



Contribution ID: 628 Contribution code: THU-OR5-501-04

Type: Oral

Methods of Estimating AC Losses in Multi-filamentary Superconducting Windings with Spatial and Time Harmonics

Thursday 18 November 2021 19:15 (15 minutes)

Recent developments in low ac loss MgB₂ conductors are of significant interest, given revived interest in fully superconducting (SC) generators. Evaluating AC losses in SC armature windings is critical to develop a feasible fully SC machine. In fully SC machines, SC armature windings experience rotating magnetic fields with spatial and time harmonics which has an undisputed impact on ac losses. Existing ac losses models in the literature are validated for stationary sinusoidal external fields. But there is not enough research on validating the ac loss models for multifilament MgB₂ cables with rotating magnetic fields. Further, available models do not capture the time and spatial harmonics impacts on the ac losses. This paper evaluates ac losses in SC with simulated current and field waveforms experienced by an armature conductor in a machine. Various analytical models available in the literature to estimate ac loss in multi-filament MgB₂ conductors are compared. Spatial and time harmonics obtained from a transient fully SC machine analysis are fed into the analytical model to estimate the losses. These results are then compared against the finite element analysis (FEA) results to evaluate model fidelity. The analytical models are then refined to capture different parameters influencing ac losses in machine application. Using the analytical and FEA results, new ac loss estimation methods are proposed for multifilamentary cables with spatial and time harmonics with rotating magnetic field. Typically, to evaluate the total loss in a machine, losses are evaluated across a strand and then integrated over total armature conductor length. However, when the strands are packed in to winding the losses may differ from the losses generated from an individual strand. Therefore, the packaging effect in SC winding ac loss is analyzed using FEA. These results are then compared against the individual multi-filament wires modeled in an FEA.

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Session Classification: THU-OR5-501 Superconducting Rotating Machine, Levitation and Flywheel