Measurement of Trapped Charge Density and Trap Depth in XLPE Based on Polarization and Depolarization Current Method

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ABSTRACT

Accumulation of space charge in XLPE is related to aging. To characterize accumulation of trapped charge in XLPE, a trapped charge measuring method based on Polarization and Depolarization Current (PDC) test is presented. First, by subtracting the depolarization current and the stable value of conduction current from the polarization current, the de-trapping current of trapped charge is extracted. Then, parameters τ_n *and* $A_n \cdot \tau_n$ *are calculated and* $i_{de\text{-}trap} \cdot t \sim \ln t$ *curve is obtained, which characterize trapped charge density and trap depth. Finally, to verify the proposed method, trapped charge measurement was conducted under different conditions.*

KEYWORDS

polarization and depolarization; space charge; de-trapping current; XLPE; trapped charge density; trap depth

INTRODUCTION

After a High Voltage Direct Current (HVDC) cable is put into operation, its insulation will gradually age under the influence of electric field, mechanical stress, temperature, and moisture. During the aging process, cross-linked polyethylene (XLPE) molecular chain breaks and the microscopic defects are expanded. Under DC electric field, space charge is easy to accumulate in microscopic defects, causing local electric field enhancement. It will further accelerate XLPE aging and even cause breakdown. Therefore, it is important to measure the accumulation of space charge in XLPE.

Methods for measuring space charge distribution in insulation mainly includes Pulse Electro-Acoustic Method (PEA) [1-2] and Pressure Wave Propagation Method (PWP) [3-4]. The development of those methods is relatively mature. But testing and signal processing progress of those methods are complicated. The geometry of test objects is limited. Besides, test results of those methods cannot characterize depth of traps in dielectric. From the de-trapping current of trapped charge, trap depth and trapped charge density can be reflected. Methods for measuring de-trapping current mainly include Thermally Stimulated Depolarization Current Method (TSDC) [5-6] and Isothermal Relaxation Current Method (IRC) [7-8]. Because TSDC requires adjusting temperature in a wide range, its test system is complicated. So, TSDC is difficult to be applied to practical size cables. IRC method measures depolarization currents after dielectric is polarized. However, a depolarization current contains dipole relaxation component and trapped charge de-trapping component, which is not distinguished in IRC method. Therefore, it is worthwhile to investigate a convenient method for analysing trap depth and trapped charge accumulation in dielectric.

Because Polarization and Depolarization Current (PDC) method is a non-destructive method and can reflect lot of aging information, it is gradually applied in XLPE cable insulation assessment. According to Poole-Frenkel effect, in an electric field, trapped charge needs less energy to escape. So, during the dielectric polarizing progress in PDC measurement, trapped charge is easy to get into conduction band. Polarization currents are supposed to contain de-trapping currents component. Therefore, it is possible to separate the de-trapping currents from polarization currents and calculate trapped charge density and trap depth in dielectric.

In this paper, a method for estimating trapped charges in XLPE is proposed. De-trapping currents are separated from polarization currents through the proposed method. Then, through extracting parameters and obtaining $i_{de\text{-}trap} \cdot t \sim \ln t$ from de-trapping currents, trapped charge density and trap depth in dielectric are characterized. The effectiveness of the proposed method is verified by comparing the experiment results of the sample under different polarization electric field strengths, the results of the sample after different durations of space charge injecting dand the results of the samples with different thermal aging degrees.

TRAPPED CHARGE MEASUREMENT BY PDC

Extraction of de-trapping currents

After PDC test, the polarization current i_{pol} and the depolarization current i_{depol} are obtained. After ignoring the capacitance current component and the displacement polarization current component, the polarization current i_{pol} mainly includes three parts: dipole polarization current component $i_{dipole\text{-}pol}$, conduction current component $i_{conductivity}$, and de-trapping current component $i_{de\text{-}trap}$:

$$i_{pol} = i_{dipole\text{-}pol} + i_{conductivity} + i_{de\text{-}trap} \qquad [1]$$

Where $i_{dipole\text{-}pol}$ is the current produced by dipole polarization; $i_{de\text{-}trap}$ is the current contributed by carriers escaping from traps; $i_{conductivity}$ is the current contributed by carriers have not been captured by traps.

During the depolarization progress, the electric field is removed and the dielectric is grounded. So, the main component of a depolarization current is the relaxation current of dipoles. It is assumed that the polarization and depolarization processes of dipoles are linear processes, which means:

$$i_{dipole\text{-}pol} = i_{depol} \qquad [2]$$

Then, equation [1] is subtracted from equation [2] to obtain the conduction component in a polarization current:

$$i_{pol} - i_{depol} = i_{conductivity} + i_{de\text{-}trap} \qquad [3]$$

In equation [3], $i_{de\text{-}trap}$ decays with time. $i_{conductivity}$ is a constant during the polarization process. So, when the polarization time is long enough, $i_{de\text{-}trap}$ approaches 0.