Utilisation of voltage and frequency dependence of stress-grading materials in dielectric diagnostics

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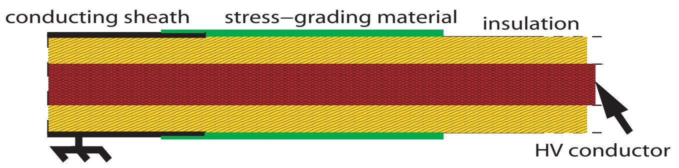
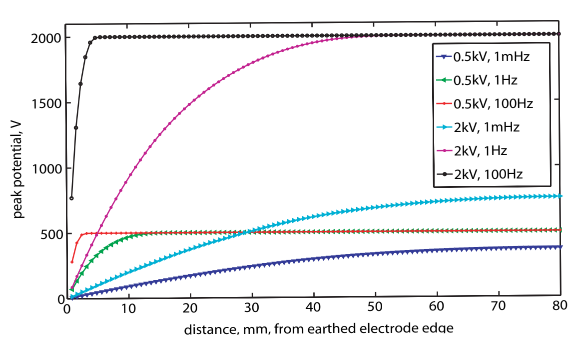
Introduction

The end-winding regions of large electrical machines and the terminations of medium-voltage cables are situations in which an earthed shield stops abruptly, which would naturally lead to a stress concentration around its edge. Several broad methods are used to control this effect; current practice commonly uses SiC in a base material to give a voltage-dependent resistance. Modern stress-grading materials result in capacitance and loss components that vary with frequency and with voltage. Dielectric measurements from some stress-grading systems are presented here, to indicate the considerable voltage and frequency dependence and the resultant distortion of currents.

The general case of surface stress-grading



Simulated example of grading potential using NL resistance



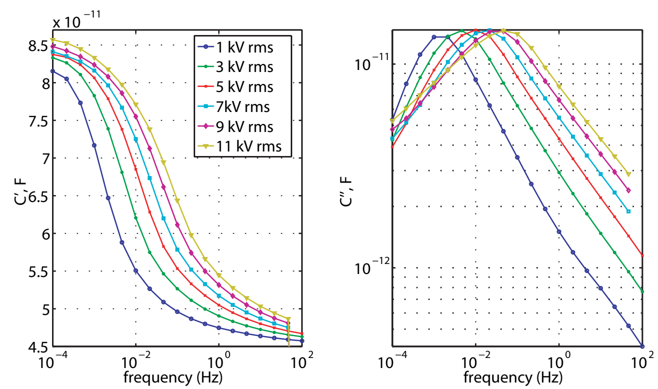
Focusing on the common non-linear resistive grading systems, it can be expected that:

- measured capacitance will increase with lower frequency or higher voltage, as the earth potential spreads further through the grading
- the loss from the graded area may be significant even compared to a much greater volume of a typical dielectric
- harmonics in the current will arise from the non-linearity, varying with frequency and voltage

Experimental results

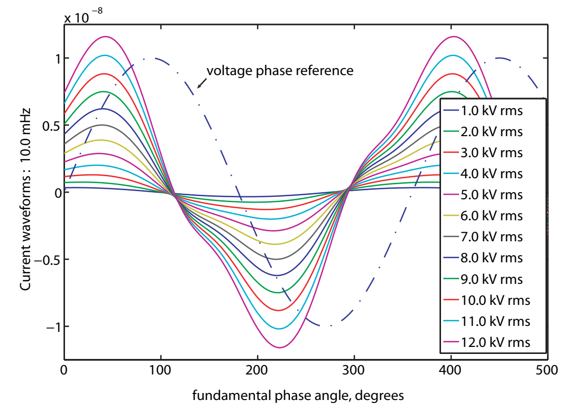
Dielectric responses of several stress-grading systems have been measured on simple models made of PTFE insulation around a bar. The grading reponse then accounts for almost all loss and for a significant capacitance. In the examples below, there is no PD activity to influence the response.

Capacitance and Loss: corona-protection paint on test-bar



From the fundamental frequency capacitance and loss plot, it can be seen that above about 10mHz the capacitance and loss curves for all voltages differ mainly in a significant shift in frequency as the higher stresses cause the grading resistance to be lower.

Current with sinusoidal applied voltage: pad on test-bar



The plot of current shows normalised time-domain waveforms calculated from the harmonics 1 to 8 that were stored by the measurement apparatus. Strong non-linearity is apparent particularly at higher voltages.

Conclusions

Commonly used field-grading systems make a large contribution to frequency-dependent and voltage-dependent components in DS measurements. Control of both voltage amplitude and frequency, and simultaneous PD measurement to distinguish PD and other non-linearities, may be worthwhile in helping to distinguish the responses of PD, stress grading and the main dielectric.