VLF TAN-DELTA CRITERIA FOR XLPE INSULATED POWER CABLES IN KEPCO

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ABSTRACT

VLF tan δ diagnosis was established in 2001 as the IEEE Std 400 and proposed as evaluation criterion in an effective way of detecting water tree which mainly causes the failure of XLPE insulated cables. In order to inspect the accuracy of the VLF tan δ diagnosis for XLPE insulated power cables in Korean distribution system, 41 cable samples were diagnosed. Regarding the 41 cables, it was hard to reveal any relation between the VLF tan δ values and AC breakdown voltages, and also water tree in the insulation was not detected. However, the other diagnosis with additional cables explicitly exhibited failures after several days of testing. For these additional cables, water trees were found and their VLF tan δ values were also much higher than the criteria of IEEE standard. In this report, it has been ascertained that we need to change the IEEE criteria in order to improve the accuracy of detecting water trees by analyzation of additional field examples of failure and case studies from overseas countries. Finally, the amended VLF tan δ test voltage and evaluation criteria have been proposed.

KEYWORDS

VLF tan δ; XLPE insulated; diagnosis; breakdown voltage

INTRODUCTION

WATER-TREE DEGRADATION BY MOISTURE PENETRATION

In KEPCO underground cable system, CNCVs(Concentric neutral type cross linked polyethylene insulated vinyl sheathed power cables) has been used from middle of 1980s. Nowadays, the breakdown ratio is increasing significantly because those CNCVs are approaching the end of life. Even though more than 30 years life cycle is designed for practical operation in power utility, the operating conditions such as water logging, being exposed excessive current by short circuit and sharp skirt of load variation considerably affects to shorten the life of cable. In our URD system, the breakdown caused by water treeing is occasional in 13years or older cables.

The XLPE cables operated in frequently water logged conditions could exhibit lots of white dots in their insulation layer (Fig. 1). As shown in the cross section picture of Fig. 1, so-called "water tree", the micro voids shape like tree branch or chestnut bur and water is filled in. The moisture from surrounding the surface of XLPE is forced to penetrate by electric field and propagate into the XLPE while making micro void paths filled with water. This phenomenon continues and the water trees grow through the thickness of insulating layer. In conclusion, conductible path is formed from the concentric layer to the core or in the reverse way and cable breakdown occur as a result of flowing conductive current through the path. Fig. 2 shows that the more water tree is growing, the less dielectric strength is. This consequence takes time about more than 10 years.

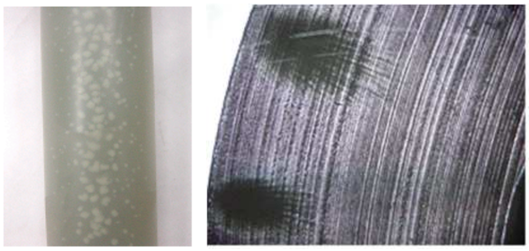

Fig. 1: Water Tree in XLPE Insulated Cables

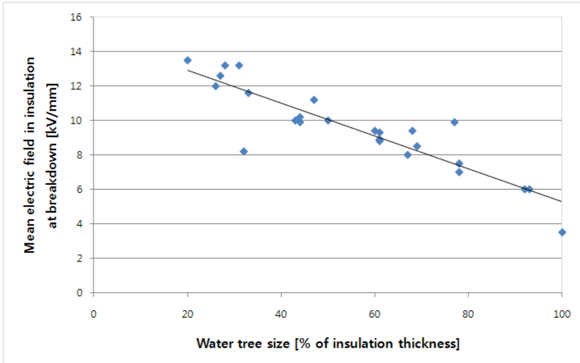

Fig. 2: Water Tree Size and Breakdown Voltage

VLF TAN-DELTA STANDARD OF JUDGMENT FOR XLPE INSULATED CABLE

The principle of VLF tan δ(Very Low Frequency tan-delta) diagnosis for water treeing cable could be explained like Fig. 3 as shown below. The XLPE insulating layer which contains water tree tends to have less insulation resistance as the density of water tree increases and it increases loss current expressed as loss factor "tan δ". By measuring the magnitude of tan δ, it is possible to judge the degradation of the cable.

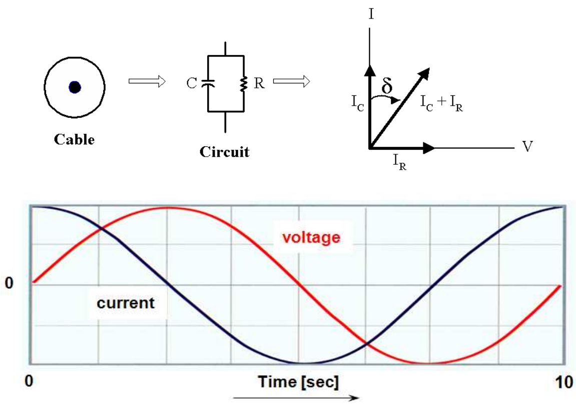

Fig. 3: Definition of tanδ and Voltage vs. Current in Cable

Tan δ, usually called tan delta, is defined as a ratio of resistive loss current to capacitive current and the equation is followed below;