Water tree Degradation on Long Term Operated 60 kV Class XLPE Cables Decommissioned from Actual Power Grid

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ABSTRACT

Many of 60 kV class underground XLPE cables are laid into underground ducts, where some of them are exposed to the risk of water tree degradation. Therefore, the pre-breakdown discharge detection testing has been applied for the decommissioned XLPE cable body with 40-year operation at most without water barrier layer, to understand both their electrical insulation capability and the cause of the degradation. As a result, it is revealed that some of cable specimen has relatively low electrical insulation capability caused by a water tree, and some of rest has almost same insulation capability as that in initial stage of commissioning, even after more than 30-year operation.

KEYWORDS

Highly aged XLPE cable, Pre-breakdown discharge detection test, Water tree, Deterioration, Electrical insulation capability

INTRODUCTION

60 kV class XLPE cable system has been introduced into power transmission line since middle 1960's, and their installed amount was rapidly increased in 1980's and 1990's, in Japan [1]. Some of them has been already replaced due to increase of transmission capacity, re-route, aging, etc. However, the rest cables have been still under operation, and their age increases year by year. Therefore, the electrical insulation capability of such highly aged 60 kV class XLPE cable is taken a considerable interest by utility companies in Japan, from viewpoints of keeping high reliability of power supply, deciding more appropriate replacement and on the other hand conducting as long operation as possible.

The electrical insulation capability of XLPE cable is often investigated by a breakdown test with ac high voltage [2]. However, not enough investigation has been carried out up to now, especially for the aged ones [3], not for the new ones. Additionally, breakdown test wreaks the irreversible damage to the cable, cannot find out any cause of breakdown. Breakdown usually accompanies a partial discharge (PD) right before, thus breakdown would not wreak and the cause of degradation of electrical insulation capability would be kept as it would be, if the applied voltage shut down immediately after the PD detection [4, 5]. The pre-breakdown discharge detection test can realize it, i.e., both keeping the cause of degradation and acquiring the electrical insulating capability.

In this paper, the pre-breakdown discharge detection test is applied to the 60 kV class XLPE cable decommissioned from actual power grid to understand the their electrical insulation performance, to find out the cause of their degradation, as well as their deterioration characteristics. The number of the cable specimen is 99, all of which were sampled from the aged and decommissioned XLPE cable laid in underground cable duct. Finally, the obtained data will be evaluated in terms of the relationship between their electrical insulating capability and corresponding operating duration, to clarify the degradation characteristics of XLPE cable laid in underground cable duct operated in actual power grid.

METHODOLOGY AND TEST SETUP

Figures 1 (a) and (b) show the schematic illustration and outer view of the experimental setup, the pre-breakdown discharge detection testing system, respectively. The system mainly consists of two parts, an ac high voltage source with a high-speed breaker and a PD detection and measurement system. The high voltage source can apply ac high voltage to the cable specimen up to 500 kV, which is 11 and 13 times higher than the phase-to-ground voltage of 66 and 77 kV XLPE cable, respectively. The ac high voltage source has its rated current of 2 A, which enables to apply ac approximately 200 kV to the 60 kV class XLPE cable of around 200 m in its length, corresponding to the typical underground cable length between two consecutive joints, although the test length depends on the cable capacitance. The ac high voltage source is equipped with a high-speed breaker in its primary winding. A shutdown signal which is sent to the high-speed breaker from the PD measuring system, activate the semiconductor switch to short the primary winding of the ac high voltage source. At the same moment, the energy accumulated on the cable specimen is consumed by the resistance connected serially to the semiconductor switch. The occurrence of PD would raise breakdown in a while, unless the applied ac voltage was shut down immediately after the PD occurrence. In this paper, the applied voltage was increased step by step which was such as 5 kV / 5 min or 5 kV / 1 min, until detection of PD signal. Thus, the applied voltage value at which the PD firstly occurs in the cable specimen can be considered as the electrical insulation strength, namely breakdown voltage.

In the test, the other important issue is measurement of PD occurred in the cable specimen. As mentioned before, the PD measurement and generation of the trigger signal to shut down the high voltage application is quite important in order to avoid the breakdown. The authors had developed PD measuring technique specified to the pre-breakdown discharge detection test, as shown in Fig. 2 [6]. In order to conduct the reliable and precise PD measurement, a PD measuring circuit had been developed with a high frequency differential amplifier and inverting amplifiers. The application of developed circuit to plural measuring points with its time resolution of sub-nano second order and their simultaneous measurement enable us to estimate the position of PD source by time difference of arrival method.