Loss of dielectric strength of polymers due to high-frequency voltages in HVDC applications

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This paper deals with the dielectric stress and breakdown voltage of polymer insulation materials in HVDC applications. The measured breakdown voltage of flat polymer specimen at mixed-voltage stress shows a correlation between the subordinated direct or power-frequency voltage and the superimposed high-frequency voltage. At the example of polyvinylchloride it is shown that in spite of a homogeneous field stress local overheating occurs which leads to the failure of specimen. The overheating is a result of the dielectric heating due to the superimposed high-frequency (kHz) high-voltage.

The differential scanning calorimetry (DSC - method) is used to analyze the specimen after the breakdown tests. Therefore material samples from different points are extracted and examined. The DSC - analysis shows that local parts of the sample reached the glass transition temperature and cooled down after the breakdown test with different velocities. At mixed-voltage stress the DSC - curves show different enthalpy relaxation peeks compared with high-frequency voltage stress. This indicates a different state of order in microscopic structure of the polymer in the viscoelastic state (temperature higher then glass transition temperature).

Further high-resolution current and voltage measurement signals during the glass transition are presented. Thus a sinusoidal high-frequency voltage is used with complex calculation the change of the relative permittivity and the resistance of the samples is calculated based on RC - electrical equivalent circuit (see Fig. 1). At the viscoelastic state the permittivity of polymers is higher caused by the additionally moving of main chains. Compared to high-frequency voltage stress the measurements and calculations show that the change of permittivity during glass transition is lower at mixed-voltage stress. The change of the electric resistance implies the polarization losses and losses by electrical conductivity. After passing glass transition the electrical strength of the material is decreased which leads to a breakdown.

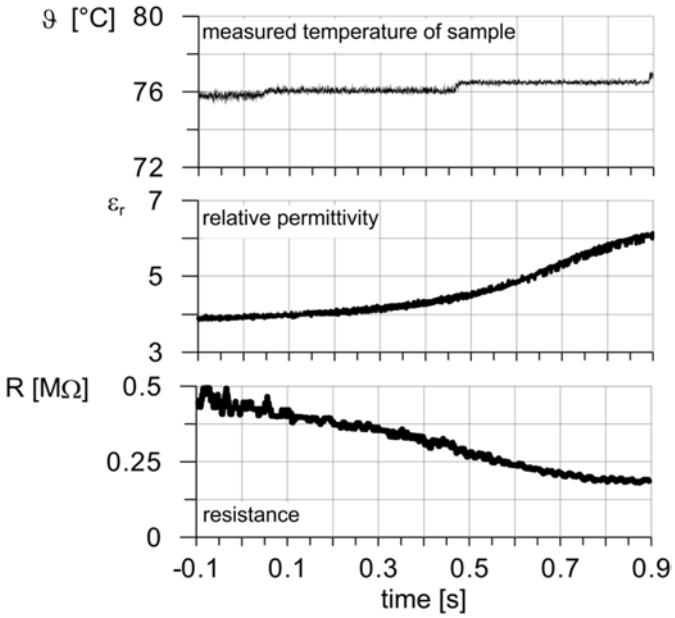

Fig. 1: measured temperature of the sample and change of permittivity and resistance during glass transition