Influence of heat-shrink joints and terminations on Tan δ values of a medium voltage cable installation at very low frequency

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ABSTRACT

High voltage testing of cables are a control measure of the jointing process on new and serviced aged cables and its accessories. Previous publications show that the Tan δ value of a heat shrink joint and termination are not a direct function of the frequency as is the case with a single layer insulation of XLPE cables. This paper describes the simulated results when the influence of joints on the Tan δ of a cable system is determined. The simulated results are then explained based on the mechanisms involved in the stress distribution in multi-layer insulation systems such as joints.

KEYWORDS

Tan δ, Multi-layer insulation, cable accessories, permittivity, resistivity, conductivity, interfacial polarization, dielectric.

INTRODUCTION

Cross linked polyethylene (XLPE) cables have been widely used for decades. Several sections of cable are needed to create a long distance cable line and consequently the line quality strongly depends on the reliability of the cable joints. Simulation modelling of the cable joint offers an elegant way to evaluate current testing of cable joints. A joint is made by connecting the conductors of two consecutive sections of cable, stripped of insulation and joined together with a copper or aluminium ferrule. Sophisticated multilayer materials are used for electrical stress control and to insulate the ferrule and to fill in the space left by the missing dielectric. The joint is then covered with a heat shrinkable tube for protection. Different cable joints are in use but most often with capacitive/geometric, refractive or resistive control of the electric field inside the joint [1].

Medium voltage distribution cables and their accessories form a critical part of the power delivery system [2]. Due to the changes in the electrical energy market, cost optimization at utilities and industries is of great company interest. The infrastructure gets increasingly aged and therefore a change in the maintenance strategies should be observed [3]. Tan δ constitute a cable diagnostic technique that assesses the general condition of the cable system insulation [4]. Global conditioning assessment tests rely on changes occurring in certain dielectric properties of the cable insulation, such as permittivity (capacitance), conductivity and loss factor that are caused by certain dielectric phenomena associated with insulation aging and existence of defects [2]. Dielectric loss is measured by the dissipation factor (tan δ) at power frequency, at VLF or at several different frequencies [5]. When interpreting high values of tan δ measurements in cable systems, the number of accessories, their condition, and types must be considered in order to evaluate their effects on the measurement [4]. Tan δ values measured at system frequency is used as guidelines and reference values to evaluate the condition of insulation. It is therefore necessary to understand the behaviour of multi-layer insulation systems when a test is performed, on cable systems, at a frequency lower than the rated frequency in order to do a sound evaluation of the condition of the insulation [6].

CABLE ACCESSORIES

Dissipation factor testing (tan δ) also called loss angle is a diagnostic method of testing cables to determine the quality of the cable insulation. This is done to predict the remaining life expectancy and in order to prioritise cable replacement [5]. Tan δ can be applied to all cable types, however, when interpreting test results care must be taken with respect to the specific cable insulation material, installation conditions, and accessories, all of which can influence the validity of the equivalent circuit. In some topologies the cable accessories could have an effect on the measured tan δ values. However, this effect is likely to be most significant if the accessories, regardless of design, are degraded. In these cases, the accessories themselves could dominate the measurement especially at high voltages since the losses in the local accessories will be much higher that the cable insulation losses [4]. Therefore consideration should be given to the performance of the entire cable system, including joints, terminations, and associated equipment.

SIMULATION OF A CABLE SYSTEM USING QUICKFIELD™ FEA PROGRAM

For this investigation the parallel plate capacitance equivalent of a typical MV (medium voltage) cross linked polyethylene (XLPE) insulated cable as well as a typical heat shrink joint were simulated using Ouickfield ™ simulation software. The same model with the same number of nodes and the same grid size was used respectively for the single cable and multi-layer heat shrink joint simulations. The models used were drawn to scale and the dimensions used are the material thicknesses in a 95 mm^2, 11 kV cable.

The problem was defined as plane-parallel, only the top half of the cable in the length was drawn. The values for the properties of the insulation materials used for the simulation are given in Table 1.

The permittivity and conductivity of the materials were taken as being constant under all frequencies and electrical fields. The simulations were performed with an applied voltage of U_0 = 6 350 V(rms) for the single and the multi-layer dielectrics respectively.