NB: The date given in this course description in the first published version on Canvas was unfortunately WRONG! It was stated as 10 Jan without any time given and this is a Sunday.

The correct date is 15 Jan, which has been given in KTH Schedule all the time since the schedule was published in spring -20.

COURSE DESCRIPTION

EJ2410 HYBRID VEHICLE DRIVES

Period 2, autumn 2020, 7,5 credits

There is an increasing demand today to produce environment friendly vehicles with high performance. This can to a large extent be accomplished by electrifying the systems on-board, including the propulsion of the vehicle. This means for example that systems traditionally mechanically driven from the combustion engine will now be supplied from the electrical system. This will increase the efficiency and simplify the physical distribution of loads in the vehicle.

If the propulsion of a vehicle combines the traditional combustion engine and an electrical machine, the vehicles are referred to as “hybrid vehicles”. The introduction of hybrid vehicles requires more knowledge on a system level, both in the design and operation of the vehicles. This course aims at providing a fundamental understanding of the new technology.

Learning outcomes

The aim of the course is to give a broad insight into alternative solutions for conversion of primary energy to transport activity for road vehicles. Different types of fuel (e.g. fossil and bio), different types of conversion methods, different topologies and auxiliary power systems are considered.

After completed course the student should be able to:

- explain how a hybrid vehicle works and describe its main components and their function,
- describe the different hybrid topologies with respect to their functional blocks and their characteristics,
- design and implement both simple and advanced models of the vehicles,
- analyse the performance of a hybrid vehicle,
- build efficiency models of important components,
- evaluate environmental impact of road vehicles,
- calculate basic electrical and thermal properties for power electronic converters,

- describe the operating principle and properties for the most common types of electrical motors in hybrid technology,
- describe the operating principle for fuel cells and energy storage elements and calculate basic performance of them,
- describe the fuel alternatives for hybrid vehicles,
- solve, in a group, a given assignment and both in written form and orally present and discuss the result,
- discuss future trends.

Course main content

Course main content

Vehicles of today – propulsion and auxiliary systems

Driving factors for environment friendly vehicles

Propulsion and auxiliary systems for hybrid vehicles

Generic components

System concepts and simulations

Development trends

Course structure

The course is based on lectures/tutorials, computer exercises and two major assignments. At the end there are two seminars, one laboratory demonstration and written examination divided into two home exams.

Course material

The course material is available via Canvas. Participants are expected to obtain additional information for the projects via other sources too.

There are several animation programmes for electrical machines and power electronics on internet, e.g. http://webfiles.portal.chalmers.se/et/Files/elkraft/Engelsk/start/

Animated engines are e.g. found at http://www.animatedengines.com/.

Computer access: The course requires access to Matlab / Simulink. It is assumed that all students have access to suitable computer facilities. ~~However, during the computer exercises it is possible to use the computers offered in the computer room if that is preferred.~~ KTH offers a possibility to login remotely to computers at KTH so that it is possible to use software on the KTH student computers, please refer to https://remotelab.sys.kth.se/ for further details.

Computer exercises

There are three computer exercises on the system topologies. They will help in understanding the behaviour of the basic hybrid topologies and thereby prepare for the first assignment. It is very important that the models are fully understood during the computer exercises. There is also one computer exercise on power electronics.

The exercises will all be performed online. All students are pre-assigned to certain time slots. An exercise will start with a general introduction of the TA and then students are split into breakout rooms (basically according to group belonging). The participants are then expected to go through the exercise together in the room and the TA will visit now and then to answer questions and discuss difficulties. At the end all students are brought back to the main Zoom room and the TA makes a summary of the exercise.

Remember to download and install Matlab and the toolbox Simulink before the exercise! (As said above, it is also possible to use https://remotelab.sys.kth.se/ but still, make the preparations in advance!

Assignments and student groups

There are two assignments in the course. Course participants are divided into groups of 2 persons. Each student group shall submit a report on their work. The reports will be published in Canvas for opposition by other students. All reports are checked for plagiarism.

The reports are limited in size: 12 pages / 4500 words / 22500 characters. This limit means that the rports should not use more than 12 pages (or 4500 words) to report *the actual work*, out of which no more than 20-30% should be figures/tables. In principle there is no need to repeat things that are 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. Some guidelines for the report are published on Canvas.

N.B. As an under-graduate student it is not allowed to use the KTH logo (this is only allowed for the final thesis); so no logos on reports, no logos on presentations.

