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

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ABSTRACT

This paper deals with the thermal-electrical stress of polymers in HVDC applications due to mixed voltages with high frequency content. Based on measured breakdown voltages of PVC in a homogeneous field, the DSC-method (Differential Scanning Calorimetry) is used to analyse the specimen with regards to local overheating and influence of the mixed voltage. Further current, voltage and temperature measuring signals of different polymers are presented to analyse the process immediately before loss of dielectric strength of the specimen. Additionally the alteration of electrical material data during the test is calculated based on the measured quantities.

KEYWORDS

Mixed voltages, high-frequency high-voltage, HVDC, polymers, dielectric heating, breakdown, PVC, PMMA, POM, DSC, differential scanning calorimetry

INTRODUCTION

In conjunction with the changing structure of our energy grid to renewable energy production, innovative converter topologies and HVDC technologies are used to transmit and convert electrical energy in an optimized manner.

Thus mixed voltages, such as high direct or power frequency voltages superimposed by repetitive transients or square voltage forms, are produced by the functional principle of the converter and power electronic valves switching. Insulation materials such as polymers have to withstand these different types of mixed voltages to ensure a reliable operation of electrical apparatus in our power grid.

The effect of high frequency voltages on insulation materials or insulation systems is different to power frequency voltages respectively direct voltages. The intensity of effects which leads to a decrease in electrical strength in a long-term view is usually higher. These effects are

- the heating of insulating materials due to the dielectric heating mechanism [1],
- thereby an accelerated thermal aging [2],
- a different partial discharge inception and extinction voltage [3],
- an increased partial discharge intensity [4] and
- an accelerated electrical field aging due to an superimposed alternating field [2].

The dielectric heating mechanism is one of the fundamental effects and relevant because the thermal energy of an insulation material is increased. Due to this, the possibility of insulation materials and insulation systems to withstand this combined thermal-electrical stress is of special interest.

METHODOLODGY OF MIXED VOLTAGE TESTING

Mixed voltage forms, which typically appear in praxis, are enormous diverse and depends on the converter topology, the load case or damping of high frequency components. Therefore it is not useful to test insulation materials with any voltage form, but with well-defined mixed voltage forms. The aim is to understand basic effects and the influence of superimposed dielectric and conductive fields, amplitudes and frequencies.

The synthesis of mixed voltage as a test voltage depends on the impact of the mixed voltage, which is in the focus of interest. Here, a well-defined heat source density and sinusoidal voltage forms are necessary.

Hence at the used mixed voltage forms the characteristic form of the subordinated voltage is maintained, because it is the actual electrical field stress. The energy input due to dielectric heating is realized by a superimposed sinusoidal high frequency voltage. Therefore high voltage circuits are realized with the use of a high-frequency high-voltage generator, based on the resonance principle and a SF_6 – polymer-insulation system [5, 6]. Particular attention should be paid on the correct measurement of the mixed voltage.

Figure 1 shows the used principle to synthesize test voltages for dielectric heating investigations from mixed voltages which occur in praxis.

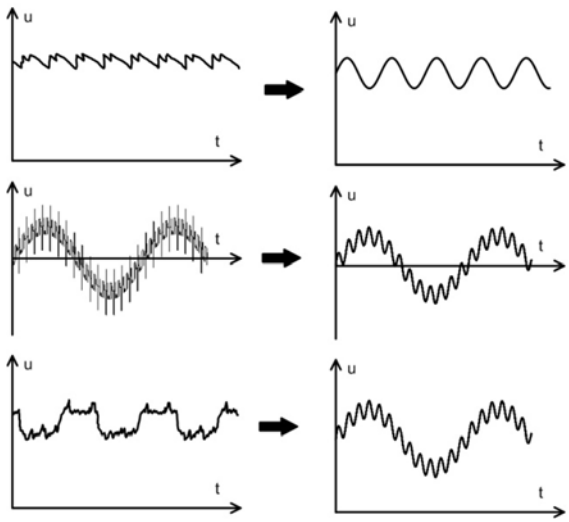

Fig. 1: Real and synthesized mixed voltages for replication of voltage stress with the focus on dielectric heating