A NEW LUMPED EQUIVALENT CIRCUIT FOR ELECTRICAL TREE IN XLPE CABLE INSULATIONS

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ABSTRACT

In this paper, a new equivalent circuit is introduced for cable insulations containing electrical tree. The proposed model is based on assuming that the treed region is as a unique cone, and then the calculation of the components of the proposed equivalent circuit will become so simple. The stochastic characteristics of PD occurring in tree channels are applied to the model, using probabilistic functions in controlling the circuit components (switches). The simulation results have shown good agreements with previously published experimental results.

KEYWORDS

Equivalent circuit; Lumped model; Electrical tree; Partial discharge; Power cables.

INTRODUCTION

Nowadays, XLPE cables are very popular because of their good thermal, electrical and mechanical characteristics. One of the major problems of these cables is electrical treeing. Generally, in studying the characteristics of any phenomenon such as electrical trees, an appropriate, flexible model with acceptable accuracy should be employed.
Three kinds of models exist for electrical trees in cable insulation: Experimental models [1], Field models [2], Circuit models. Experimental models, such as needle-plane and plane-plane, create accelerated electrical trees in samples of cable insulation, for seeking and processing its behavior under different conditions, Field models calculate the electrical field in every differential part of cable insulation including electrical tree and then analyze the criticality of the electric field at any part of the insulation and simulate electrical tree initiation, propagation and completion, and circuit models simulate the electrical tree behavior through equivalent electrical circuits including capacitors and resistors.

Whenever pattern recognition based methods are used for diagnosing the PD phenomenon and defect types, there is an essential need to have a complete knowledge about insulation behavior under a large number of conditions; such as geometric properties of the defect, physical characteristics of the enclosed gas, stochastic characteristics of discharges, age of the insulation, insulation temperature, pressure, humidity and so on. Therefore constructing a good database with acceptable number of combined conditions is needed to train pattern recognition machines for insulation diagnosis approaches. But, experiences have shown that applying the combination of all of these conditions through experimental methods is so difficult or even impossible. Then, an accurate flexible model is needed which can apply and change a large number of conditions to the insulation and defects, through available analytical relations.

This paper introduces a simple flexible circuit model for electrical trees whose components can be simply defined and calculated. A large number of combined conditions can be applied to the model based on analytical relations and available mathematical models. The validity of the proposed model is proved and the model is reliable, first, due to its bases which are fundamental theorems in physics and mathematics, and then according to the comparisons shown with qualitative features and/or trends. The validity procedure is resorted to the second reason, because of the impossibility in making associated experimental setups for different conditions.
In the rest of this paper, first, existing PD patterns of solid insulation including electrical tree is mentioned; then, previous circuit model for treed insulation is analyzed and its problems are discussed; and finally the proposed model is introduced and the evaluation of the proposed model is given.

PD PATTERN OF INSULATION INCLUDING ELECTRICAL TREE

Fig.1-(a) has illustrated typical pulse sequence diagram for an insulation containing electrical tree [4]. According to experimental reports [3]-[9], the φ-q-n pattern of an insulation including electrical tree, has a wing-like pattern, as shown in Fig.1-(b). The typical φ-n pattern of treed insulation is shown in Fig.1-(c).
As reported, some characteristics of partial discharge signals due to electrical trees are:

- The amplitude of PDs is proportional to the instantaneous value of the applied voltage. It means that the larger the instantaneous value of the applied voltage makes the amplitude of PDs larger.
- The number of PDs is proportional to the derivative of the applied voltage. It means that the larger the derivative of applied voltage makes more PDs occurrence in those phase angles.
- At any time, partial discharge just occurs in a few numbers of branches.
- Partial discharge is a stochastic phenomenon. It means that partial discharge happening extremely depends on the existence of electrons.
- Positive PDs occur when the derivative of the applied voltage is positive and negative PDs occur when it is negative.