KTH Electrical Engineering

EJ2221 Design of permanent magnet synchronous machines

Course description

7.5 ECTS credits, 1st period, autumn 2009

Objectives

The aim of the course is to understand how to make an electromagnetic and thermal design of permanent magnet synchronous machines from any given set of specifications. The knowledge is applied by designing a machine for an industrial application.

Aim

After the course, the student should be able to:

- list different existing topologies of permanent magnet machines.
- describe and compare distributed and concentrated windings.
- explain the principle of field-weakening for permanent magnet synchronous motors.
- choose the appropriate permanent magnet materials for a given construction with regard to functionality, operating conditions, economical and environmental factors.
- explain and compare the properties of iron laminations and soft magnetic composites in relation to their use in electrical machines.
- enumerate different loss components in a machine and relate them to different existing models.
- develop a simple analytical model of the thermal behaviour of a machine taking into account the relevant losses for the application.
- explain all the tasks in the design procedure and apply them to a surface mounted permanent magnet motor with distributed windings with simplified analytical models.
- explain discrepancies between results from different analytical methods through knowledge about the various approximations they are based on.
- describe the concepts of finite element software tools and apply them in the analysis of permanent magnet synchronous machines.
- report and present the results of the design project that has been conducted for a chosen application.
- do a critical evaluation of the report and presentation of the specific studies conducted by the other students.

Pre-requisites and number of students

Electrical Machines and Drives (EJ2200), 7.5 ECTS credits, or equivalent.
The number of participants in the course is limited to 10, due to restricted computer resources and intensive project supervision. The results of EJ2200 will be considered to select participants if the number of pre-registered students is higher than the number of places.

Course examiner and lecturer

Juliette Soulard, room 3323, Teknikr. 33, 1st floor, tel: 070-749 7736, juliette@ee.kth.se

Course head teacher

Stephan Meier, room 3216, Teknikr. 33, laboratory floor, tel: 08-790 7779, stephan.meier@ee.kth.se

Course assistants

Dmitry Svechkarenko, room 3320, tel 08-790 7724, project assistant
Mats Leksell, room 3319, tel 08-790 8135, project meetings

Course material

Course folder “Design of Permanent Magnet Synchronous Machines”, Juliette Soulard, KTH, 2009.

Course web page

Login to Bilda (Ping Pong) with your KTH account at http://bilda.kth.se

All the course documents will be available on the web page. The status reports, opposition reports and power point presentations have to be submitted to the web page in accordance to the course schedule.

Course language and structure

The language of the course is English for all activities.

Six lectures of 2 hours each deal with the common knowledge needed by designers of permanent magnet machines independently of the application.

Two computer-assisted tutorials are scheduled to introduce the web-based educational design tool EMETOR and to investigate how to design motors with concentrated windings.

Due to the nature of the objectives (skills of a working engineer), most of the planned activities in the course are part of a project that is based on an industrial application.

The progress of the project is reported both orally and in written form on a weekly basis to provide training for the oral examination, final report and opposition.

Project work

The project is the core part of the course. Each student works on different tasks that can be linked to one or several applications defined in conjunction with one of the companies working with the division.

Tasks are assigned by the teaching team and can be revised in conjunction with progress meetings. The set of tasks is the same for everybody but different sets of specifications are provided for each student and tasks can be dealt with at different times.

For each **progress meeting**, each student produces a short status report (6 reports should be submitted as stated in the course schedule) to be handed in by **Mondays at 8:00**. The contents of the status report are presented orally (12min maximum) on **Tuesdays,** beginning week 38 (5 times).

Advice on how to improve your reporting skills is given by another student with a written opposition (4 times to train for final opposition) and the teaching team. The tasks to be conducted for the coming week are discussed and agreed upon. It is expected that you actively participate in the discussion on how to solve the difficulties faced by all the students. Your **participation** is only **compulsory for 2 of the 4 hours** of presentations (morning or afternoon session) but you are welcome to participate to both sessions if you wish to.

Project hours are scheduled on Wednesdays, Thursdays, and Fridays. During these sessions, at least one project assistant is available in the project room. Project assistance may also be provided during normal working hours on request if a member of the teaching team is available.

Requirements

To obtain 7.5 credits, you have to pass the following tasks:

- Oral examination and submission of final report (3 ECTS credits)
- 6 status reports (3 ECTS credits)
- 5 presentations, 4 progress oppositions, 1 final opposition (1.5 ECTS credits).

A pdf-version of the **final report** (based on the contents of the weekly reports) has to be **submitted** no later than **Monday 19th of October at 8:00**. The **written opposition** on the final report has to be submitted at the latest by Tuesday 20th of October at 8:00.

The oral examination is scheduled on **Wednesday 21st of October at 10-12:00 and 13-15:00**. It is basically a final project meeting with each student presenting for 15min the completed investigations, followed by 10min of questions from the audience.

Grading

The grading is based on the directives from KTH for the evaluation of Master of Science projects. The process and presentation criteria are exactly the same as for the final project but the criteria have been adapted to the course nature for the engineering-related and scientific content. The course criteria are described in Table 1 (last page).

In order to pass the course, all three criteria must be met with a grade of sufficient or better. All the activities leading to credits are considered. However, the status reports, oppositions and presentations are considered as working material for the evaluation.

