The dielectric response of stator end-winding stress-grading

N. Taylor and H. Edin

ROYAL INSTITUTE OF TECHNOLOGY

KTH - Department of Electrical Engineering, Stockholm, SWEDEN

Background and Aim

The electrical windings of a high-voltage machine's stator are a complex object to study with electrical tests, since there are several distinct parts all being measured together, each with different behaviour. Stator windings are a large part of the failure risk of such machines, and their reliable Condition Assessment (CA) is greatly desirable.

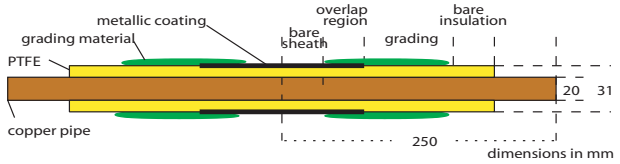
Traditional methods of stator-insulation CA are resistance measurements with DC supply, and capacitance, loss and Partial Discharge (PD) measurements at power frequency. More modern methods in widespread use are Phase-Resolved PD Analysis (PRPDA) giving more chance of identifying the nature of the PD source or sources, and on-line PD measurement. Modern methods not widely used include variable frequency PRPDA down to the <1Hz range, helping to resolve different PD sources, and Dielectric Spectroscopy (DS) with variable voltage, which has given good detection of problems in other constructions such as cables and transformers.
The authors anticipate a system of measurement with variable frequency and magnitude of an applied test-voltage and with measurement of the resulting smooth current (capacitance, dielectric loss, low harmonic spectrum) and PD currents: the technology for coordinating and making such measurements is ever closer to the reach of machine users.

The stator end-windings have a coating of non-linearly (electric-field dependent) resistive compound for the purpose of preventing excessive stress on the winding surface. The smooth-current quantities mentioned above are all affected, with frequency and voltage dependence, by this region. The very different potential-distribution at low frequency may also cause surface PD. The appearance of these end-winding effects is significant in interpreting measurements of whole stator-windings.

Measurements

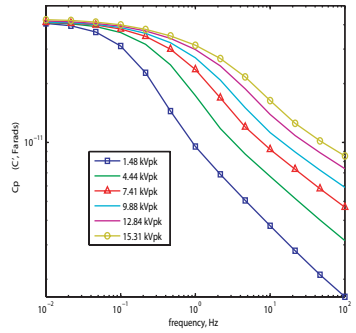
In order to see the effects due, as nearly as possible, to the stress-grading material alone, some short bars were made, each with two stress-graded regions of SiC paint or band and a very stable and low loss dielectric (PTFE).

Construction of the test-bars

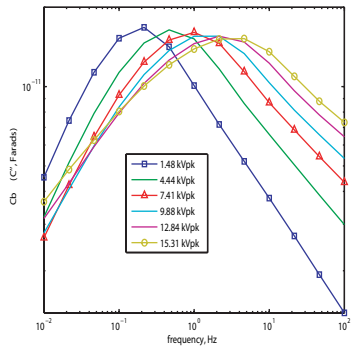


It is expected, and here confirmed, that:

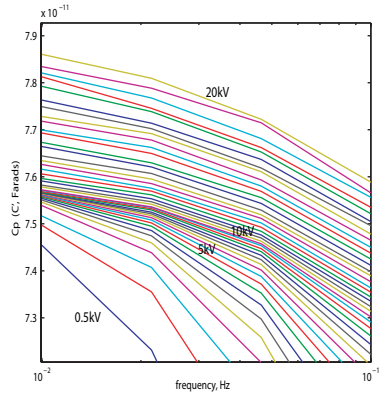
- measured capacitance will increase with lower frequency or higher voltage, as the earth potential spreads further through the grading
- the loss from the graded area may be significant even compared to a much greater volume of a typical dielectric
- harmonics in the current will arise from the non-linearity, varying with frequency and voltage
- at some extreme (high) magnitude and (low) frequency, PD will occur at the end of the stress-grading material



C' (above) and C'' (below)



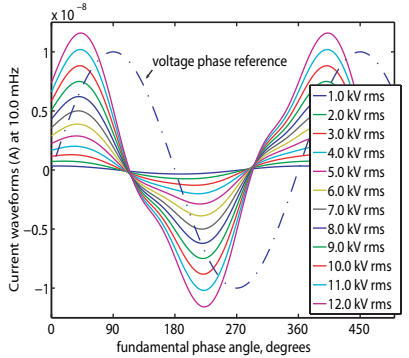
C' at low frequency with many voltages



The quite steady increase in C' here after the apparent stagnation at about 12kV may be the result of PD on the grading edge. No PD signal was consistently detected, but it is known that the DS equipment can measure PD currents each two small for the PD system to record.

Here is shown the highly non-linear consequence of the stress grading material, after subtraction of the current due to the capacitance from sheath directly to central conductor. The harmonic content increases with voltage.

Time-view of harmonic currents



Summary

The effect of the stress-grading material on measured capacitance, loss and harmonics is strong, easily becoming comparable to the voltage- or frequency-dependence of the actual insulation material and its cavity PDs.

Phenomena that could be explained as PD have been observed at low frequency: more measurement is needed to confirm their nature.