ENM061 - Power Electronic Converters 2017
7.5 ECTS

Introduction:

Power electronics deals with the conversion of electrical energy by applying solid state electronics. Power electronic converters can be applied in many different areas such as computers, electric vehicles and power systems. The course presents an introduction to the different circuits used to convert and control electrical energy. It also covers methods for designing converters which in combination with selection of suitable converter topologies, power semiconductors and passive components will give the students a basic knowledge of power electronic converters.

Aim:

The main goal of the course is to make the students familiar with the operating principles of the most common power electronic converter topologies. Basic converter design, analysis of wave-shapes and efficiency calculations are among the items that the students will be able to perform after having participated in the course. The students will perform both simulations using Cadence PSpice as well as experimental work on real DC/DC-converters. The course also lays the foundation for the continuation course 'ENM070 - Power Electronic Devices and Applications'. The items treated in the course are also useful for engineering work in many different areas, e.g. design of power supplies, electric drive systems or power system applications.

Course Material:

Mohan, Undeland, Robbins, Power Electronics - Converters, Applications and Design, Wiley 2003, 3rd ed.
Extra handouts will be given out during the course.

Course Staff:

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Written Examination (6.0 ECTS): Jan. 13, 2018 at 14:00

A written exam at the end of the course decides the final grade (U, 3, 4 or 5). The limits for the grades 3, 4 and 5 are 40%, 60% and 80% of the maximum point, respectively. Only a Chalmers-approved calculator (Casio FX-82..., Texas Instruments TI-30... and Sharp EL-W531) and the attached formula sheet are allowed on the exam. **Registration for the exam (Nov. 22 – Dec. 20/2017) is compulsory to be allowed to sit for the exam.**

Approved Laboratory (1.5 ECTS):

Both practical and PSpice exercises must be completed and approved to obtain a final grade (U or G).

Midterm Exam: Nov. 20/2017 at 8:00

The midterm exam gives bonus points (1, 2, 3, and 4) to be added to the final points of the written exam. The limit for the bonus points are 20%, 40%, 60%, and 80% of the maximum point, respectively. The bonus points are valid for the standard exam and all re-exams one year from the date of the mid-term exam.

Teaching plan and Location:

Lectures and Tutorials:	See course plan for schedule, location HC1.
Consultant hours:	In these occasions, nothing new will be thought. A teacher will be available to answer questions. Check course plan for location (ML2, ML11 and Room 2503).
PSpice Exercises:	Group 1 (13:15 – 15:00) and Group 2 (15:15 - 17:00), Thursdays in E-Studion. Both groups: 12:30 – 13:15 is an occasion for approval of past assignments. Booking is made on the course webpage in Ping-Pong.
Practical Labs:	Buck converter (weeks 46 & 47) and Flyback converter (weeks 47 & 48) in Grundkurslab (Room 3502). Booking is made on the course webpage in Ping-Pong.

Learning outcome (after completion of this course, the student should be able to)

- Determine Fourier components and total harmonic distortion (THD) for basic current and voltage waveforms.
- Recognize the operating principle of the most common active components (e.g. diode, thyristor, IGBT, and MOSFET) as well as the most common passive components (e.g. capacitors, transformers and inductors).
- Explain how pulse width modulation (PWM) works. Describe the purpose as well as the means to control the desired quantity and recognize the need for a controller circuit within the power electronic converter.
- Analyze and perform analytical calculations of ideal DC/DC converters such as the buck, boost, buck-boost, flyback and the forward converter. The operating principles of each topology is differentiated and thoroughly evaluated in both continuous and discontinuous conduction mode by its current and voltage wave-shapes. In addition to this, other topologies (e.g. the push-pull, half-bridge and full-bridge converters) and circuit enhancements (e.g. converter interleaving and active clamp demagnetization) are exemplified.
- Describe the basic operating principles of both single-phase and three-phase AC/DC inverters. Different modulation strategies (e.g. PWM and square wave operation) are implemented and the resulting current and voltage waveforms are evaluated and compared.
- Explain the operation of multilevel converters (e.g. NPC, flying capacitor and MMC topologies) by current and voltage waveform analysis and apply the benefits and drawbacks in terms of harmonics and losses.
- Perform calculations on single- and three-phase diode rectifiers operating with voltage-stiff and current-stiff DC-side. Apply the concept of line impedance within the converter circuit (current commutation) and evaluate the influence.
- Perform calculations on single- and three-phase thyristor rectifiers operating with a current stiff DC-side. Apply the concept of line impedance within the converter circuit (current commutation) and evaluate the influence. Analyze more advanced topologies (e.g. 6-pulse and 12-pulse connections) of the thyristor rectifier and distinguish the benefits and drawbacks.
- Identify simple power electronic converter schematics. Recognize the different parts in a physical circuit on which basic wave-shape and efficiency measurements is performed.

