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T-A Formulation for Modelling and AC Loss Reduction Studies in a Superconducting Synchronous Generator for a 10 MW Wind Turbine

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The properties of high-temperature superconductors (HTS) have inspired several applications in electric power systems. In particular, their zero resistance and high current capacity can lead to more compact and efficient generator designs.

Despite its zero resistance, HTS experiences losses under time-changing current or magnetic fields. These losses are fundamental during the design of superconducting devices since they can strongly influence the cooling power requirements and operating temperature. Several analytical solutions have been developed to estimate losses in HTS tapes and wires. However, these expressions can not be directly used to study complex operating conditions such as AC transport current and externally applied magnetic fields in superconducting electrical machines.

Maxwell's equations in the T-A formulation form can be used to model and estimate losses in HTS tapes and coils by employing the finite elements method (FEM). This formulation requires the current as a function of time in each superconducting tape as an input. We show in this work a methodology to calculate this current distribution in superconducting generators. The approach is applied to a 10 MW machine with permanent magnets in the rotor and superconducting coils in the stator. Particular attention is given to the position of the coils inside a slot and several coil configurations are presented. It is shown that certain coil arrangements lead to a significantly lower loss in the coils, a more uniform loss distribution, which ultimately leads to the possibility of increasing the operating temperature.

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Primary author: VARGAS-LLANOS, Carlos Roberto (Karlsruhe Institute of Technology)

Co-authors: Mr LENGSFELD, Sebastian (Fraunhofer Institute for Energy Economics and Energy System Technology); GRILLI, Francesco (Karlsruhe Institute of Technology)

Presenter: VARGAS-LLANOS, Carlos Roberto (Karlsruhe Institute of Technology)

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