PhD Course 2017

High efficiency electrical machines
(Course code FENM100)

Department Energy and Environment,
Chalmers University of Technology

Background:
Many studies show that energy efficiency is one of the most effective ways to reduce the global energy consumption. About 40% of electricity produced worldwide is consumed through electric motors with average operating efficiency of 80%. The energy wasted in electric motors causes near 0.5 billion tons of CO₂ emission per year. To develop cost-effective high efficiency motors is highly required.

During last 10 years, the losses in the newly installed industrial motors have been reduced by 20%. Today the major motor manufacturers only produce motors in classes of High-Efficiency (IE2) and above. The leading companies even strive after Super Premium Efficiency (IE4) and Ultra Premium Efficiency (IE5).

Compared to the conventional ones, the electric motors used as in full electric and hybrid electric vehicles are operated in much higher dynamic loads and thermal cycles. The challenge is to design an electric motor that is able to not only handle peak power, thermal stress, and insulation aging, but also be compact, low-cost and highly efficient.

The rare earth based permanent magnets provide opportunities to build more compact and more efficient electrical machines. The fast growing usage of PM wind generators and PM vehicle motors have great demands on availability of rare earth materials. To avoid using such strategic materials becomes another trend for new motor research. The developments in the high efficiency and high performance motors without rare earth magnets have advanced significantly in the recent years. Copper rotor motors and synchronous reluctance motors nowadays can reach a similar efficiency level as PM motors.

Course objectives and contents:
The objective of the course is to provide the latest knowledge and study results on loss analysis and efficiency measurements, as well as the state-of-art motor designs for high efficiency. The ambition is to help the participants reach a higher-level knowledge platform beneficial to their research toward energy-efficiency.

The course consists of 2 periods: lecture week, assignment month and examination.

1. There will be 8 lecture modules in the intensive course week (15th – 19th May 2017). Each lecture module will include 2 x 45 min presentation plus 30 min discussion. Introduction, assignment discussion, lab visit, technical tour and a common course dinner will be arranged after the lectures.

2. An assignment will be a study on a selected topic related to the scope of the course. The topic is usually defined by the participant according to his/her own research topic. There are also some pre-defined the topics available. The examination of the assignment will include assignment report and presentation in the form of a seminar or a video conference. The presentations should be arranged in groups between the 10th June and the 30th August 2017. The report should be handed in not later than the 15th September 2017.
Date & Time: Lectures: 2017-May-15 13:00 — 2017-May-19 13:00
Assignment: 2017-May-20 – 2017-Sept-15

Place: Hörsalsvägen 11, Room Analysen, Division of Electric Power Engineering, Chalmers University of Technology.

Registration: At the latest 28 April 2017 to yujing.liu@chalmers.se

Working language: English

Lecturer and examiner: Prof. Yujing Liu, Chalmers University of Technology. Guest lecturers from industry and other universities

Participants: PhD students and industrial engineers in electrical engineering

Course material: Hand-outs of the presentations

ECTS Credits: 7.5 (lecture week and assignment); 4.0 (only lecture week)

Hotel recommendation: Quality Hotel Panorama, Göteborg

Course leader:
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Programme
### Monday, 15th May 10:30-16:30

**Registration**

**Introduction**

**Module-1: Machine losses (physics and calculation)**
- Losses in electrical machines
- Losses based on FEM
- Iron losses due to punching
- Iron losses due to rotating flux
- Copper losses due to proximity effects and eddy currents

### Tuesday, 16th May 9:00-16:30

**Module-2: Traction motor efficiency for road vehicles**
- Requirements on traction motor for heavy vehicles
- Efficiency of electric machine and hybrid drivetrain
- Drive cycle and efficiency map
- Review of motors used for electric vehicles
- Motor losses and thermal management

### Wednesday, 17th May 9:00-17:30

**Module-3: Motor control for maximum efficiency**
- Traditional motor control methods
- Advanced control methods
- Field weakening control for maximum efficiency

- Lab visit at Chalmers

**Module-4: Harmonic losses due converter driven and 3D losses**
- PWM voltage and current
- Additional iron losses
- Eddy current losses in solid parts
• 3D losses and calculations

Module-5: Permanent magnet machine
• Surface-mounted PM machine
• Interior PM machine (IPM) and comparison to PM-SynRM
• Concentrated winding machine and applications

- Technical tour: Big Glenn (GE 4.2MW wind power) and HVDC test facilities, 2 hours.

Module-6: Synchronous reluctance machine
• Introduction of synchronous reluctance machine
• Design of synchronous reluctance machine
• PM-assist synchronous machine

Module-7: High efficiency industrial motors
• Efficiency standard (IEC, NEMA)
• Measurement methods and IEC standards
• Design principle for high efficiency induction motors
• Outlooks for high efficiency VSD motors

- Discussions on the topics of assignments
- Common course dinner in the downtown, 18:00-21:00

Module-8: Measurement of motor efficiency
• Conventional tests (no-load, short-circuit, heat run)
• Test set-up, instrumenting, and data analysis (calculation of losses)
• Loss measurements at different loads and speeds
• Loss balance between motor and converter for optimal system efficiency
• Calorimetric measurement

- Summary and evaluation of the course

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* Notes:
1) Final program on course contents, lecturers, technical tour, and schedules will be fixed on the 28th February 2017. Some small changes from this daft program may exist.
2) This course has been run in May 2015 with 28 participants. The overall satisfactory rate is 4.8/5.0.