- Determine the losses in both passive and active components. The resulting temperature in the active component is evaluated and an appropriate heat-sink is chosen. Gain a basic understanding of how the lifetime of a component can be determined.
- Utilize the software Cadence PSpice to simulate basic power electronic circuits and the practical labs to have a firsthand experience of how real DC/DC converters operate. The exercises will help to understand the operating principles of the circuits, analyze waveforms, evaluate parameter variations and perform harmonic/Fourier analysis.

PSpice Exercises:

All home assignments must be prepared before each occasion. The simulation files can be downloaded from the course website one week in advance of each occasion.

Study week 1 (W44)	1	A basic power electronic circuit
Study week 2 (W45)	2	Buck and Boost converter
Study week 3 (W46)	3	Flyback converter
Study week 4 (W47)	4	Single-phase inverter
Study week 5 (W48)	5	Three-phase inverter
Study week 6 (W49)	6	Single- and three-phase diode rectifier
Study week 7 (W50)	7	Converter enhancements: Loss analysis and control

Before each PSpice occasion (12.30-13.15) there is an additional time slot for approval of previously completed PSpice tasks (E-Studio). **Please use this to avoid crowding during the lab occasions.**

Practical Labs:

Two practical labs and all home assignments must be prepared before each lab. The lab-PM can be downloaded from the course website one week in advance of each occasion.

Planned and recommended self-study exercises

	Planned tutorial exercises	**Self-study exercises**
Week 44	Tutorial 1 3.3 to 3.5 for Fig. *a* and *g*, 3.7, Extra three-phase problem	1.1, 1.3, 1.5 3.2 and 3.3 to 3.5 for fig b, c, f
	Tutorial 2 Extra Problem and 3.8	
Week 45	Tutorial 3 Extra Problem	7.1, 7.2, 7.3
	Tutorial 4 7.7, 7.8 and Extra Problems	7.9, 7.12
Week 46	Tutorial 5 10.2 and Extra Problems	10.3, 10.4
	Tutorial 6 7.18, extra problems on bridge converters	7.19, 7.22, 10.5, 10.6, 10.7
Week 47	Tutorial 7 8.1, extra problems on single phase inverters.	8.2, 8.3, 8.4
Week 48	Tutorial 8 8.7, 8.10	8.8, 8.11
	Tutorial 9 Extra Problem	
Week 49	Tutorial 10 Exercise 5.4, 5.10, 5.23 and 5.24.	5.5, 5.6, 5.7, 5.8, 5.11, 5.26
	Tutorial 11 Exercise 6.1, 6.12.	6.3, 6.11, 6.15, 6.16, 6.17

Week 50	Tutorial 12 Extra Problem	10.1
	Tutorial 13 Old Exams	Old Exams

Changes from 2016

The following changes are made for 2016 based on the feedback in the course evaluation process and other course improvement actions.

- More blackboard teaching during the lectures.
- More blank pages in the handouts for the students to sketch waveforms during lectures.
- Brief summary and a formula sheet of the important equations at the start of each tutorial.
- Sample theoretical questions at the end of lectures to improve students writing skills for the exams.
- More demand on explanations of the concepts for the approval of the Pspice and practical exercises.
- More detailed coverage as well as complimentary handout on the flyback converter.
- One optional extra consultation time in week 7 of the study period.
- Bonus points for the midterm exam have been changed to (0, 1, 2, 3, and 4) from (0, 2, and 4).

Course plan:

W44	Mon 30 Oct	Tue 31 Oct	Wed 1 Nov	Thu 2 Nov	Fri 3 Nov
08:00 09:45	Lecture 1 (HC1) Review of electronics and Fourier series Ch. 1 and 3.				
10:00 11:45	Tutorial 1 (HC1) Review on electronics, 3-phase, Fourier transforms		Lecture 2 (HC1) Active Components Ch. 2.		
13:15 15:00			Lecture 3 (HC1) Passive Components Ch. 3.	PSpice 1 (E-studio) Basic circuits and Fourier analysis	
15:15 17:00			Tutorial 2 (HC1) Active and passive components	PSpice 1 (E-studio) Basic circuits and Fourier analysis	

W45	Mon 6 Nov	Tue 7 Nov	Wed 8 Nov	Thu 9 Nov	Fri 10 Nov
08:00 09:45	Lecture 4 (HC1) Basic converter principles. Step-down converter. Ch 7.1 to 7.3.				
10:00 11:45	Tutorial 3 (HC1) Step-down converters. Extra Problem 7		Lecture 5 (HC1) The step-up and the buck-boost converter. Ch. 7.4 to 7.5.		
13:15 15:00			Tutorial 4 (HC1) Step-up converters. 7.7, 7.8.	PSpice 2 (E-studio) Buck converter Boost converter	
15:15 17.00			Lecture 6 (HC1) Flyback and isolation. Ch. 10.1, 10.3, 10.4.1 and 10.4.2	PSpice 2 (E-studio) Buck converter Boost converter	

