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Abstract (Doctor)

Title of Thesis	Development of Space Charge Measurement System for HVDC Cable and Joint Using Pulsed Electro-Acoustic Method
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Approx. 800 words

The accumulation of space charges in polymeric insulation under high-voltage direct current (HVDC) conditions can distort the electric field, accelerate material degradation and lead to dielectric breakdown. Accurate space charge measurement is therefore essential for evaluating the reliability of HVDC insulation systems, especially in full-size power cables and accessories. Furthermore, in recent years, HVDC cables have become increasingly long to support long-distance power transmission. To achieve this, cable accessories such as joints are commonly used. However, the cable joint box, as a composite structure, is considered a potential weak point in the system. Thus, in the near future, space charge measurements in the joint box will become just as critical as that in the main body of the cable. Among various diagnostic techniques, the Pulsed Electro-Acoustic (PEA) method is widely employed due to its ability to directly measure space charge distributions under high DC stress.

In the application of PEA method, a coupling capacitor is generally used in the PEA method to superimpose a pulse voltage onto the insulation system already under high DC stress. However, for full-size cable specimens, the capacitor must be significantly large to withstand the applied high voltage, making pulse application challenging due to the cable specimen is normally as long as several meters and has large end-terminals. Moreover, this configuration introduces significant impedance and inductance between the pulse source and the specimen, which causes deterioration of the frequency characteristics of the applied pulse, leading to signal distortion and reduced measurement accuracy. Additionally, multiple reflections due to the distributed nature of the cable system can further complicate waveform interpretation. To overcome these limitations, this study proposes a method in which the cable itself serves as the pulse-coupling medium, eliminating the need for an external capacitor. In addition, in terms of accuracy improvement, the system utilizes and develops the newly proposed PEA cell, which achieves a four-fold increase in sensitivity compared to the conventional PEA cell, enabling better signal acquisition.

Based on previous improvement, a prototype PEA cell was developed by integrating the high-sensitivity polymer acoustic coupler with a 16-channel piezoelectric sensor array for space charge measurement in a cable joint model and the results will be analyzed through the signal processing required to convert the obtained waveforms into charge and electric field distributions, which can be used for further interpretation.

Chapter 1 provides background and overview of this study. Chapter 2 reviews the HVDC power transmission cable systems, space charge formation in solid polymer materials. Chapter 3 discusses how acoustic signals are generated and affected by factors such as geometry, attenuation, and dispersion during space charge measurement.

Chapter 4 discusses a method for applying pulse voltage using the cable itself as a

pulse-coupling device, eliminating the need for an additional coupling capacitor. Furthermore, the conditions for accurate space charge measurement are evaluated in terms of frequency components, spatial resolution, and cable specimen length.

Chapter 5 presents the development of the newly designed PEA cell, incorporating a polymer acoustic coupler for enhanced acoustic transmission and electrical isolation. This improved cell was then applied to a full-size HVDC cable specimen with 20 mm insulation thickness using the method described in Chapter 4. Space charge measurements were conducted under DC voltages up to 50 kV. The results demonstrated that the electric field estimation error was less than 0.25 kV/mm, equivalent to 2% precision when scaled to a 250 kV operating voltage.

Chapter 6 describes the application of PEA cell in Chapter 5, incorporating a 16-channel piezoelectric sensor array cable joint model consisting of 6.6 mm XLPE and 11 mm EPDM insulation layers. Using deconvolution methods which takes into account for acoustic divergence, pulse field distribution, and attenuation, two-dimensional cross-sectional profiles of space charge, electric field, and potential were successfully visualized, revealing charge accumulation along the joint interface.

Chapter 7 presents a summary of the conclusions of this paper and future improvement of the study.