An effective method to avoid charge leakage along the surface in voltage response measurement

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ABSTRACT

The voltage response measurement is a non-destructive method to diagnose the aging condition of insulation and is used extensively. The characteristics about the volume polarization and resistance can be obtained by analyzing the measured decay or return voltage of a charged dielectric, which is important for aging diagnosis. To eliminate the influence of the charges leaking along the sample surface on the voltage response analysis, we present an effective three electrode configuration with a potential guard electrode. The voltage decay results show that adopting electrodes with a potential guard electrode can effectively avoid charge leakage along the sample surface.

The voltage response method is a stable and destruction free determination of the aging degree of insulating materials.[1–5] It measures the decay and return voltage of the dielectric that is charged for a long time and then disconnected from the voltage source. This method is based on the background that aging contributes changes to electrical, physical, chemical, and morphological properties of the insulation and so the dielectric response will also be different.[1]

After the dielectrics are charged and disconnected, the free charges and bounded charges on the surface of dielectrics and electrodes are released gradually accompanied with depolarization. The voltage decay or recovery process is mainly dominated by volume dielectric properties including volume polarization and volume resistance.[6] However, the surface conductivity is an important factor that can influence the surface charge kinetics, which results in a change in the characteristics of the voltage decay or recovery. The measured voltage response will be combination reflection of the surface conductivity and volume polarization and resistance without eliminating the possibility of charge leakage along the sample surface. This will give an inaccurate assessment of the insulation aging status.

We present an effective method by using a three electrode configuration with a potential guard ring electrode to eliminate the surface charge leakage along the surface during the measurement of voltage response. The electrode configuration is shown in Fig. 1.

The diameters of the high voltage electrode and potential guard electrode are 50 and 54 mm, respectively. Hence, the gap between two electrodes is 2 mm, which is small to achieve a closer uniform electric field distribution within the sample.

The surface potential is measured with a non-contacting electrostatic voltmeter (Trek model 341B). Real-time voltage equal to the surface potential value measured by the probe is applied to the potential guard electrode, which can be easily achieved by a voltage follower; hence, there is no voltage gradient in the gap between the high voltage electrode and the guard electrode. This guarantees that no motivation force will work on the surface charges, and as a result, the surface charges cannot be released by surface conductivity. The voltage response measured by this method only reflects the volume dielectric response and provides more accurate characteristics related to the aging status of insulation.

In this Note, the voltage applied to the potential guard electrode can be conveniently provided by the probe assembly whose voltage is generated by the high voltage source within the model 341B and in the same value to the measured voltage. To ensure the introduction of the potential guard electrode in the measurement does not have an

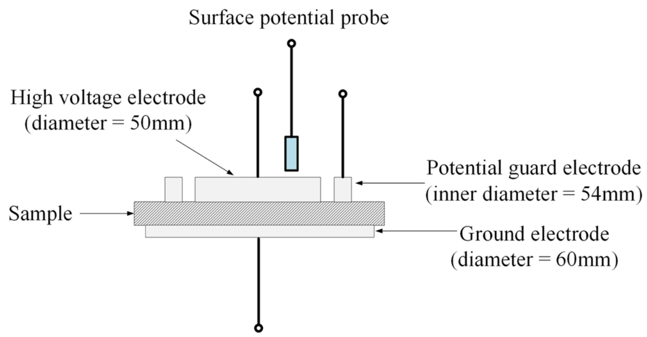

FIG. 1. Three electrode configuration with a potential guard electrode.

influence on the stability and accuracy of the electrostatic voltmeter, the insulating sample is placed in the three electrode configuration and the high voltage provided by a Keithley 2290-10 power supply from 1011 to 9627 V is applied to the sample for about 30 min, as shown in Fig. 2. During the polarization process, the surface potential of the sample is measured. The result shows that the maximum fluctuation of the measured surface potential is about ±0.53%, which is able to satisfy the requirement of the measurement.

