

## VLF TAN-DELTA MEASUREMENT ON SUBMARINE CABLES IN KEPCO

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### ABSTRACT

Since 2007, KEPCO has taken the VLF (Very Low Frequency)  $\tan\delta$  measurement to detect the aged submarine cables. Our field experience shows that the values of VLF  $\tan\delta$  are influenced by the leaking current on terminations of submarine cables. By replacing terminations of submarine cables assessed as degraded, the result of re-diagnosis is turned to "Good" from "Seriously aged". External factors such as terminations need to be considered on the VLF  $\tan\delta$  measurement; the trend or historic analysis of VLF  $\tan\delta$  measurement is also recommended to assess degradation of submarine cables because the cost of construction of submarine cables can be considerably reduced.

### KEYWORDS

VLF  $\tan\delta$ , Submarine cable, Diagnostic, Termination

### INTRODUCTION

The submarine cables of medium voltage have been installed to supply electricity to islands since 1979. The voltage rating of submarine cables is the same as in the common distribution system in Korea: 22.9 kV in phase-to-phase voltage and 13.2 kV in phase-to-ground. The insulation is XLPE. The submarine cables have had 4 failures. However, no diagnostic system and equipment for measuring degradation of submarine cables has been used. Since 2007, KEPCO has done the research on the VLF  $\tan\delta$  measurement to detect the aged submarine cables. In this paper, we present the results from diagnostic experiences in the field and instructions when VLF  $\tan\delta$  measurement is carried out.

### INSTALLATION OF SUBMARINE CABLE

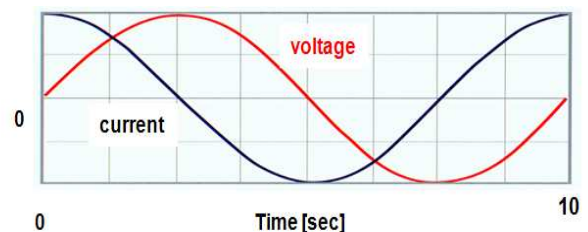
The installations of the medium voltage submarine cables have been increasing to supply electricity to islands as shown in Table 1. There have been 4 failures on submarine cables, in which 3 of them were failures from external damage and the other was from insulation breakdown. It occasioned huge expenses for the restoration work and temporary power supplies. There were 10 sites that have been used more than 30 years. For the reason, there is a strong possibility of degradation failure. Therefore, we need to assess the aging condition of the submarine cables exactly to plan to new construction or replacement of them. Accordingly, we began to diagnose it using VLF  $\tan\delta$  system from 2008.

**Table 1: Installation of submarine cables by year**

Year	~'80	~'90	~'00	~'05	'05~	Total
Number of sites	10	5	2	4	7	28
Length[km]	25.3	33.2	7.8	26.3	24.9	1175

### VLF TAN-DELTA MEASUREMENT

VLF  $\tan\delta$  measurement is a method that measure voltage and current at cables by utilizing AC signals in 0.1 Hz and then calculates the dissipation factor ( $\tan\delta$ ). As voltage increases, magnitude and rate of  $\tan\delta$  can change.  $\tan\delta$  is the most important factor to assess the ageing condition of cable insulation. (Fig. 1)



$$\text{Dissipation Factor} = \tan\delta = \frac{\text{true power}}{\text{reactive power}} = \frac{U^2/R}{U^2\omega C} = \frac{1}{\omega CR}$$

**Fig. 1: Principle of VLF  $\tan\delta$  measurement**

The IEEE Std. 400 had been used as a degradation assessment criterion until 2009 in KEPCO. However, we found that IEEE criterion was not suitable for the distribution system in Korea and suggested the new degradation assessment criterion through study and experiences in the field. The new criterion has applied in underground distribution cables and submarine cables since 2010.

### Criterion of IEEE

The degradation assessment criterion of IEEE Std. 400 established in 2001 is as shown in Table 2. In this Criterion, degradation is decided by  $\tan\delta$  measurement while testing voltage is raised up to 2 times of  $U_0$ . The criterion will be revised in several years.

**Table 2: Criterion of IEEE 400-2004**

$\tan\delta$ at $2U_0^*$	Differential of $\tan\delta$ $\tan\delta_{2U_0} - \tan\delta_{U_0}$	Assessment
Less than $1.2 \times 10^{-3}$	Less than $0.6 \times 10^{-3}$	Good
Greater than or = $1.2 \times 10^{-3}$	Greater than or = $0.6 \times 10^{-3}$	Aged
Greater than or = $2.2 \times 10^{-3}$	Greater than or = $1.0 \times 10^{-3}$	Highly degraded

\*  $U_0$  : phase-to-ground

※NOTE: It has been found that copolymer dielectric materials such as TR-XLPE or silicon fluid treated insulations exhibit different  $\tan\delta$  characteristics; therefore, other criteria are valid.