A Numeric Estimation of the Aging Processing of Polymeric MV Cables Applying Three Dimensional Assessment of VLF tan δ

Sung-min Kim, Seong-Geun Kim, Nam-ki Cho, Il-rae Roh, KEPCO, Korea, 03100481@kepco.co.kr, sg7905@kepco.co.kr, nkcho@kepco.co.kr, noill@kepco.co.kr

Jangseob Lim, Division of Marine Mechatronics, Mokpo National Maritime University, KOREA, janylim@mmu.ac.kr

ABSTRACT

Recently, diagnostic on Medium Voltage(MV) underground cables using tan δ measurement that measures dissipation factor with 0.1Hz VLF (Very Low Frequency) high voltage source has emerged as an efficient way to assess water tree aging of MV cables. This study has verified the validity diagnostic evaluation criteria defined by IEEE400.2-2013 and it's pervious drafts of DTD (Delta tan δ) and STDEV (Standard Deviation) - indicating voltage-stability and time-stability of tan δ respectively - by applying VLF tan δ measurement to KEPCO (Korea Electric Power Corporation)'s power distribution system and suggested a new assessment factor being defined as the normalized Skirt, and its new formula in order to identify the precursor of insulation breakdown with complex patterns of tan δ. By 3-dimensional visualizing matrix correlations between various assessment factors and proposing a 2 or 3-dimensional assessment standard that can normalize the deterioration processing of a cable into a uniform value, this study has established a foundation to calculate the remaining life time of a cable through VLF tan δ diagnostic.

KEYWORDS

VLF, tan δ, TD, DTD, STDEV, Skirt, 3-dimentional matrix

1. INTRODUCTION

Starting from 1978, KEPCO (Korea Electric Power Corporation) launched underground cable power distribution system projects and today underground cable systems account for more than 15% of the distribution power grid. One of the main dilemmas of our today's power utility is how to prevent abruptly power interruptions due to underground cable failures and to reasonably estimate the time of repair so that the statistical diagnosis of insulation aging step is crucial decision for economical maintenance. Since 2010, KEPCO has carried out 0.1Hz VLF (Very Low Frequency) tan δ measurement to diagnose MV (Medium Voltage) underground cables and established the database with more than 20,000 practical field test results with commercial VLF tan δ equipments, PHG 80. With the application of the evaluation criteria according to IEEE Std. 400.2-2001[1], the first year of adopting the methodology of tan δ measurement, surprisingly about 34% of the diagnosed cables were categorized as "highly degraded". After analyzing the practical results by means of the Weibull distribution [2], KEPCO found the empirical fact that the criteria need to be adjusted according to the cable specification and its operating conditions[3-4].

This study was intended MV level underground cable system that is operated at a nominal voltage of 22.9 kV_{p-p} ($V_{phase-phase}$) and investigated operation conditions of cables based on 0.1 Hz VLF tan δ measurements. The purpose of the study is to evaluate the validity of the present assessment standard applied by KEPCO in order to suggest a modified formula which is capable of describing the condition of cables more precisely and to verify the validity of it on the basis of measured VLF tan δ value of approximately 20,000 D/L of cables. By presenting a 3-dimensional matrix model that combined the above mentioned factors this study intends to propose a new method to interpret the deterioration condition of water tree of cables based on comprehensive analysis of tan δ diagnostic results.

2. VLF TAN-DELTA CRITERIA

According to the IEEE Std. 400.2-2001 criteria, TD (tan δ) and DTD (Delta tan δ) were introduced as factors used for the evaluation criteria [1]. TD refers to the arithmetic mean of 6-8 measuring points of tan δ at different voltage levels. DTD (Delta tan δ), is defined as the difference of the TD value of measurements at high test voltage and at low test voltage and indicates the stability of dissipation factor in respect to the applied test voltage. According to IEEE Std. 400.2-2001, the condition of a cable has three levels, "Good", "Aged" and "Highly Degraded", and the ranges of TD and DTD are specified respectively. In addition, IEEE Std. 400.2-2013 has presented the variable of STDEV (Standard deviation)[5]. The STDEV represents the time stability of dissipation factor with respect to a set of tests performed 6–8 times at the same voltage.

IEEE std. 400.2's field data analysis confirmed the validity of STDEV, TD and DTD, and verified that the linearly increasing or decreasing patterns of tan δ at one individual voltage level is the precursor of insulation breakdown. This analyzing method that allows measuring this tan δ characteristics has been named "the Skirt" by KEPCO and it is being used as KEPCO's own assessment standard [6-7].

3. VLF TAN-DELTA CRITERIA OF KEPCO

In 2012, KEPCO established an assessment standard shown in table 1 by combining the factors of TD, DTD and