Strategy of partial discharge measurement for electrical insulation diagnosis of XLPE power cable system

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ABSTRACT

The insulation diagnosis by partial discharge (PD) measurement can be effective for terminations and joints where PD can sustain for the long term. Then, some attempts to improve the accuracy of PD measurement at accessories are presented. Among them is the importance of simultaneous three-phase measurement or measurement at plural locations to identify the termination or joint where PD is occurring and the estimation method, i.e., localization of the PD source by measuring PD signal propagation characteristics using the high frequency current transformer and the high-frequency foil electrode method.

KEYWORDS

Partial discharge (PD); Insulation diagnosis; XLPE cable system, Localization; High frequency current transformer (HFCT); High-frequency foil electrode method

INTRODUCTION

Partial discharge (PD) is widely considered to be a precursor phenomenon of an electrical breakdown thus its measurement is considered to be one of major measure for electrical insulation diagnosis [1]. PD measurement is widely adopted for XLPE power cable systems at its new condition, such as type, prequalification, routine and commissioning tests, as well as at its aged condition for the electrical insulation diagnostic measure [2, 3].

In recent years, there has been a growing trend to perform insulation diagnosis by PD measurement on aged XLPE cable systems [3, 4], where PD does not always occur continuously in all cases, but rather often occurs intermittently or temporarily. On the other hand, continuous PD measurement is not always possible in many cases due to the conditions of the facility to be measured. Therefore, it is important to develop effective insulation diagnosis methods that include the localization of the PD source by temporal PD measurements.

This paper firstly discusses the applicable occasion of PD measurement, including the effectiveness of PD measurements on the cable itself and on the accessories. Then, some attempts to improve the localization accuracy of PD source are presented. Among them is the importance of simultaneous three-phase measurement and simultaneous measurement at plural locations to identify the termination where PD is occurring and the estimation method of PD source by measuring PD signal propagation characteristics using the high-frequency foil electrode method.

EFFECTIVENESS OF PD MEASUREMENT

PD is generally considered to be a precursor phenomenon of a sign of deterioration in electrical insulation. Indeed, the occurrence of PD is usually confirmed for a breakdown under the inhomogeneous electric field in solid dielectrics. However, the following phenomenological conditions must be considered to perform insulation diagnosis by PD measurement; one is time margin between the start of PD and the breakdown of insulation. The insulation diagnosis by PD measurement is practically impossible if there is less time margin between the start of PD and the breakdown of insulation. This is because the breakdown would occur during or before PD measurement and its analyses. Another one is frequency of PD occurrence. The following two issues need to be considered in this regard; one is transition of PD frequency before breakdown. If PD frequency is not so high in the process from the start of PD to the breakdown, the breakdown may occur without allowable sufficient PD measurements nor capturing enough number of PD for diagnosis. Another important consideration is the easiness of PD measurement. This issue influences on measuring technique and discussed later.

In consideration of XLPE cable system, the parts to be diagnosed can be roughly divided into two categories in terms of insulation structure: one is the cable, and the other one is the accessory.

The insulation degradation aspects of XLPE cable under stable operation include degradation represented by water treeing and external damage caused by third-party construction. Regarding the first case that is insulation degradation with age, insulation diagnosis by PD measurement is unlikely because stable PD is not expected to occur prior to breakdown. The author's group is conducting a pre-breakdown discharge detection test in order to elucidate the degradation aspect of the insulation performance of aged XLPE cables [5, 6]. In the test, AC high voltage is applied to the XLPE cable specimen in a stepwise manner. At this time, PD is continuously measured, and when PD ignition is confirmed, the high voltage application is immediately stopped. This process is repeated to locate the PD source, and then the insulation layer at that point is sliced and observed to determine the cause of insulation degradation. In the author's experience, it is understood that if the high voltage application is not stopped immediately after the detection of PD, breakdown occurs within a few seconds. In some cases, it could be confirmed that the breakdown occurred within a few μs after the start of PD. This characteristic is not so dependent on the voltage at which PD occurs, i.e., the insulation performance of the XLPE cable specimen. Therefore, when PD occurs in the insulation of the XLPE cable, there is no time margin before breakdown occurs, and therefore, insulation diagnosis by PD measurement is considered unsuitable.

On the other hand, the external damage caused by the third-party, such as a damage on the metallic screen and the outer semiconducting layer, can be a cause of PD with relatively stable occurrence without immediate breakdown,