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COURSE DESCRIPTION

EJ2440 ELECTRIC TRANSPORTATION

Period 4, spring 2023, 6 hp

Transportation of people and gods is fundamental for a modern society. Apart from trains, almost all transportation is driven by fossil fuel like diesel and petrol and is therefore a large source for green-house gas (GHG) emissions. Despite the fact that we cannot explain exactly the effects of the GHG emissions, there is a large consensus that in the long run we will have to move to renewable energy sources. Also the transport sector will have to do this and the enabling technology is likely to rely on electrical solutions. The rail-bound transportation is already to a large extent electrically driven but the road-bound still has a long way to go before it will be substantially less dependent on fossil fuel.

In order to increase flexibility and efficiency of road-bound vehicles, various electrical solutions can be adopted. Both the actual traction system and the sub-systems can benefit from being more or less converted into electrical variants.

This course aims at providing a fundamental understanding of the new technology that will be introduced in the future transportation sector.

Learning outcomes

Aim of the course is to give a broad insight into electrification of both rail and road bound transportation systems.
After completed course the student should be able to

- describe fundamental system issues in electric transportation including e.g. tractive demands and power and energy consumption
- calculate tractive effort, power, acceleration and velocity of rail and road vehicles
- make estimations of voltages, currents and power of electrical drives for electric transportation
- explain the most important electric drives for rail vehicles
- describe generic hybrid topologies
- explain how a hybrid vehicle works and describe its main components and their function
- construct and apply models for electric and hybrid vehicles in order to analyse their performance
- describe the operating principle for energy storage components, such as batteries and super capacitors, and calculate basic performance of them
- describe the design of ac and dc power supplies for electric railway traction
- calculate the power capacity for different railway power supply systems
- describe the background to electromagnetic interference in electric traction.

Examiner

Prof. *Stefan Östlund*, 08 - 790 7745, stefano@kth.se

Course responsible

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Teachers

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Student service support and service centre

For issues concerning your studies you should contact the student service support via the web forms available on EECS's web pages. For practical issues such as access cards, course literature or certificates, please visit one of the service centres.

Course main content

Historical survey

General principles of electric traction and traction systems. Tractive and braking effort. Power requirements and energy consumption

Rail bound vehicles; electric drives, transformers and converters, control and mechanical transmission.

Power supply systems; AC and DC supplies, power capacity, overhead catenary systems, over voltages, line interferences. Electromagnetic compatibility (EMC).

Driving factors for environment friendly transportation

Propulsion and auxiliary systems for conventional light and heavy road vehicles

Propulsion and auxiliary systems for electric and hybrid vehicles

Batteries - energy storage for transportation

Development trends

Course structure

The course is based on lectures, computer exercises and 2 assignments.

Course material

Östlund, S. *Electric Railway Traction*, KTH 2019. The text book will be provided for free at the lectures.

Hybrid drive systems for vehicles - System design and traction concepts. Available on Canvas.

Computer access: The course requires access to Matlab/Simulink.

Assignments

There are 2 compulsory and graded assignments in the course.

1st assignment (individual work, introduced see time schedule)

The first assignment is about the traction drive. It is handed out in the second week of period 4 and can give up to 5 points. This assignment is done on an individual basis. It is not

required to submit an extensive report for this assignment. You should submit your solutions and comments regarding how you have solved the problem.

Deadline for submission of assignment no. 1 can be found on Canvas.

2nd assignment (group work, introduced see time schedule)

The second assignment concerns propulsion systems for hybrid vehicles and can give up to 10 points. This assignment is done in groups of two students. The groups are created by the course responsible and can be found on Canvas. Each student group shall submit a short description via Canvas of how they plan to solve the assignment. The final report for the assignment is also to be submitted via Canvas. The reports will be distributed via Canvas for opposition by other students. All reports are checked for plagiarism.

The reports are limited in size: 12 pages / 4500 words. This limit means that you should not use more than 12 pages (or 4500 words) to report *your own work*, out of which no more than 20-30% should be figures/tables. In principle there is no need to repeat things already covered in the textbook. Cover page, table of contents, references etc. are not included in the 12 pages. Names of students and group number should be placed on every page in the footer. *N.B. You are not allowed to use the KTH logo as a student. So do not put KTH logos on the reports, and not on the presentations*.

The propulsion systems analysed in assignment 2 will be discussed during seminars held toward the end of period 4.

Deadline for submission of assignment no. 2 can be found on Canvas.

Evaluation of the second assignment

The grade on the second assignment is based on: How well is the problem described? How well has the group managed to find and describe the method they use to solve the problem? How successful has the group been in drawing conclusions from their own work?

Seminars

Towards the end of period 4, there will be several time slots available for seminars. At each seminar 2 (or 3) student groups will present and discuss their work. There will be several 2 hour time slots offered for the seminars and you register as a group for one of them via the calendar function in Canvas. The time slots will be published in week 3 of period 4.

Each group has to prepare a 15 minutes presentation of their work and then be prepared to defend and discuss it. Prepare to do the presentation in English but if all participants at a seminar are fluent in Swedish, then Swedish may be used. Projector will be available.

Preparatory work for the seminars

Prepare for a seminar by reading the other group's report(-s) that will be presented during the seminar. Reports and a list of seminar groups will be available via Canvas.

