Investigating the Switch Reluctance Machine's applicability in a Pump Application

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The Switched Reluctance Machine (SRM) is one of the oldest electrical machines but has not had a commercial appeal due its complicated control requirements. In the last decade, electrification has caused a higher demand on rare earth metals, used to produce permanent magnets, which are required for most common electric machines. This makes it interesting to re-investigate the potentials of the SRM, an electric machine which does not require permanent magnets.

Instead of having permanent magnets in the rotor, the rotor consists solely of laminated steel. It functions on the same principle that makes a nail align itself to an external magnetic field. Only in this case the nail (rotor) aligns itself to a magnetic field created by electromagnets (stator). Because the rotor is not round, the magnetic interaction between the rotor and the stator is nonlinear and complex. In order to control the machine/rotor at a desired speed, in a pump for example, the magnetic fields produced by the electromagnets need to be controlled. This is done by controlling the currents in the stator's copper windings.

Because of the nonlinearity, a mathematical machine model was needed to express how the machine's properties relate to one another. It was created in Finite Element Analysis (FEA) and later verified by experimental measurement. In this thesis, two different control methods were implemented, Instantaneous Torque Control (ITC) and Average Torque Control (ATC). The methods differ in how the currents are chosen. These methods were compared with each other and benchmarked to BorgWarner's current BLDC machine in simulations and testing rig.

It was shown that a simulated machine model can accurately represent the behavior of the real machine. The importance of an accurate simulation model in order to produce well performing control methods was also proven. Any discrepancies between the model and the real machine will directly affect the performance of the SRM. The machine model must therefore take into account outer factors such as friction, load disturbances and the machine's magnetization characteristics.

The different control methods developed performed similarly but ATC showed the best results for the tested machine. This was surprising since ITC is the more complex method and should theoretically perform better. This result was explained by the fact that the position in which the current was turned off for the ITC had not been chosen in regards to the speed of the machine. Thus, the current did not have time to fall to zero before the machine entered its negative torque region which resulted in worse performance.

Regardless of which control method that was used, the SRM could, however, not perform as well as the BLDC machine which BorgWarner currently has in their pump application. The machine configuration, a 4/2 asymmetrical SRM, has by default trouble with producing even torque throughout its electrical stroke. Therefore, it was concluded that the SRM would probably perform better with higher pole number configurations, which allows for a smooth torque. However, it was shown that implementing control methods for an SRM is realizable and that there are many possibilities in which one can improve its performance.

It was shown that the used methodology was viable and that the present technology allows for an adequate control of this type of machines. To match the performance of machines such as the BLDC and PMSM, it is necessary to evaluate other SRM types that can produce smooth torque. Thus, the SRM will possibly be a candidate in future motor applications, if rare earth metal prices increase and a cheaper machine design is desired.