Analysis and reduction of power losses in a BLDC-motor with field-oriented vector control

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Different control strategies are used today for driving electrical motors depending on the application. The choice of motor control strategy can affect efficiency if not implemented correctly or if the motor model in the control loop is overly simplified. A increased energy-loss is often detected as increased heating of the motor caused by too high currents. Finding the origin if these high currents and minimizing energy losses is the object of interest in this master thesis project.

BorgWarner, a key manufacturer of automotive components, experienced a significant increase in energy losses and reduced performance when switching their BLDC motors' control strategy from block-commutation to field-oriented vector control. The company required an analysis of the differences between their implemented control algorithms and the identification of the source for the increased losses with the aim of reducing them.

The measured stator currents in the rotating dq-frame revealed that the company's block commutation algorithm effectively utilizes the direct axis current when driving the motors on high speeds. Recognizing the energy efficiency benefits of a negative direct axis current in the motor, a strategy was developed to incorporate this feature into a Field-Oriented Control (FOC) algorithm. A CAD-model of the BLDC-motor was used in combination with a numeric computing environment and measured data to optimize the combination of direct and quadrature currents and minimize power losses, in other words, to find the Maximum Torque Per Ampere curve (MPTA).

The outcome of this optimization process is a detailed mapping of the recommended control currents based on rotational speed and desired mechanical torque (see Figure 1). This new mapping of the motor not only deepens the understanding of BorgWarner's BLDC-motor but also achieves a significant reduction in power losses from 85 W to 35 W at 2500 RPM and 0.15 Nm when applied to the FOC control algorithm. The updated algorithm makes the FOC control as efficient as the company's block commutation algorithm for middle high speeds, marking a noticeable improvement over the previous FOC control implementation (see Figure 2).

Furthermore, the project establishes a foundation for future development and enhancement of BorgWarner's field-oriented vector control, preparing for further efficiency improvements in their implementation.

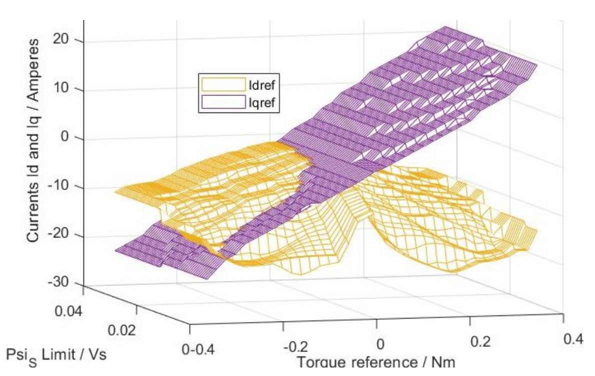

Figure 1: Recommended direct and quadrature currents depending on the operating conditions.

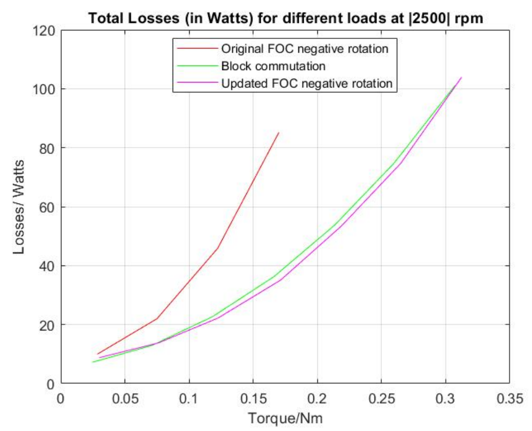

Figure 2: Losses as a function of load at 2500 RPM. FOC (red), BC (green), updated FOC (purple).