviour of different LV distribution cables with different designs. The samples are exposed to thermal stress, and the change of dielectric parameters is investigated.

KEYWORDS

LV cables, dielectric measurement, tan δ, capacitance, thermal ageing, cyclic thermal ageing, PVC insulation, insulation degradation, condition monitoring, FDS, DRM

INTRODUCTION

Global warming remains a massive threat to the planet. The greenhouse effect is still a crucial source that feeds global warming. Therefore, the countries gathered around the 2030 Climate Target Plan that aims to reduce greenhouse gas emissions by at least 55% below the 1990 level and to become climate neutral by 2050. Fossil fuels must be given up as a primary energy source, and countries should move towards renewable sources. The energy transition is the process that aims to reduce conventional energy production and increase production through renewable sources such as solar, wind etc. The power cables are essential for the energy transition and supply system's future. Therefore, their integrity is crucial. As renewable power plants expand, electricity distribution shifts toward a decentralized model called distributed generation [1]–[5]. This power distribution model allows the network to be divided into small-scale grids, opposite to the traditional centralized grid strategy. These small grids can operate independently from the primary grid and feed the main grid if their generation is exceeded [6]. It is known that existing power distribution networks were built some decades ago, and distributed generation poses new challenges to the existing distribution infrastructure. These challenges are cyclic loads, unbalanced loads, and voltage pulses due to inverters on LV cable networks [2]. Such challenges may lead to insulation degradation and jeopardize the cable integrity. It is also called insulation ageing, which refers to the irreversible degradation of material characteristics caused by external environmental stimuli such as heat, radiation, moisture, and electric fields, resulting in chemical alterations, evaporation of plasticizer and additives, forming new molecule chains [7]–[11]. Ageing of dielectric impacts its insulation properties negatively and eventually leads to electrical breakdown [11]. Therefore, CM has become a hot topic among researchers.

The distribution network is built up from different cables with different construction. Nonetheless, the used insulating material is commonly PVC in LV distribution cables. The degradation of insulating material depends on many factors. Moreover, the different structure of cables makes it difficult to detect ageing on the cable network. Therefore, this paper aims to compare the thermal ageing behaviour of different LV distribution cables with various designs. Three different PVC-insulated LV cable specimens with different structures and cross sections were prepared and exposed to short-term cyclic thermal stress in the climate chamber at 110°C for 6 hours/round. Eighteen hours of total ageing time was reached. The dielectric parameters tan δ and capacitance were measured after each ageing round with Wayne-Kerr Impedance Analyzer in a frequency range from 20 Hz to 500 kHz. The results support that measuring tan δ and capacitance are useful condition-monitoring (CM) methods for cables with different structures and cross-sections.

The focus of this research is LV cables and their ageing phenomenon. Considering the majority of LV cables are buried underground, a non-destructive CM technique is desirable. Hence, the dielectric spectroscopy method has been chosen.

METHODOLOGY

Measuring tan δ and capacitance is commonly used in condition-monitoring studies [12]. Tan δ and capacitance of cable samples were measured after each ageing round in the frequency range 20 Hz to 500 kHz with Wayne-Kerr 6430A Impedance Analyzer. It is aimed to measure the whole frequency range of the device. The input voltage is set as 5 V_{rms}. During the measurements, the ambient temperature was set to 25±1°C.

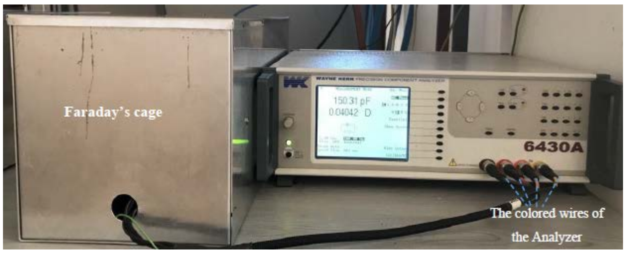

Fig. 1: Wayne-Kerr Impedance Analyzer