It is well known that SiC nanoparticles are usually doped into the polymer matrix to improve the dielectric performance.[7–9] Hence, a SiC/LDPE composite sample is prepared in our verification experiments, where the SiC nanoparticle doping concentration is 5phr%. The sample is ~260 μm, and the relative permittivity is about 2.7 at room temperature. The voltage decay of the sample with and without the potential guard electrode is measured. Besides the potential guard electrode, the other condition and procedure are the same in two measurements, where the poling voltage applied to the sample is 4050 V and poling time is 1 h. After poling, the sample is disconnected from the voltage source and the surface potential decay is recorded. The sample is discharged in the interval between two

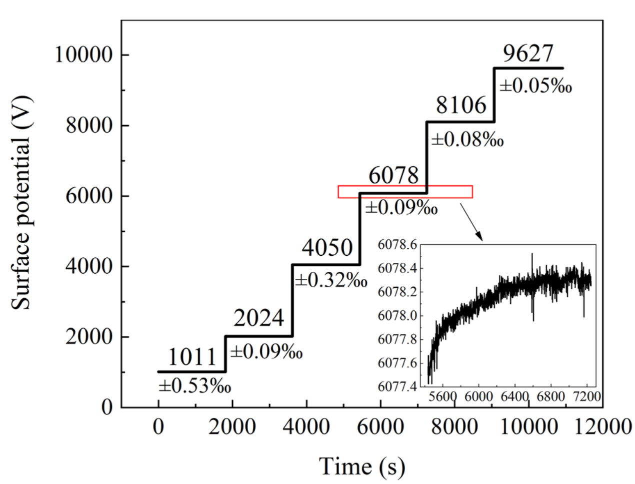

FIG. 2. Stability and accuracy of the surface potential measurement when using the three electrode configuration with a potential guard electrode.

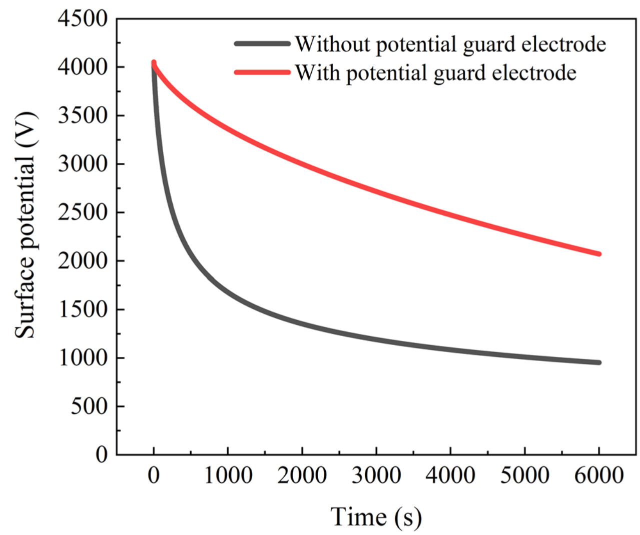

FIG. 3. Effectiveness of suppression of surface charges leaking along the surface in the voltage decay measurement with the potential guard electrode.

measurements to eliminate the influence of the first measurement on the sample.

The voltage decay of two measurements is shown in Fig. 3. It can be seen that the voltage decays more slowly when there is a potential guard electrode during the measurement. As analyzed above, the equal potential of the high electric field and guard electrode results in zero electric field in the region between them. Hence, the surface charge can only dissipate through the sample volume rather than through the surface. The result well indicates that the potential guard electrode can effectively eliminate the surface charge leakage along the sample surface during the voltage response measurement.

In summary, we have presented an effective method by using a three electrode configuration with a potential guard electrode to eliminate the surface charge leakage along the sample surface during the voltage response measurement. The electrode system has no influence on the stability and accuracy of the surface potential measurement. The charges leaking along the surface can be effectively avoided with the electrode configuration, which will give a more accurate assessment of the aging status of insulation when using voltage response methods.

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DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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