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ORIGINAL ARTICLE

Influence of Fuzzy Parameters on the Modeling Quality of XLPE Insulation Properties under Thermal Aging

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Abstract In this work, we have used the fuzzy logic approach to predict mechanical properties (hot set test) of cross-linked polyethylene (XLPE) used as insulation in high voltage cables. The studied property presents non linear variations according to the aging time under high temperatures. So it is very difficult to find a theoretical or experimental model of the properties evolution under thermal aging. For that reason, several factors have been considered such as aging time and applied temperature. The obtained results are very encouraging and pointed out that the fuzzy logic is a powerful tool to predict the insulation proprieties. In other words, the obtained results are in good accordance with the experimental results with an acceptable error margin.

Keywords Fuzzy logic · Thermal aging · Cross-linked polyethylene · Fuzzy inference system · Prediction

1. Introduction

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Insulated underground cables are mainly used for transport and distribution of electrical energy in highly urbanized areas in the vicinity or within large cities [1]. In recent years, the cables insulated with oil impregnated paper have gradually replaced by insulation using polymers like polyethylene (PE), XLPE and polyvinyl chloride (PVC) [2]. The synthetic insulated cables, sometimes called plastic, have significant advantages both technically and economically. Among these advantages, we can cite: the easy implementation of cables, their reduced volume, their easy operation and they do not need maintenance. In addition to these qualities, they have good electrical and mechanical properties. This change in insulation technology increases the service operating conditions from 15kV/mm to 40kV/mm, and decreases the energy losses [3].

However, although the polymer insulation presents serious advantages, it remains that these materials have some disadvantages including the dielectric losses, which starts rising rapidly from a certain value of working voltage. On the other hand, the heat and the electric field can have degradation effects on the long-term behavior of the polymers insulations. In consequence, during their use, these insulators may lose some of their qualities. This phenomenon is known as the aging of the material [2]. Many factors influence the aging mechanism of solid insulating namely: the level of applied thermal stress and the time of application. The aging process of dielectric insulation is a very complicate phenomenal and a lot of research work is carried out through the world to understand different mechanisms affecting the aging process. Recent investigations aimed with the effect of thermal and electrical stresses on the endurance capability of the insulation materials [4], degradation mechanisms of insulation cable under thermal and radiation aging [5] and the effect of water tree aging on the properties of cables insulation [6]. These investigations are costly and need so much time. They need sometimes few years to get sufficient database to solve economical problems of energy and making maintenance in a simplest way. This obstacle forces researchers into finding powerful modeling methods to solve this problem. Recently, several intelligent systems have been developed, which help scientists and engineers to use in efficient way the database and get with more precision future states of the insulation system. Among these intelligent systems, artificial neural networks (ANN) and fuzzy logic (FL) present a powerful tools to predict and diagnosis high voltage insulation materials. Over the last two decades, a lot of applications of ANN in electrical engineering, especially in high voltage field, can be found [7-10]. In recent studies, a novel extension neural network algorithm was used in recognition of partial discharge pattern in high voltage power apparatus [11]. Other application aimed with use of the radial basis function Gaussian (RBFG) neural network to predict properties of cables insulation [12-14]. However, a small amount of papers aimed with applying of FL in high voltage field can be found [15]. The extensive application of ANNs highlights the existence of several problems in their implementation. The most problem resulting from the application of gradient descendant method (the frequently used method in the training of the network) is the requirement of the choice of learning rate for adjustment of many parameters (adjustment of weights, Gaussian centers and variances for example). These adjustments are the most causes of local minima because of their dependence on the error gradient. Added to this problem,