Study the report so that you are able to participate in a technical discussion on it. Furthermore, study also the structure of the report, how well the work is described and how easy it is to understand the content.

Your preparation for the seminar should be summed up in a ***single page summary per report***. A summary should cover:

- Comments on the analysis that the report presents
- Comments on the quality of the written report (outline, structure, readability, grammar etc.)
- Comments to the results given in the report

A ***single page summary*** must have a **HEADER** according to:

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Single page summary of the work by group no: XX (Student 1 and Student 2)
Title of the report: Title of the report of group XX
Summary written by: Your own name
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Deadline for submission of summaries can be found on Canvas.

Furthermore, prior to your seminar send your presentation to leksell@kth.se (just as a precaution).

Examination

TEN1 (4 credits, A-F) Written examination

PRO1 (2 credits, P/F) 2 assignments

The examination consists of two assignments and one written exam. Both the assignments and the written exam contribute to the final grade of the course.

The written exam gives a maximum of 30 points, assignment no. 1 a maximum of 5 points and assignment no. 2 a maximum of 10 points. The total maximum of points is thus 45. At least 20 points is needed to pass the course. The following grade boundaries apply:

00-17 = F
18-19 = Fx
20-24 = E
25-29 = D
30-34 = C
35-39 = B
40-45 = A

Permitted aid during the written exam: calculator.

The written exam is scheduled for Monday May 31st, 14.00-18.00. If possible as in-class written exam but alternatively as Zoom proctored written exam.

Extra support needed

If you have a disability, you may receive support from Funka, KTH's coordinator for students with disabilities, see https://www.kth.se/en/student/studentliv/funktionsnedsattning . Please inform the course coordinator if you have special needs not related to the written exam, and show your certificate from Funka.

Time schedule

The dates for the seminars are tentative. A detailed schedule will be decided in cooperation with the course participants.

Numbered items in italic in the schedule below refer to the corresponding recorded video lecture.

HDS: Textbook *Hybrid Drive Systems for Vehicles - System design and traction concepts*.

L1	20/3 10-12	SÖ	Running resistance, tractive effort, braking effort, adhesion *2.1 Traction mechanics* (and for the interested student: *1. Electrification of railways)*
L2	22/3 10-12	SÖ	Power electronics for propulsion *3.1 Basics of power electronics, 3.2 Voltage source converters*
L3	24/3 10-12	SÖ	Traction motors, general aspects, induction machines, induction motor drives *4.1Mechanical transmission, 4.2 AC Traction motors*. ~~Introduction to Assignment no. 1~~ TBC.
L4	27/3 10-12	SÖ	Control of induction motors, permanent magnets synchronous motors *4.2 AC Traction motors cont., 4.3 Control of induction motor drives, 4.5 PM traction motors*
L5	29/3, 13-15	ML	Why hybridisation, The ideal road-bound vehicle, Simulink. *Introduction, slide hand-out, HDS pp. 1-6*
L6	30/3, 10-12	SÖ	Propulsion systems with Voltage Source Converters *5.2 Control of the line side converters*
L7	3/4, 13-15	ML	Non-ideal vehicle components, The conventional vehicle. *HDS pp. 7-35*
L8	4/4, 10-12	ML	The series hybrid, The parallel hybrid *HDS pp. 35-49* Introduction to Assignment on Hybrid topologies (group work)
CE1	5/4, 10-12	ML/ TA	Computer exercise 1: Ideal and conventional vehicles.
L9	17/4, 13-15	ML	Parallel hybrid, Alternative drive trains *HDS pp. 44-60*
L10	19/4 10-12	SÖ	AC and DC power supplies, power capacity *10.1 AC Power supplies, 10.2 DC Power supplies*
CE2	20, 21/4	ML/ TA	Computer exercise 2: Series and parallel hybrid, Ideal motion profile.
L11	24/4, 13-15	ML	Auxiliary systems *HDS pp. 61-92*
L12	3/5, 13-15	RWL	Batteries I

L13	8/5, 13-15	GL	Batteries II
SEM	15, 17/5	ML	Seminars. (Pre-assigned groups, time slots selected in calendar.)
Exam	2/6, 8-12		Written examination

Outline of material for Rail part

The recorded video lectures have the corresponding number in the textbook for the rail part of the course.

There are pre-recorded videos in Canvas and slide hand-outs are available.

Outline of material for Road part

HDS Hybrid drive systems for vehicles - System design and traction concepts.
Slide hand-outs from lessons.

BAT Excerpt from Handbook of batteries (3rd edition), Linden et al. Available as electronic resource at the library. Chapters 1, 2 (*not* 2.6), 3, 15 and 29 (sec. 5-9)
”In search of the perfect Battery”, The Economist, 6th March 2008.
”Batteries and electrochemical capacitors”, Interface, Spring 2006.
Slide hand-outs from lessons.

Lecture	Content	Reading
4	Why hybridisation, The ideal vehicle, Simulink	Introduction, slide hand-out HDS pp. 1-6
6	Non-ideal vehicle components, the conventional vehicle	HDS pp. 7-35
7	Alternative drive trains, the series hybrid, design aspects, modelling in Simulink	HDS pp. 35-42
8	Case study of the series hybrid, the parallel hybrid, introduction to the complex hybrid	HDS pp. 42-64
10	Auxiliary systems	HDS pp. 64-85
	Energy storage	BAT and over-head slides