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A Numerical and Experimental Study on Dynamic Operation of a Synchronous Rotating Machine with NI HTS Field Windings

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A no-insulation (NI) high-temperature superconductor (HTS) winding technique has been mainly applied to direct-current (DC) high field magnets, while its application to alternative-current (AC) machines is limited. One of the potential applications of the NI HTS winding technique is a synchronous rotating machine, typically employed in aircraft and ship electric propulsion. Under an ideal steady-state operation of a synchronous machine, the NI HTS field winding experiences essentially DC magnetic fields, therefore the steady-state responses of an NI HTS field winding are likely to be identical to those of the conventional insulated windings. However, in an actual operation, the NI HTS field winding inevitably experiences transient operational dynamics such as an acceleration, load fluctuations and more, which obviously affects the torque and speed characteristics of an NI HTS synchronous machine mainly due to the well-known "NI"characteristics of the NI HTS field winding. Here we report a numerical and experimental study on the dynamic responses of a synchronous machine with NI HTS field windings. A 300-W 4-pole machine was designed, constructed and operated in a bath of liquid nitrogen at 77 K as coupled to a customized dynamo test bench. Its dynamic characteristics were evaluated in selected transient operation scenarios, and the effect from NI characteristics was thoroughly analyzed based on the proposed equivalent circuit model as well as the finite element model.

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