저밀도 폴리에틸렌에 있어서 전압 파형의 두께 의존성

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Film Thickness Dependences of Ac High Field Dissipation Current Waveform for LDPE

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Abstract : Polyethylene is widely used as the insulator for power cable. To investigate the conduction mechanism for power cable insulation under ac high field, it is very important to acquire the dissipation current under actual running field. Recently, we have developed the unique system, which make possible to observe the nonlinear dissipation current waveform. In this system, to observe the nonlinear properties with high accuracy, capacitive current component is canceled by using inverse capacitive current signal instead of using the bridge circuit for canceling it. As the results of these estimations, it was found that the dissipation current will depend on not only the instantaneous value of electric field but also the time differential of applied electric field due to taking a balance between applied field and internal field. Furthermore, two large peaks of dissipation current for each half cycle were observed under certain condition. In this paper, to clarify the reason why it shows two peaks for each half cycle, the film thickness dependences of dissipation current waveforms were observed by using the three different thickness LDPE films.

Key Words : Film Thickness Dependences, LDPE, Ac High Field Dissipation, Current Waveform

1. Introduction

Nonpolar polymers, such as polyethylene, polypropylene and so on, are widely used as power cable's insulation and power capacitor's dielectrics. Although these materials have excellent short-term mechanical and dielectric properties they are susceptible to long-term degradation caused by the effect of the high electric field. It is well known that at high electric field charge injection and space charge formation can occur in the polymer and cause insulation aging. To access the operating condition of the insulation, absorption current and tanδ are usually measured for dc and ac applications respectively.

Under ac high field, it is extremely difficult to measure the dissipation current component of the conduction current because it is around 0.01 % of the capacitive component. Conventionally, bridge circuits will be used to cancel the large capacitive current; however, in this case only the fundamental component of the dissipation current is precise. Therefore, the accuracy of harmonics is not enough. However, accuracy of harmonics is getting important to study the conduction mechanism and space charge effect under ac high field.

Recently, a new method which does not use a bridge system, was developed by authors. In this method, an arbitrary function generator was used to compensate the capacitive component of the charging current and the measurement system was automated and controlled by a computer. The use of computer and digital signal acquiring system makes it possible to save and analyze the large amount of data instantly. FFT technique also is utilized to obtain the spectra of dissipation current and separate the signal and noise. This new method can provide harmonics of dissipation current with high accuracy, which will be enough to analyze the space charge effect.

In this paper, the instantaneous internal electric field enhancement effect at the later part of each positive and negative half cycle which mentioned above and the effect of the time differential of electric field will be discussed. Electric field dependences of dissipation current waveforms observation were carried out by using three different thickness LDPE films to confirm the bulk effect. FFT analyses are employed to know the behavior of spectrum distributions, especially 3rd and 5th harmonics of the dissipation current. Furthermore, from the results of high field triangle waveforms application, the E-I properties in each case is discussed.

2. Experimental

2.1 Sample

LDPE films in three different thickness 37, 72 and 93 μm were used as the sample for sinusoidal waveform application and thickness 21.5 μm was used for triangle waveform application, respectively. Four same thickness film samples were prepared at the same time to confirm reproducibility. A three-terminal electrode system was employed. Here, these electrodes were formed by gold evaporation. This film sample was put into the sample holder. Then, to avoid the partial discharges, the holder was set in high-pressure N2 gas chamber (0.2 MPa).

