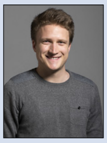

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Impact of Inverter Topologies on the Iron Losses in Electrical Machines

Figure 1: Investigated Permanent Magnet Synchronous Motor (PMSM)
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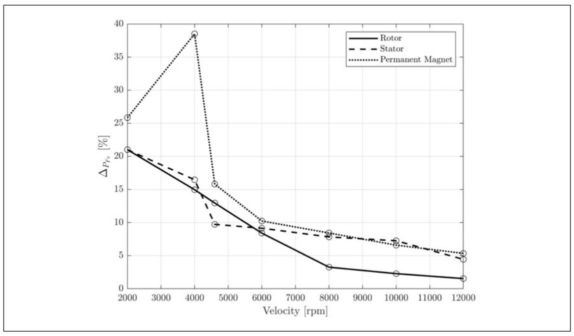

Figure 2: Iron loss difference between 2-level inverter and 3-level inverter
Own presentment

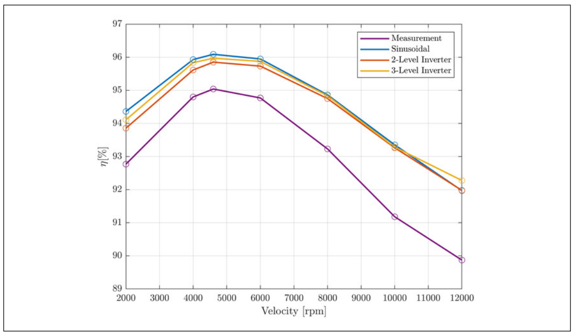

Figure 3: Motor efficiency comparison
Own presentment

Introduction: Electrical machines in automotive applications should feature a high efficiency in order to increase the drive range for a given battery capacity. The wide speed range of the motor is thereby achieved with a voltage source inverter, which is usually designed as a 2-level inverter. The use of different inverter topologies as in the 3-level inverter could bring improvements in terms of motor losses and thus improve efficiency. In this thesis, the influence of different inverter topologies on the iron losses in electrical machines is investigated by comparing the performance of a 2-level and 3-level inverter. The major difference between the inverter topologies is the additional voltage level of the 3-level inverter, which enables a better sinusoidal voltage modulation and thus fewer harmonics in the system. The improved voltage and current quality of the 3-level inverter indicates a possible reduction of the iron losses. Additionally, the iron losses caused by the inverter supply contribute strongly to the total losses and therefore offer a great opportunity for improvement.

Approach: The iron loss investigation is performed on a Permanent Magnet Synchronous Motor (PMSM) from BRUSA Elektronik AG, presented in figure 1. The motor has a maximal torque of 440 Nm at a power of 210 kW and 600 A RMS phase current. First, a verification of the motor FEM model was conducted with sinusoidal excitation and BEMF simulations in ANSYS Maxwell. The simulated motor performance was compared with measurement data and the iron losses of the sinusoidal simulation were extracted. A simulation study was built in Simulink in order to implement and evaluate the investigated 2-level and 3-level inverter. The inverters are implemented with ideal IGBT modules at a switching frequency of 20 kHz and a DC-voltage of 400 V. The current control was designed and a performance simulation with a simplified magnetic model of the PMSM was conducted. The inverter topologies were finally implemented in the ANSYS Simplorer environment for a coupled simulation analysis of the FEM model fed by the different inverter topologies. After the performance verification in Simplorer, the investigation of the iron losses could be started and a thorough comparison between the inverter topologies was conducted.

Result: The verification simulations showed small difference in performance compared to the measurement. However, a deviation of the losses led to a large efficiency gap. The current control design was challenging due to the motor model complexity. The coupled simulation in ANSYS was implemented and verified with simulations, which enabled the comparison of the inverter topologies. The 3-level inverter showed an improvement in the phase voltage quality and current shape compared to the 2-level inverter, which was expected due to the additional voltage level. Consequently, a maximal iron loss reduction of 21.6 % at 2000 rpm was observed with the 3-level inverter. A thorough analysis of the inverter impact on the different iron loss components was performed. The results are presented in figure 2, showing a big inverter topology impact in the lower speed region. The motor efficiency comparison in figure 3, shows an increased efficiency trend for the 3-level inverter in the lower frequency range with a maximal difference of 0.26 % at the 2000 rpm operation point.