Assignment 1: Simulation of a hybrid vehicle on system level. The systems are modelled by map tables. Fuel consumption is a prime characteristic to study.

Assignment 2: Study of hybrid vehicles on component level. In this assignment the actual components and auxiliary systems are further analysed.

Dates for distribution and submission, see Canvas.

Seminars

There are two separate weeks with allocated time slots for seminars on the two assignments. All students will be pre-registered for a seminar but if there are problems will the allocated time slot, get in contact with Mats Leksell.

The purpose of the seminars is to present, defend and discuss the student reports. Active participation in the discussions is expected from all participants.

Each group is expected to give a 15 minutes presentation of their own work. Computer and projector will be available as we hope to have the seminars IRL.

Preparatory work for the seminars

All students have to prepare for the seminars by reading the other reports that will be presented during the respective seminar. A list of seminar groups will be available via Canvas.

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

It is compulsory for every student to individually write a ***single page summary for each respective report***. That means that *each student* shall in total submit 2 x 2 opposition reports. 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 on the results given in the report

There is only one formal rule on the single-page summaries and that is that they at the top must contain: *the name of the student that has written the single-page summary* and the *names of the authors for the discussed report*!

Deadline for submission, see Canvas.

Laboratory demonstration

There is one compulsory laboratory demonstration on a PM motor drive. The demonstration takes place in the *Electrical Machines Laboratory*, Teknikringen 33, 1 floor down.

Registration for the *laboratory demonstration* is done via Canvas.

Deadline for submission of the *preparatory work* is found on Canvas.

Requirements

TEN1 (4,5 credits, A-F)

Written examination. The examination is divided into two parts.
First on 24/11, there is a problem solving part exam where students an individual problem on the analysis of a hybrid topology. It is done as a home exam, details to come.
Second, the allocated time slot in January will be performed as a home exam on the remaining four areas in the course, again, details to come but be aware that the time slot will be fully used.
Standard calculator (no text storage) is the only permitted aid.
N.B. All of the above is based on individual performance so students are assumed to solve the problems on their own, but they are allowed to use the material from the course.

PRO1 (3,0 credits, P/F)

2 reports from the assignments
4 single page summaries for the seminars, 1 for each participating group
Active participation in seminars
1 laboratory demonstration (compulsory preparatory work)

Grading

The written exam can give a maximum of 50 points and the 2 assignments 15 points each, in total 80 points.

36 - 39 p: Fx
40 - 48 p: E
49 - 56 p: D
57 - 64 p: C
65 - 72 p: B
73 - 80 p: A

Evaluation of assignments

The grades on the project reports are 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?

Extra support

In case of disability, support may be received from Funka, KTH's coordinator for students with disabilities, see https://www.kth.se/en/student/studentliv/funktionsnedsattning. Please inform the course responsible of any special needs and show the certificate from Funka.

Teaching staff

Mats Leksell, leksell@kth.se, 070-6025657, Course responsible, main teacher

Stefan Östlund, stefano@kth.se, Examiner

Yixuan Wu, yixuanw@kth.se, TA

Rakel Wreland-Lindström, rakel2@kth.se, Batteries

Carina Lagergren, carinal@kth.se, Fuel cells

Study visit

A study visit to Scania will not ~~hopefully~~ be possible to arrange. We all know the reason ☹

Instead there will be an on-line presentation of the company and their activities, hopefully on the allocated time slot in the Schedule.

Time schedule

Le: Lesson

CE: Computer exercise, ~~Room 2314 *Frances Hugle*, Teknikringen 33, ground floor.~~

Lab: Laboratory work / demonstration, Teknikringen 33 (physical attendance not compulsory)

