COURSE DESCRIPTION

EJ2311
MODULATION OF POWER ELECTRONIC CONVERTERS
6 credits, 3rd period, spring 2025

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.
- Explain the operation of a simple space vector modulator and explain the analogies with carrier-based modulators.
- Describe different kinds of zero-vector placement in three-phase PWM.
- 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.

Lectures
There are eight two-hour 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 two-hour 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 assignments demonstrating the use of computers and numerical methods in the synthesis and analysis of converter modulation patterns. Ahead of the first assignment, a preparatory work

must 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 assignment. The results from the two computer assignment 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 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 to complete the course requirements.

Requirements
To pass the course, the student must complete the two computer assigments, the laboratory exercise and a written exam. Registration for the exam is compulsory and can be done via the course web. Date: Tuesday 11/3, at 1400-1800 in room K51.

Course responsible
Staffan Norrga, norrga@kth.se

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

Tutorials, Computer exercises, and Laboratory exercise
Enes Ayaz, enesa@kth.se

Student Office
On-line at the EECS homepage:
https://intra.kth.se/eecs/vs-stod/servicecenter

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://ieeexplore.ieee.org/book/5264450

News and Web-links
Via Canvas

Time schedule and reading guideline

w. 3

Lecture 1. Tue 2025-01-14, 15 - 17, room Ivar Herlitz*

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. Wed 2025-01-15, 13 – 15, room E36

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

Tutorial 1. Fri 2025-01-17, 8–10, room Sten Velander*

w. 4

Lecture 3. Mon 2025-01-20, 10–12, room Ivar Herlitz*

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. Tue 2025-01-21, 15-17, room K53

Computer Lab 1. Thu 2025-01-23, 10–12, room Frances Hugle*

w. 5

Lecture 4. Mon 2025-01-27, 10—12, room Sten Velander *

Tolerance-band methods	Handouts

Tutorial 3. Thu 2025-01-30, 15–17, room Ivar Herlitz *

w. 6

Lecture 5. Mon 2025-02-03, 10–12, room Ivar Herlitz *

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. Tue 2025-02-04, 10 - 12, room Ivar Herlitz *

Laboratory exercise, Group 1. Thu 2025-02-06, 8 - 12, Sustainable Power Lab*

Laboratory exercise, Group 2. Fri 2025-02-07, 8 - 12, Sustainable Power Lab *

w. 7

Laboratory exercise, Group 3. Mon 2025-02-10, 8 - 12, Sustainable Power Lab *

Lecture 6. Tue 2025-02-11, 15 - 17, room Sten Velander*

Impact of harmonic distortion on electrical machines	Handouts

Tutorial 5. Wed 2025-02-12, 13 - 15, room Sten Velander*

Computer Lab 2. Thu 2025-02-13, 15 - 17, room Frances Hugle*

w. 8

Lecture 7. Fri 2025-02-21, 8 - 10, room Sten Velander *
Torque pulsations, Insulation aspects, Acoustic noise, Electromagnetic interference — Handouts

w. 9

Tutorial 6. Mon 2025-02-24, 10 - 12, room Ivar Herlitz *

Computer Lab 3. Thu 2025-02-27, 10 - 12, room Frances Hugle*

w. 10

Lecture 8. Mon 2025-03-03, 15 - 17, room K53
Harmonic filtering, Summary — Handouts

w. 11

Examination Mon 2025-03-10, 14-18, room K51

* rooms at Teknikringen 33 (The laboratory is in the basement)