ABSTRACT

DESIGNING AND OPTIMIZING HYBRID-PM VARIABLE FLUX MACHINES

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Research interest in variable flux machines has been steadily growing in recent years. Permanent magnet machines provide a high-power density and efficiency across the entire speed-torque curve. However, this type of machine experiences a drop in efficiency as it transitions into the high-speed region. On the other hand, eliminating the rare-earth permanent magnet used in the variable flux machine is increasingly garnering interest among researchers, especially in traction applications. The interest in this field is due to the scarcity of rare-earth magnets because of the limited availability of the elements necessary to produce these magnets, and because they originate predominantly from a single source.

The permanent magnet-variable flux machines have the potential to reduce the rare-earth magnet utilization as well as improve the efficiency at a high-speed region. The non/reduced-rare-earth magnets, which are employed as variable permanent magnets, would fill the gap resulting from minimizing the utilization of the rare-earth permanent magnet. Hence, the amount of magnetic flux can be altered and regulated in these machines by intentionally demagnetizing or re-magnetizing the low-coercive force magnets.

This dissertation proposes two novel hybrid permanent-magnet variable flux machines. In both machines, the NdFeB magnet is utilized as a high-coercive-force magnet, whereas the AlNiCo magnet and the new Iron Nitride (FeN) magnet are employed as a low-coercive-force magnet, alternately. The magnets are arranged in the rotor precisely in order to fully capitalize on the advantages of these magnets in the machines. The level of demagnetization of the low-coercive-force magnet with different sizes is explored in this study. Moreover, the equivalent magnetic circuit is established to analyze and understand the behavior of the magnetic system in each machine. The analytical solution of the magnetic circuit is determined and compared to the Finite Element Analysis (FEA) solution. In addition, the designs are investigated using FEA software to search for the potential enhancement in electromagnetic performance. An optimization process is used for both designs and the outcomes are compared to the Nissan Leaf conventional baseline IPM design machine. Furthermore, efficiency maps will be provided at various levels of demagnetization.