Sem: Seminars for 3 groups at each time slot, venue: online / Teknikringen 33

Stu: Study visit, virtually to Scania hybrid development group

Le1	26 Oct	Why hybridisation, The ideal vehicle, Simulink
Le2	27 Oct	Non-ideal vehicle components, The conventional vehicle.
Le3	28 Oct	The series hybrid , intro to the parallel hybrid
Extra	28 Oct	Introduction to the basics of Simulink, tbd.
CE1	29 Oct	Comp. ex. 1.Time slot option 1
CE1	30 Oct	Comp. ex. 1. Time slot option 2
Le4	3 Nov	Parallel hybrid, Alternative drive trains
Le5	4 Nov	Alternative drive trains, Auxiliary systems Assignment 1 is handed out.
CE2	4 Nov	Comp. ex. 2. Schedule is published on Canvas.
CE2	4 Nov	Comp. ex. 2. Schedule is published on Canvas.
Le6	5 Nov	Auxiliary systems
CE3	6 Nov	Comp. ex. 3. Schedule is published on Canvas.
CE3	6 Nov	Comp. ex. 3. Schedule is published on Canvas.
Le7	10 Nov	Power electronics
Le8	11 Nov	Power electronics
Stu	11 Nov	Scania, virtual study visit. Tentative date, tbc.
Le9	12 Nov	Power electronics
CE4	13 Nov	Comp. ex. 4. Schedule is published on Canvas.
CE4	13 Nov	Comp. ex. 4. Schedule is published on Canvas.
		Submission of 1st report.

Le10	17 Nov	El. machines and drives
Le11	18 Nov	El. machines and drives
1st Sem.	18-23 Nov	Seminars on 1st assignment. One 2-hour session per group, organised via Canvas.
Le12	19 Nov	El. machines and drives Assignment 2 is handed out.
Le13 / Exam	24 Nov	Written examination 1st part.
Le 14	25 Nov	Batteries and super caps.
Le 15	26 Nov	Batteries and super caps.
Le16	2 Dec	Reserve
		Submission of 2nd report.
Le17	3 Dec	Fuel cells
2nd Sem.	7-10 Dec	Seminars on 2nd assignment One 2-hour session per group, organised via Canvas.
Lab demo	Dec	Dates t.b.d. (Discussion on Canvas.)
Exam	~~10 Jan~~ ERRATA wrong date, should be 15 Jan as given in KTH Schedule!	Written examination, 2nd part.

Outline of reading material

Course participants are assumed to have basic knowledge of electrical engineering. The document "System components – introduction to Electrical engineering" gives a rough idea of what is needed.

Lecture	Content	Reading
1	Why hybridisation, The ideal vehicle, Simulink	Introduction, slide hand-out HDS pp. 1-6
2	Non-ideal vehicle components, the conventional vehicle, case studies	HDS pp. 7-35
3	Alternative drive trains, the series hybrid, design aspects, modelling in	HDS pp. 35-42

	Simulink	
4	Case study of the series hybrid, the parallel hybrid, introduction to the complex hybrid	HDS pp. 42-49
5	The complex hybrid, fuel cell hybrid, Auxiliary systems	HDS pp.49-64
6	Auxiliary systems	HDS pp. 64-85
7	Power electronic, switch-mode conversion, basic circuits and components	HDS pp. 84-91 (important from EE pp. 1-5, 12-22, 32-38) PE pp. 1-9 Numerical example.
8	Dc/dc-conversion, mainly step-down (buck)	PE p. 9-12 (no calculations on boost or ac/dc) Concentrate on the step-down converter when it comes to calculations. There is one numerical exercise for the lecture and one for training at home.
9	Ac/dc-conversion, cooling	PE p. 12-25 (overview) pp. 26-27 (main characteristics) pp. 33-41
10	Electrical machines	EMD pp. 1-10 CTH basic electromagnetic relations
11	Electrical machines	CTH the DC machine EMD pp. 10-18
12	AC machines Electrical drives	EMD pp. 19-44
13,14	Energy storage	BAT and over-head slides
15	Fuel cells	FC

HDS	Hybrid drive systems for vehicles, part 1 - System design and traction concepts
PE	System components – Power electronics 2 papers “Vehicle electronics” and “Automotive electrical systems”
EE	Introduction to electrical engineering
EMD	System components – Electrical machines and drives
FC	Fuel cells – Green power
BAT	Parts of *Handbook of batteries* (4th edition), *Linden* et al. Available as electronic resource at the library. Chapters 1, 2 (*not* 2.6), 3, 15 and 29 (sec. 5-9) , are included. https://www-dawsonera-com.focus.lib.kth.se/readonline/9780071624190 ”In search of the perfect Battery”, The Economist, 6th March 2008 ”Batteries and electrochemical capacitors”, Interface, 2006
CTH	Machine animation: http://webfiles.portal.chalmers.se/et/Files/elkraft/Engelsk/start/ (requires Flash which is not allowed on KTH computers …)
LS	Lecture slides

CE1	The ideal and conventional vehicle
CE2	The series hybrid, ideal motion profile
CE3	The parallel hybrid
CE4	Power electronics – step-down dc/dc converter