PhD Public Defence

Title: Design of Parameter Independent, High Performance Sensorless Controllers for Permanent Magnet Synchronous Machines

Location: Pontoppidanstræde 101, Room 23

Time: Thursday 1 October 2015 at 13.00

PhD defendant: Ge Xie

Supervisor: Associate Professor Kaiyuan Lu

Moderator: Associate Professor Ewen Ritchie

Opponents: Associate Professor Laszlo Mathe, Dept. of Energy Technology, AAU (chairman)
Professor Torbjörn Thiringer, Chalmers University of Technology, Göteborg, Sweden
Professor Jian Guo ZHU, School of Electrical, Mechanical and Mechatronic Systems, University of Technology, Sydney, Australia

All are welcome. The defence will be in English.

After the public defence there will be an informal reception in Pontoppidanstræde 101 room 25/27.
Abstract:

The Permanent Magnet Synchronous Machine (PMSM) has become an attractive candidate for various industrial applications due to its high efficiency and torque density. In the PMSM drive system, simple and robust control methods play an important role in achieving satisfactory drive performances. For reducing the cost and increasing the reliability of the drive system, eliminating the mechanical sensor brings a lot advantages to the PMSM drive system. Therefore, sensorless control was developed and has been increasingly used in different PMSM drive systems in the last 20 years. However, machine parameters such as resistance and inductance are involved in many existing sensorless control algorithms. Therefore, varying machine parameters due to different operation conditions may affect the accuracy of the position estimation and the drive performance consequently. For power converter manufactures, a generalized, universal sensorless controller that can be used for different types of PMSMs is desired. It is highly preferred that there should be no machine parameters involved in the sensorless controller.

The understanding of the PM machine model is a foremost requirement for the machine control. In this thesis, the mathematical models of the Permanent Magnet (PM) machine are first introduced. The control fundamentals including Field Oriented Control (FOC) strategy and two other basic sensorless control methods are presented as well.

The experiment platform setup used to validate the proposed sensorless control algorithms is described next. Since the inverter voltage error may affect the performance of the sensorless control system, the nonlinear inverter voltage error is analyzed and discussed in detail. Two compensation methods are implemented and the results are given.

As a comparison example, one of the typical sensorless algorithm – the INFORM method is implemented and tested. It is demonstrated that the voltage error may seriously affect the performance of the position estimator. To overcome this difficulty, a new implementation scheme of the INFORM method with easy inverter voltage error compensation strategy is therefore proposed.

In this thesis, two new machine parameter independent sensorless control methods are proposed. The zero voltage injection method is first introduced for e.g. medium speed operation. In this method, the zero voltage vector is injected between two FOC (Pulse-Width Modulation) PWM periods. In the injection period, the voltage output from the inverter is forced to be zero. The rotor position and the speed are then estimated simply from the current changes during this zero voltage injection period. This method provides a good performance for the rotor position estimation. The transient fluctuation of the estimated rotor position error is around 20 degrees with a step load torque change from 0% to 100% of the rated torque. The position error in steady state is within ±2 electrical degrees for the best case. The proposed method may also be used for e.g. online machine parameter identification and an application example is given. For low speed operation, a new minimum voltage injection sensorless algorithm is introduced. A voltage vector with constant magnitude is inserted between two FOC PWM periods. The currents sampled before and after the injection period are then used for estimating the rotor position and speed. This method is further developed to suppress the inverter voltage error effects on the position estimation accuracy. Experimental results have shown that the transient position error during a step load change from no-load to full-load is around 20 degrees. The ripple in the rotor position error in steady state is around ±3 degrees with the real rotor speed as the feedback and ±6 degrees with the estimated rotor speed as the feedback. These two proposed methods ideally need one injection voltage vector only for position estimation. This will benefit increasing the control bandwidth and minimizing the current distortion. The implementations and extensive experimental results of these two methods are presented in detail in the thesis.