W46	**Mon 13 Nov**	**Tue 14 Nov**	**Wed 15 Nov**	**Thu 16 Nov**	**Fri 17 Nov**
08:00 09:45	Tutorial 5 (HC1) The Buck-boost and the flyback. 10.2 and extra problems.			Practical Lab 1 The Buck Converter Group 3	
10:00 11:45	Lecture 7 (HC1) Forward and intro to H-bridge. Ch. 10.4.3 and Ch. 7.7		Lecture 8 (HC1) Half-bridge and full-bridge Ch. 10.4.4, 10.4.5 and 10.4.6		
13:15 15:00	Practical Lab 1 The Buck Converter Group 1		Tutorial 6 (HC1) Bridge converters 7.18 and extra tasks	PSpice 3 (E-studio) Flyback converter	
15:15 17.00			Consultation Time (ML2)	PSpice 3 (E-studio) Flyback converter	
17:15 21.00		Practical Lab 1 The Buck Converter Group 2			

W47	**Mon 20 Nov**	**Tue 21 Nov**	**Wed 22 Nov**	**Thu 23 Nov**	**Fri 24 Nov**
08:00 09:45	Mid Term Exam (HC1)			Practical Lab 2 The Flyback Converter Group 1	
10:00 11:45	Lecture 9 (HC1) Single Phase Inverters Ch. 8.1 to 8.3.		Tutorial 7 (HC1) Single phase inverters. 8.1 and extra		
13:15 15:00	Practical Lab 1 The Buck Converter Group 4		Lecture 10 (HC1) Three Phase Inverters. Ch. 8.4 to 8.7.	PSpice 4 (E-studio) Single-phase inverter	
15:15 17.00			Consultation Time (ML11)	PSpice 4 (E-studio) Single-phase inverter	
17:15 21.00		Practical Lab 1 The Buck Converter Group 5			

W48	**Mon 27 Nov**	**Tue 28 Nov**	**Wed 29 Nov**	**Thu 30 Nov**	**Fri 1 Dec**
08:00 09:45	Tutorial 8 (HC1) Three phase inverters. 8.7, 8.10			Practical Lab 2 The Flyback Converter Group 5	
10:00 11:45	Lecture 11 (HC1) Multilevel inverters		Tutorial 9 (HC1) Multilevel inverters		
13:15 15:00	Practical Lab 2 The Flyback Converter Group 2	Practical Lab 2 The Flyback Converter Group 3	Lecture 12 (HC1) Single phase diode rectifiers. Ch. 5.1 to 5.3.3, 5.5., (18.6.2)	PSpice 5 (E-studio) Three-phase inverter	
15:15 17.00			Consultation Time (ML11)	PSpice 5 (E-studio) Three-phase inverter	
17:15 21.00		Practical Lab 2 The Flyback Converter Group 4			

W49	**Mon 4 Dec**	**Tue 5 Dec**	**Wed 6 Dec**	**Thu 7 Dec**	**Fri 8 Dec**
08:00 09:45	Lecture 13 (HC1) Three phase diode rectifiers. Ch. 5.6.				
10:00 11:45	Tutorial 10 (HC1) Single and three phase diode rectifiers. 5.4,		Lecture 14 (HC1) Single Phase Thyristor rectifiers. Ch. 6., (17.2.1)		
13:15 15:00			Lecture 15 (HC1) Three Phase Thyristor rectifiers. Ch. 6.	PSpice 6 (E-studio) Diode rectifier	
15:15 17.00			Tutorial 11 (HC1) Thyristor rectifiers. 6.1, 6.12.	PSpice 6 (E-studio) Diode rectifier	

W50	**Mon 11 Dec**	**Tue 12 Dec**	**Wed 13 Dec**	**Thu 14 Dec**	**Fri 15 Dec**
08:00 09:45	Lecture 16 (HC1) Converter Improvements Ch. 10.5.				
10:00 11:45	Lecture 17 (HC1) Temperature Control and component lifetime Ch. 29.		Tutorial 12 (HC1) Losses and temperature control		
13:15 15:00			Lecture 18 (HC1) Repetition	PSpice 7 (E-studio) Converter enhancements	Extra Consultation (Fredrik Lamm room Room 2503)
15:15 17.00			Tutorial 13 (HC1) Old Exams	PSpice 7 (E-studio) Converter enhancements	

W1	**Mon 1 Jan**	**Tue 2 Jan**	**Wed 3 Jan**	**Thu 4 Jan**	**Fri 5 Jan**
08:00 09:45					
10:00 11:45					
13:15 15:00					
15:15 17.00					