The Validity of the Determination Factor of VLF tanδ for Water Treeing Diagnosis

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ABSTRACT

Korea Electric Power Corporation (KEPCO) maintains and manages underground power cables using VLF tanδ to diagnose deterioration. A determination factor is calculated to classify the degradation grade and establish a replacement criteria based on acquired data. However, uncertainty diagnosis data or differences in test voltages can make it impossible to calculate determination factors. This paper evaluates the effectiveness of determination factor combinations in terms of linearity, variability, and reproducibility to establish priority and ensure scalability of the replacement criteria. Second-best determination factor combinations can be selected to address these issues.

KEYWORDS

Aging Diagnosis, Water treeing, VLF tanδ, Determination factors, Validity evaluation

INTRODUCTION

With the economic growth resulting from industrialization, the amount of cable installation has rapidly increased in Korea since the 1980s. As a result, the need for maintenance and management of previously installed cables has emerged. The major deterioration of underground power transmission cables is water tree, which is caused by the permeate of moisture and foreign substances. According to research, water tree occurs after 13 years of operation [1].

Very low frequency tanδ (VLF TD) is known as one of the methods for measuring water tree occurrence and progression. It is a method of measuring the fine phase difference between voltage and current by applying a 0.1Hz sinusoidal AC power to the off-line state of the power cable. If abnormal signs such as water tree or voids exist in the cable, a slight dielectric loss occurs, causing a phase difference. This method is superior to other condition assessment methods for degradation diagnosis due to its reproducibility during remeasurement. It is also resistant to external noise. Figure 1 shows the measurement principle of VLF TD.

VLF TANδ

The VLF TD research in Korea began in 2009 to diagnose the degradation of distribution power cables. In the early stages, the IEEE standard was applied, but it had limitations such as excessive maintenance actions and voltage mismatch for the Korean condition [2].

To improve this, the VLF TD diagnostic technique was proposed and registered as an international patent for application to Korean power cable installation history in 2012 [3].

KEPCO classified the change in VLF TD with respect to number of measurements into four patterns by deriving various factors using VLF TD diagnostic data [3]. The condition based on VLF TD measurement values was divided into six degradation grades, enabling measures to be taken for each grade. In 2019, factors DTD(differential tanδ)2 and DTD3 were added to consider the possibility of failures during diagnosis, and diagnostic criteria were proposed. Table 1 shows the diagnostic criteria proposed in 2019.

KEPCO suggested a way to quantitatively represent the condition of power cables for replacement or repair decisions after classifying them into six grades from A to F using several determination factors. Another way is to use index. The index that quantitatively represents the condition uses 3 determination factors, 1.5 U_0 TD, DTD, and Skirt 1.5 U_0. The selection criteria for factors were based on visual and experiential methods [4].

With this index, the increase rate of the index can be calculated when diagnostic data is accumulated twice or more for the same power cable. If the increase rate and the threshold of the index are determined, a method to estimate the lifetime of the power cable can be established. KEPCO reduced the failure rate from 3.37 to 0.29 [fault/1,000km/yr] using index-based replacement decisions from 2015 to 2019 [5].

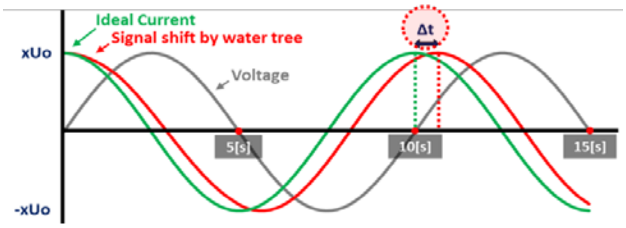

Fig. 1 Measurement Principles of VLF tanδ

Table. 1 VLF tanδ Criteria table in 2019.

[Unit: 10^{-3}]

Grade	Voltage Stability (VS)					Time Stability (TS)						Down Grade
	1.0 U_0	1.5 U_0	DTD	DTD2	DTD3	STD 1.5 U_0	Skirt 1.5 U_0	DEV 1.5 U_0	STD 1.0 U_0	Skirt 1.0 U_0	DEV 1.0 U_0	
A	⩽1.0	⩽1.4	⩽0.6	⩽0.3	⩽0.2							
B	⩽2.0	⩽2.8	⩽1.2	⩽0.6	⩽0.4							
C	⩽5.5	⩽8.8	⩽5.5	⩽3.0	⩽2.2	⩾0.3	⩾0.1	⩾0.5	⩾0.2	⩾0.06	⩾0.4	D
D	⩽9.0	⩽15.0	⩽12.0	⩽6.0	⩽4.5	⩾0.4	⩾0.45	⩾1.2	⩾0.3	⩾0.20	⩾0.8	E
E	⩽25.0	⩽50.0	⩽45.0	⩽25.0	⩽20.0	⩾1.0	⩾4.5	⩾3.0	⩾0.8	⩾1.40	⩾2.5	F
F	>25.0	>50.0	>45.0	>25.0	>20.0							
1st condition	OR					Action			No Action			2nd condition
	AND											

However, in cases where there are missing values or