The grades A till E are obtained based on the sum of the points collected for each criterion.
A: 21-25 points, B: 16-20 points, C: 11-15 points, D: 6-10 points, E: 3-5 points

A grade Fx is obtained if maximum one of the criteria is insufficient and if the examiner estimates that the lacking skills can be acquired by working on a new project task, together with the submission of a complementary report. If all the three criteria are met with a grade sufficient or better after the submission of the complementary report, grade E is obtained.

According to these directives, the respect of the deadlines is considered in the grading.

Missed progress meetings

If you can not attend one progress meeting, please contact in advance the head teacher by e-mail or telephone. In any case, the complete set of status reports, opposition reports and PowerPoint files to oral presentations has to be handed in.

Work load

7.5 ECTS points = 4 weeks of full-time work = minimum of 160 hours
It is highly recommended and partly compulsory that you attend the course activities. They are planned to help you go through the course contents and organize your learning activities. These represent 69 hours (12 hours lecture, 42 hours of project, 15 hours progress meetings). It means you are expected to work a minimum of 91 hours *on your own or with other students (*average of 13 hours a week during 7 weeks).

The same task may take double as much time for you as for your friends, depending on your and their abilities. Working together is encouraged as long as it is beneficial for every member of the group. If your work load during the course does not seem to match the present description, please feel free to book time with the head teacher to help analyze why and find appropriate remedies.

Opposition

To widen your knowledge, you should be able to critically review another student's work: This is called ***opposition***. The results of the opposition are presented in a written form (opposition report of max. 2 pages). The review should clearly show that you have read the report and familiarized yourself with the content of the report.

The opposition report should at least contain the evaluation of the following points:

- Organization and structure of the report (aim, goal, models, methods, results, conclusions, etc...)
- Consideration of previous work in the report (literature review).
- Used methods.

- Relevance and significance of conclusions drawn in the report.
- The language and graphical presentation of the results.
- A handful of relevant questions (2-5) on the scientific contents of the work to lead a discussion with the presenting student

Guidelines for evaluating the structure of the report, practical aspects of the writing, and the language:

- Does the report contain cover page (with a title, names, student/personal number, course number, etc), abstract, table of contents, introduction, literature study (not obligatory), method, theoretic results, experiment results, discussion, conclusions, future work, references, list of symbols, appendix…?
- Are the units of quantities when listing numbers in text, calculations, tables, or figures specified?
- Does the report have page numbers?
- Do all the figures and tables have a number and a caption?
- Is there a structured outline of the report and are the headings numbered?
- Does the report print well and is easy to read (check especially the figures)?
- Has the report gone through a spell and grammar check?
- Is the past tense used for events that occurred in the past?
- Is the present tense used when discussing general scientific facts or conclusions that are not tied to a particular event?
- Are any first-person pronouns such as *I* and *we* avoided?
- Are sentences short or far too long for the understanding?

Guidelines for evaluating the scientific contents of the report:

- Are the aims and goals clearly stated?
- Are the used methods described?
- Has previous work been considered in the report and has it been clearly referred to when used (plagiarism check)?
- Are the results presented and discussed?
- Are the different parts of the report placed in a logical order?
- Are the conclusions relevant and meaningful?

Language or type errors should not be included in the report but can be appended separately by scanning the report with hand-written corrections.

Table 1: Grading criteria for EJ2221

The student should, for the respective criterion:

Criteria	Process [1]	Engineering-related and scientific content	Presentation [1]
Excellent	• Independently plan and carry out the project within pre-ordained time constraints, have good initiative and be open to supervision and criticism • Independently identify one's own need for new knowledge and assimilate it. • Show a good ability to adopt the perspective of another's work and formulate relevant and constructive criticism. **4-5 points**	• Show a very good ability to apply engineering-related and scientific skills[1] required to design permanent magnet synchronous machines. **11-15 points**	• Show a well disposed report, with clear accounts of the project and the results, clear analysis, and well founded argumentation, as well as good language usage, format and scientific accuracy. • Show a good ability to orally present with clear argumentation and analysis, and also a good ability to discuss the work. **4-5 points**
Good	• Plan and carry out the degree work within the pre-ordained time constraints, show initiative and be open to supervision and criticism. • Show the ability to assimilate new knowledge. • Show the ability to adopt the perspective of another's work and formulate relevant criticism. **2-3 points**	• Show a good ability to apply engineering-related and scientific skills[1] required to design permanent magnet synchronous machines. **6-10 points**	• Show a well disposed report with clear accounts of the project and the results, analysis and argumentation, as well ass good language usage and format. • Show a good ability to orally present and discuss the project. **2-3 points**
Sufficient	• Carry out the project work within the pre-ordained time constraints, show certain initiative and be open to supervision and criticism. • Show a sufficient ability to assimilate new knowledge. • Show the ability to adopt the perspective of another's work and formulate criticism. **1 point**	• Show a sufficient ability to apply engineering and scientific skills[1] required to design permanent magnet synchronous machines. **1-5 points**	• Show a written report with acceptable structure, format and language usage. • Show the ability to orally present the report. **1 point**
Insufficient	• Insufficient respect for agreements, severe lack of independence, or disregard for supervision. Lacks the ability or desire to assimilate new knowledge.	• Significant lack of engineering-related or scientific skills or lack of methodology required to design permanent magnet synchronous machines.	• Lacks important elements in the written report despite the request, or lack of the ability to orally present or discuss the project.

[1]For a non-exhaustive list of these skills, refer to course objectives stated in the course description.

[1] "Evaluation criteria for the degree project", English version of the appendix to KTH-Handbok 2, Flik 15.1.