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Robust and low-loss high temperature superconducting armature winding technology to realize a practical fully superconducting rotating machine: from the viewpoint of self-organizing design method and FFDS conductor technique

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We report the current state of research and development to realize a new design theory of High Temperature Superconducting (HTS) armatures that achieve both robustness and low-loss characteristics. In order to realize it, the self-organizing design method, which is the first-principles design method [1], and the Face-to-Face Double Stacked (FFDS) conductor technique [2] are effectively combined with each other.
A fully superconducting AC rotating machine, in which both the field and armature are composed of superconducting windings, is considered to be the ultimate low-dissipation as well as high-power (and/or- torque) density machine. However, the HTS conductor has a non-linear magnetic flux-flow resistance that depends on the current and the local magnetic field vector. In a rotating machine whose essence of energy conversion is modulation of a rotating magnetic field, it is essential to study the effect of the spatially distributed magnetic field on the non-linear resistance for realizing precise design.
In this study, we design a three-phase armature winding for a 150 kW-class rotating machine by means of the self-organizing method that can uniquely determine the detailed shape of the stator slot without a rule of thumb, based on the results of the 50 kW-class fully superconducting induction/synchronous motor [3]. Furthermore, by taking into account the mechanical and electrical characteristics of the FFDS conductor that joins two REBCO tapes with low resistance, a stator structure capable of increasing power density while maintaining low-loss is realized. The designed armature also show for the first time a robust structure that is stable even when an overcurrent exceeding the critical current is applied.

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[1] unpublished
[2] T. Kiss et al., 30th ISS, WB6-6-INV, 2017
[3] T. Nakamura et al., IEEE Trans. Appl. Supercond., 29(5) (2019) 5203005

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