

# Abstract

Crucial criteria for electric drives in automotive hybrid drive trains are efficiency and power density. As a consequence of the emerging rare-earth permanent magnet alloys, e.g. *NdFeB* or *SmCo*, with continuously increasing electromagnetic energy density, the efficiency and power density of Permanent Magnet Synchronous Machines (PMSM) rises accordingly. Especially high efficiencies and power densities are obtained with Interior PMSM (IPMSM), where the permanent magnets are integrated into the rotor structure. Therefore IPMSM became the dominating type of electrical machine for this field of application. However, in contrast to induction machines, which are in service in railway traction applications for decades, the experience with PMSM in this field of application is small.

This work deals with the efficiency-optimized torque control of highly utilized IPMSM drives under conditions, which are typical of traction applications, e.g. the wide motor speed range, which requires an operation in the constant-torque as well as in the constant-power range, and the special characteristics of the electrical machine and the inverter such as iron-saturation effects, non-sinusoidal back EMF and the small number of switching instants per electrical revolution. The control task can be structured as follows:

First of all the operating point has to be determined, in which the drive operates optimally with respect to efficiency, accounting for the actual motor speed and DC-link voltage.

For this purpose a control structure is derived and verified, which identifies the operating point, in which the reference torque is generated with a current space vector of minimum length (Maximum Torque per Current Operation). If the reference torque exceeds the maximum torque available, it will be limited accordingly. Furthermore it must be ensured, that the PMSM is operated in the identified, efficiency-optimized operating point. This is done by a subordinated control structure. Two alternative subordinated control structures, the "Field-Oriented Current Control (FOC)" and the "Direct Torque Control (DTC)", are implemented and their performances are evaluated and compared. Special focus is given to the torque dynamics and the torque utilization in the constant-power range, where the operation of the overall control structure is especially critical.