Transient thermal phenomenon in HVDC extruded cables under test and operating condition - numerical simulation and measurements

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Due to the temperature dependency of the DC conductivity of extruded insulation materials, the test and operation condition need to be carefully selected with respect to their thermal condition. The thermal environment has an impact to field enhancement resulting from the thermal gradient in the insulation. Optimizations in the thermal setup of the test loop to reduce this temperature gradient during test condition, can lead to premature thermal instability.

Common practice of temperature control during HV cable testing is the parallel operation of two cable loops, where one loop is used as thermal reference and is equipped with temperatures sensors on the cable surface and the cable conductor, while the cable loop under voltage is monitored for surface temperature only.

In this paper a SPICE (**S**imulation **P**rogram with **I**ntegrated **C**ircuit **E**mphasis) model is presented, which simulates the thermal behavior of both loops. The network simulating the loop for temperature monitoring consist of resistors and capacitors simulating the thermal properties of the cable and the cable environment as well as the heating source from conductor heating. The model of the loop under voltage consist of a parallel network in the structure as above to simulate the thermal behavior, and a parallel network, which simulates the electrical field distribution and leakage current in the insulation. The electrical network and the thermal network of the cable loop under voltage are linked to each other via power loss density from leakage current and temperature influence on conductivity.

Different methods of applying thermal insulation and temperature monitoring during qualification tests are compared with respect to their risk of premature thermal instability and their influence on field enhancement from temperature gradient.

Temperature measurements on real test setups of 320kV cable system are compared with the simulation results. Insulation leakage current is evaluated based on leakage current measurement and thermal observations on the test cables under voltage. The insulation resistivity calculated back from the measurements on the cable section is compared with material properties determined on small scale samples.

With the calibrated model from this observation a typical cable installation is simulated with respect to thermal behavior and risk of thermal instability.