2.2 Experiments

Outlines of the dissipation current waveform observation system has been described else where [1]. Arbitrary Function Generator (Tektronix AFG320 / NF WF1946A) and Digital Phosphor Oscilloscope (Tektronix TDS3052) were connected to personal computer via GP-IB cable. Sinusoidal waveform signal was generated from AFG320, triangle waveform signal was generated from WF1946A, respectively. Here, to make the digital noise small, this signal has 12 bit vertical resolution and 16,384 data points by using edit function. Generated signal was amplified at high voltage amplifier (Trek Model 610C) and applied to the sample in the chamber. Here, this amplifier's slew rate is 20 V/ μs. It is enough to apply the exact sinusoidal waveforms up to 200 Hz for 100 μm thick film sample (Here, in the case of the experiment at 200 Hz and 15 kV/mm, the sample thickness 100 μm, the expected maximum slew rate value will be around 2.0 V/ μs.). Furthermore, the output of the amplifier has been experimentally confirmed that there was no distortion on the applied ac high voltage waveform when the ac high voltage at 200 Hz, 15 kV/mm was applied to the 100 μm thickness LDPE film sample. During applying ac high voltage to the sample, simultaneously, a canceling signal (cosine waveform / rectangular waveform) was generated from another Arbitrary Function Generator (Tektronix AFG310 / NF WF1946A) and connected to the main electrode via serial resistor RS . Only the dissipation current component and un-canceled capacitive current flowed the detecting resistor RD. The detected voltage signal was amplified by an operational amplifier and was stored by TDS3052. The electric field was increased from 1 to 15 kV/mm in steps of 1 kV/mm with 5sec at each step. The temperature was around 25 oC. Initial setting frequency was 50 Hz. After the electric field dependence observations of dissipation current waveforms at 50 Hz, same procedures were carried out at 100, 150 and 200 Hz, respectively. To ensure the accuracy for 10th harmonics, number of data point per one cycle is set over 1,000 points. To eliminate the digital noise in extremely higher frequency region, low pass filter processing with FFT technique was introduced above 11th harmonics. Conversion from voltage unit to current unit were calculated by dividing voltage by resistance RD (10[Ω]) and amplification rate (1,000) of operational amplifier.

3. Results and Discusion

Fig. 1 is electric field dependence of 3rd and 5th harmonics for different thickness film samples. These data were deduced from the results of electric field dependence of dissipation current waveform by using FFT analysis. As shown in Fig. 1, up to 6 kV/mm, 3rd and 5th harmonics are quite small and there are no film thickness dependence. Over 7 kV/mm, both 3rd and 5th harmonics starts to increase and 5th harmonics show the relatively small peak first. Then, 3rd harmonics show the large peak. Over 10 kV/mm, 5th harmonics start to increase again. These results indicate that the time variation of dissipation current is getting rapid with the electric field increment. As shown in Fig. 1, once the 3rd and 5th harmonics appeared, then the film thickness dependence also were observed.

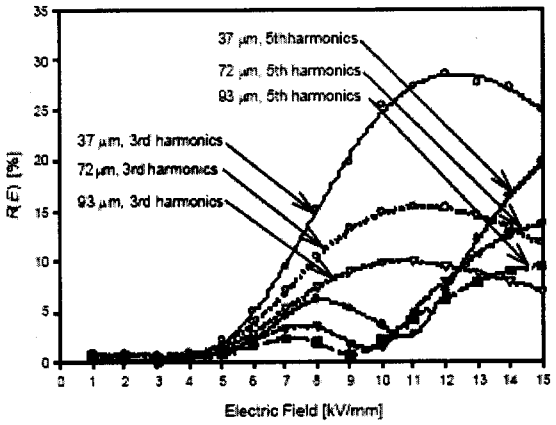

Fig. 1. Electric field dependences of 3rd and 5th harmonic component for different thickness film samples.

4. Conclusions

In order to study the charge behavior under ac high field, by using the latest observation system, dissipation current waveform under ac high field and under triangle waveform application are carried out and the film thickness dependence of dissipation current waveform and the effect of time differential of applied electric field are discussed. As the results of these experiments, where the dissipation current waveform show the nonlinearity, peaks P2 and P4 showed the film thickness dependence. It is also confirmed that the time differential of applied electric field affect the conduction under ac high field. On the experiments under high field triangle waveform application, as the quite large amount of current, which seems to consider the space charge relaxation phenomena, were observed. Image force of injected charge, filamentary conduction which makes the restricted area's internal field high and non uniform, and so on, should be carefully estimated to consider the conduction mechanism in this area.

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References

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