COURSE DESCRIPTION

EJ2311
MODULATION OF POWER ELECTRONIC CONVERTERS
6 credits, 3rd period, spring 2021

Introduction
Modulation of power converters plays a decisive role in modern power electronics where low losses as well as dynamical requirements, harmonics and electromagnetic interference (EMI) are of great importance. The purpose of the course is to provide a solid working understanding of modern synthesis and analysis methods of modulation for voltage source converters.

Course Objectives
After the examination the successful student should be able to:

- Apply Fourier series expansions to analyze arbitrary periodic signals in the frequency domain.
- Compute all electrical quantities in symmetric LTI three-phase networks when these are energized by periodical three-phase sources (asymmetric sinusoidal and symmetric non-sinusoidal).
- Apply waveform symmetries to identify spectral components in periodic signals.
- Compute common figures of merit to quantify the harmonic distortion of periodic signals, notably THD.
- Design carrier based pulse width modulators for single and polyphase voltage source converters (with natural or regular sampling).
- Explain the effect of phase shifting the carrier and reference on the harmonic components resulting from PWM in phase and line-line quantities.
- Describe different kinds of zero-vector placement in three-phase carrier-based PWM.
- Explain the operation of simple space vector modulator and explain the analogies with carrier-based modulators
- Determine suitable sets of eliminated harmonics to be used in selective harmonic elimination for different applications and compute the corresponding switching angles.
- Explain the qualitative differences between carrier-based and programmed PWM with regard to harmonic and dynamic properties.
- Conceptually design and simulate simple direct torque control systems, including derivation of the switch table.
- Draw schematics of the most common multi-level power converter topologies and explain their operation. Describe the impact on the harmonic spectra of increasing the number of levels in the waveform. Describe the synthesis of different types of carrier-based multilevel waveforms.

Due to the COVID-19 situation, most of the teaching will take place online this year, with the sole exception of the laboratory exercises.

Lectures
There are in total 16 hours of lectures. Attendance is not compulsory but should be a good help in understanding the contents of the course. Lectures are given in English. To get the best benefit from the lectures it is strongly advised to read the relevant parts of the course book in advance.

Tutorials
During the course six 2h tutorials will be given. The main objective of the tutorials is to show how problems can be solved and to prepare for the written examination. Typically, the problems are solved by a teaching assistant in interaction with the students.

Computer exercises
There are two computer exercises demonstrating the use of computers and numerical methods in the synthesis and analysis of converter modulation patterns. Ahead of the first exercise, a preparatory work has to be carried out. The preparatory work is handed out during the first lecture and should be handed in at the beginning of the first computer exercise. The results from the two computer exercises are to be uploaded to canvas for examination. Each report will be discussed in an oral session of approximately 30 minutes. Both reports must be judged passed in order to fulfil the course requirements.

Laboratory exercise (compulsory)
There is one laboratory exercise demonstrating practical aspects of power converter modulation. The laboratory report must be judged passed in order to complete the course requirements.

Requirements
In order to pass the course, the student has to complete the two computer exercises, the laboratory exercise and a written exam. Registration for the exam is compulsory and can be done via the course web. Date: Monday 15/3, 14-18, Online

Course responsible
Staffan Norrga, norrga@kth.se

Lecturers
Staffan Norrga. Lectures 1-5, 8
Hans-Peter Nee Lectures 6, 7

Tutorials
Mehrdad Nahalparvari, mnah@kth.se

Computer exercises
Mehrdad Nahalparvari, mnah@kth.se

Laboratory exercise
Mehrdad Nahalparvari, mnah@kth.se

Student Office
On-line at the EECS homepage:
https://www.kth.se/en/eecs/kontakt/studentexpedition-eecs

Course material
Holmes, Lipo: Pulse Width Modulation for Power Converters, Wiley-Interscience, (0471-20814-0, 2003). Available on-line from the KTH library for KTH students at the link:
https://kth-primo.hosted.exlibrisgroup.com/permalink/f/1vh8pa3/TN_cdi_ieee_books_5264450

News and Web-links
Via Canvas

Time schedule

w. 3

Lecture 1. Monday 18/1, 13 - 15, Online

Repetition and basics	1.1-1.6
Harmonic distortion	2.1-2.5, 2.9

Preparatory work for computer exercise 1 is handed out

Lecture 2. Wednesday 20/1, 13 - 15, Online

Carrier based modulation methods, overmodulation	3.1-3.6, 8.2
Carrier PWM for single-phase converters	4.1-4.5

Tutorial 1. Friday 22/1, 10-12, Online

w. 4

Lecture 3. Tuesday 26/1, 15 - 17, Online

Carrier PWM for three-phase converters	5.1-5.3, 5.5, 5.6
- zero vector placement	6.1, 6.6, 6.7, 6.10
Harmonic elimination methods	9.2

Tutorial 2. Wednesday 27/1, 13–15, Online

Computer Lab 1. Friday 29/1, 09 - 11, Online

Please submit your solution to preparatory work

w. 5

Lecture 4. Wednesday 3/2, 13–15, Online Handouts

Tolerance-band methods

Tutorial 3. Friday 5/2, 13 - 15, Online

w. 6

Lecture 5. Tuesday 9/2, 15 - 17, Online

Multilevel modulation methods

- multilevel converter topologies	1.8
- carrier based methods	11.1, 11.3, 11.12,12.1,12.2
- harmonic elimination	10.1-10.3

Tutorial 4. Wednesday 10/2, 13 - 15, Online

Laboratory exercise, Group 1. Thursday 11/2, 8 - 12, EPE Student Laboratory *

Laboratory exercise, Group 2. Friday 12/2, 13 - 17, EPE Student Laboratory *

w. 7

Laboratory exercise, Group 3. Tuesday 16/2, 13 - 17, EPE Student Laboratory *

Lecture 6. Wednesday 17/2, 13 - 15, Online

Impact of harmonic distortion on electrical machines Handouts

Tutorial 5. Thursday 18/2, 10 - 12, Online

Computer Lab 2. Friday 19/2, 10 - 12, Online

w. 8

Lecture 7. Wednesday 24/2, 13 - 15, Online

Torque pulsations, Insulation aspects, Acoustic noise, Electromagnetic interference Handouts

w. 9

Computer Lab 3. Monday 1/3, 13 - 15, Room 2314 at Teknikringen 33

Lecture 8. Wednesday 3/3, 13 - 15, Online
Harmonic filtering, Summary

Tutorial 6. Friday 5/3, 13 - 15, Online

w. 11

Examination Monday 15/3, 14-18, Online

* at Teknikringen 33, bottom floor