

Modeling and Remedies for Rare-Earth Permanent Magnet Demagnetization Effects in Hybrid Permanent Magnet Variable Flux Motors

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Variable-flux motors (VFMs) with hybrid permanent magnets (PMs) can limit the utilization of rare-earth PMs and reduce the high-speed losses of traction motors. These motors are often characterized by two main magnetization states (MS), i.e., the maximum and minimum. The flux variation is achieved by applying current pulses. This can be multiples of the rated current and changes the rare-earth PM operating point so that a minimum flux is produced by the low-coercive force PM (LCFPM). This paper presents a detailed study of the modeling and analysis of rare-earth PM demagnetization in hybrid PM VFMs. An iterative simulation procedure is proposed for predicting rare-earth PM demagnetization while driving the LCFPM to minimum MS. Two plausible causes of demagnetized rare-earth PM operations are investigated. Then, a series-hybrid PM VFM with partially demagnetized rare-earth PMs is tested experimentally to validate the proposed simulation procedure, and a reasonable match is found between the simulation and experimental results. Finally, some design remarks are presented, and two remedial design modifications are proposed, allowing minimal changes in rotor geometrical constraints. Results reveal that for hybrid PM VFMs, it is crucial to model the irreversible demagnetization behavior of rare-earth PM while predicting the re/demagnetization performance.