COURSE MEMO

EJ2410 HYBRID VEHICLE DRIVES

Period 2, autumn 2025, 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

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 lessons, computer exercises and two major assignments. At the end there are two seminars, one laboratory demonstration and a written examination.

Course material

All course material is available via Canvas.

For the projects, participants are expected to also obtain additional information via other sources.

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.

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.

Please use the exercises to get answers from the TA regarding the simulation models. The TA will also use *Discussions* in Canvas to answer questions but *will not prioritize to* respond to individual e-mails as this is less efficient from the course point of view.

There is also one computer exercise on power electronics.

Please make sure you have access to Matlab and the toolbox Simulink before the exercises.

Assignments and student groups

There are two assignments in the course. Course participants are pre-assigned into groups of 2 persons and the groups are re-arranged for the second assignment. 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 / 22500 characters. This limit means that the reports 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. You register for the seminars via the *calendar* in Canvas.

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

Each group is expected to give a 12-minute presentation of their work. Projector, and if needed computer, will be available.

Preparatory work for the seminars

All students must 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 a template to use for the single-page summaries. (Of course it is allowed to use Latex, but a summary must have the same type of header as the template.)

Deadline for submission, see Canvas.

Laboratory demonstration

There is one laboratory demonstration on electric motor drives. It takes place in the *Sustainable Power Laboratory*, Teknikringen 33, 1 floor down.

Registration for the *laboratory work* is done via Canvas calendar.

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

Requirements

TEN1 (4,5 credits, A-F)
Written examination.

PRO1 (3,0 credits, P/F)
2 reports one for each assignment
Short description of planned efforts for each assignment
2x2 single page summaries for the seminars (1 summary for each participating group)
Active participation in seminars
1 laboratory work (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.

38 - 39 = Fx
40 - 48 = E
49 - 56 = D
57 - 64 = C
65 - 72 = B
73 - 80 = 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 for any special needs and show the certificate from Funka.

Teaching staff

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

Nicholas Honeth, honeth@kth.se, teacher

Stefan Östlund, stefano@kth.se, Examiner

Lukas Böcker, lbocker@kth.se, TA

Björn Eriksson, bjorerik@kth.se, Fuel Cells

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

Study visit

A study visit to Scania Electric and Hybrid Group is hopefulle offered during the course, see KTH Schema for date and time. Registration via Canvas is compulsory. More details to come.

Time schedule

Le: Lesson

CE: Computer exercise

Lab: Laboratory demonstration, Teknikringen 33

Sem: Seminars for 3 groups at each time slot. Venue: Teknikringen 33

Stu: Study visit to Scania Electric and Hybrid Group

Le1	27 Oct	Why hybridisation, The ideal vehicle, Simulink
Le2	28 Oct	Non-ideal vehicle components, The conventional vehicle.
Extra	28/29 Oct, time tbd.	Introduction to the basics of Simulink, for those with NO PREVIOUS EXPERIENCE. Room Sten Velander, 2nd floor. Teknikringen 33.
Le3	29 Oct	The series hybrid, intro to the parallel hybrid
CE1	30 Oct	Computer exercise 1, group 1-9
CE1	31 Oct	Computer exercise 1, group 10-18
Le4	3 Nov	Parallel hybrid, Alternative drive trains
CE2	5 Nov	Computer exercise 2, group 1-9 Assignment 1 is handed out.
CE2	5 Nov	Computer exercise 2, group 10-18
Le5	6 Nov	Alternative drive trains, Auxiliary systems Assignment 1 is handed out.
CE3	6 Nov	Computer exercise 3, group 1-9
CE3	7 Nov	Computer exercise 3, group 10-18
Le6	7 Nov	Auxiliary systems, Charging
Le7	11 Nov	Power electronics
Le8	12 Nov	Power electronics
Le9	13 Nov	Power electronics
CE4	14 Nov	Computer exercise 4, group 1-9
CE4	14 Nov	Computer exercise 4, group 10-12
Le10	17 Nov	El. machines and drives
Le11	20 Nov	El. machines and drives Assignment 2 is handed out
Le12	21 Nov	El. machines and drives.
1st Sem.	24-27 Nov	Seminars on 1st assignment. One 2-hour session per group, register via Canvas calendar.
Le13	25 Nov	Batteries, super caps, fuel cells (/*Reserve*)
Stu	25 Nov	Scania study visit.

Le14	27 Nov	Batteries, super caps, fuel cells (/*Reserve*)
Le15	28 Nov	Batteries, super caps, fuel cells (/*Reserve*)
Le16-18	Tba	(*Reserve*)
2nd Sem.	8-12 Dec	Seminars on 2nd assignment One 2-hour session per group, schedule on Canvas.
Lab demo	10-12 Dec	Dates tbc.
Exam	See Schema	Written examination

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 Simulink	HDS pp. 35-42
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 Video basic electromagnetic relations
11	Electrical machines	Video 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*, *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.
”In search of the perfect Battery”, The Economist, 6th March 2008
”Batteries and electrochemical capacitors”, Interface, 2006

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