Contribution ID: **759** Type: **Poster Presentation of 1h45m**

Design of a Novel Double-Stator Flux Reversal Machine with Hybrid HTS and PM Excitations

Tuesday 29 August 2017 13:15 (1h 45m)

Flux reversal machines (FRMs) have a stator with permanent magnets (PMs) mounted on the surface each teeth and a reluctance rotor. As the flux field excited by the PMs is almost constant, the magnitude and phase of the stator current are often adjusted to realize the flux-weakening operation, but it usually sacrifices the output torque. As we know, HTS wound field machines can easily adjust the airgap field and realize wide speed range. Therefore, in this paper, a double-stator hybrid excitation FRM, which utilizes the merit of HTS wound field machines with adjustable d-axis flux, is proposed and analyzed. As the change of airgap flux can be enhanced or weakened by controlling HTS field winding current, the proposed HEFRM can improve both low speed overload torque and high speed flux-weakening capabilities. The proposed machine has two stators and a sandwiched rotor. The outer stator has three-phase windings and consequent-pole PMs mounted on each stator teeth. The inner stator is a conventional stator with HTS field windings and semi-closed slots. The rotor is a simple reluctance rotor. The proposed machine can be regarded as a superposition of two machines, i.e. a single-stator consequent-pole PM FRM and a double-stator HTS FRM. The operation principles will be analyzed and the feasible slot-pole combinations will be summarized. Then, in order to get maximal torque density, the proposed machine will be optimized in terms of several key parameters including slot-pole combination, split ratio and slot opening ratio. Moreover, through comparisons to a conventional FRM, it is found that the proposed FRM has much larger torque density and wider speed range.

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Session Classification: Tue-Af-Po2.06

Track Classification: E1 - Motors