SYLLABUS

Name: ***Power Electronics (MakAu>SM1PE-E-19)***
Name in Polish:
Name in English: ***Power Electronics***

Information on course:

Course offered by department: Faculty of Automatic Control, Electronics and Computer Science
Course for department: Silesian University of Technology

Default type of course examination report:

ZAL

Language:

English

Course homepage:

https://platforma2.polsl.pl/rau3/course/view.php?id=379

Short description:

The aim of the lecture is to provide students with knowledge concerning the requirements for low and medium power DC and AC supplying systems based on up-to-date standards, presenting their basic parameters, normative requirements for electricity suppliers and its customers, power issues in systems with non-sinusoidal power consumption, discussion of magnetic materials used in power electronics systems, presentation of characteristics of typical switching semiconductor devices used in these systems, presentation of switching mode DC / DC and DC / AC voltage converters design methods, used in uninterruptible power supply systems, discussion of the problem of discrete control in DC/DC and DC/AC converters, architecture and properties of basic voltage-fed impedance networks and methods of their design, discussion of power factor correction systems and active power filters. Presentation of photovoltaic power conversion systems.

Description:

Lectures:
Introduction - What is Power Electronics? What is lecture about? Basic grups of power converters. Why only switching mode power conversion is acceptable? Storing energy in inductors and capacitors. Magnetic field energy in the choke core. Electric field energy in capacitor. Two main groups of power supplies: DC and AC power supplies. DC power supply parameters. Parameters of the AC Power Supply. The presentation of basic standards concerning parameters of the AC voltage power supplies: IEC 62040-3:2011, IEC 61000-2-2:2003, 6.3. IEC 61000-3-2 Ed. 5.0 b:2018, 6.4. EN 50160, IEEE Standard 446, IEEE Std 519-2014 (Revision of IEEE Std 519-1992). Types of UPS systems configurations according to EN 62040-3/Annex A. Examples of UPS operation according to EN 62040-3/ Annex B. The other UPS classifications - VSI, VI and VFD. Basic architecture of UPS – with the transformer and transformer-free (transformerless).

Electric power definitions: background. Electric power definitions in the single-phase systems under sinusoidal conditions. Voltage and Current Phasors and Complex Impedance under the sinusoidal conditions. Complex Power and Power Factor. Concepts Of Power Under Nonsinusoidal Conditions - Conventional Approaches. Power Definitions by Budeanu (established in the frequency domain) 1927. Power Definitions by Fryze (time domain power theory). Electric Power in Three-phase Systems. Classifications of Three-Phase Systems. Power in Balanced Three-Phase Systems. Power in Three-Phase Unbalanced Systems. The instantaneous power theory. Basis of the p-q Theory. The Clarke transformation. Three-Phase Instantaneous Active Power in Terms of Clarke Components. The instantaneous Powers in the p-q Theory. The p-q theory in three-phase, three-wire systems. Comparision with the conventional theory. Use of the p-q theory for shunt current compensation. Some remarks on the p-q theory in three-phase, four-wire systems.

Analysis of magnetic circuits. Line transformers. Magnetic materials used in magnetic circuits of voltage converters and characteristics of their properties. Designing of transformers and chokes. Capacitors used in voltage converters and their most desirable properties.

Families of semiconductor power devices in power electronics systems. Basic parameters of high-power semiconductor devices. Types and parameters of power diodes. Types of controllable semiconductor devices. MOS power transistors - VDMOS. Driving MOS power transistors. Bipolar transistor with isolated gate - IGBT. Driving IGBT transistors. Comparison of parameters of MOS type elements manufactured in various technologies - Si, SiC and GaN. High power GTO switching thyristors. A brief overview of other niche switching elements.

Discussion of switching mode DC/DC voltage converters in which the energy flow is unidirectional, the voltages have a constant polarity, and the currents are unidirectional. General principles for calculation of DC/DC converters in steady state. DC/DC converters without galvanic type isolation, “buck” decreasing voltage, "boost" increasing voltage and "buck-boost" reversing voltage - their variants and modes of operation with continuous and discontinuous current flow through the choke. SEPIC DC/DC converter and Cuk converter. Inverters with galvanic isolation: forward and flyback. Small signal modelling of DC/DC converters (the method of averaged state space).

The voltage source inverters types and their parameters. Simple single-phase, three-pulse voltage source inverters. Optimization methods of puls width modulation - techniques for optimization of switching angles. Two- and three-level PWM modulation. Basic schemes of three-level PWM modulation. Natural and regular PWM single- and double-edge modulation. The basic regular symmetrical 3-level PWM. Harmonics elimination technique. Spectrum of unfiltered PWM signal with constant frequency of modulating signal. PWM signal including dead time. The output filter LFCF of the voltage source inverter design. Analysis of inverter output voltage distortion with nonlinear rectifier ROCO load. Three-phase inverters and their control. SV PWM modulation in a two-level and three-level 3-phase inverter. Multilevel inverters.

The continuous small-signal model of the inverter obtained from the Bode plots of the inverter. Two approaches to obtaining a discrete inverter model. Selection of exemplary control systems (SISO and MISO) of the voltage source inverter taking into account the real parameters of the inverter. Basic voltage-fed impedance networks - their architecture, properties and control in one- and three-phase systems. Z-Source impedance network design. The influence of the impedance network on the properties of the connected voltage source inverter.
Compensation of the reactive power and the distortion power. Power factor correction (PFC) systems. Parallel and serial active power filters in single and three-phase systems. Different methods of their control using different power theories.

Photovoltaic Power Conversion Systems. PV panels. The I-V characteristics of a PV string. Effect of shading on PV cell from a string. Hot spotting. Maximum Power Point Tracking (MPPT) methods. Three configura-tions to organize and transfer the PV power to the grid. PV inverter topologies. PV systems grid-connection demands. Control Structure for Single Phase and Three Phase Grid Connected Systems. Grid Monitoring and Synchronization in Single-Phase Systems.

Laboratory:
The static and dynamic properties of voltage source inverters devoted for UPS systems

Laboratory exercise 4 hours
The single-phase voltage source inverter devoted for UPS systems – PWM, voltage and current waveforms, standard loads.
1. Introduction to the voltage source inverter laboratory model
2. Design of an output inverter filter for a given nominal load; measurement of filter capacitance, inductance and the equivalent serial resistance of inverter filter choke using laboratory equipment for different frequencies (at the maximum voltage available in the laboratory equipment).
3. Observation of inverter operation with three basic schemes of 3-level PWM modulation; observation of the control voltage and output voltage, choke current and output current waveforms for the chosen static linear load. Using a digital oscilloscope to store waveforms as a graphic file *.bmp
4. Measurement of total harmonic distortion THDVOUT coefficient of the inverter output voltage for the 3rd modulation scheme and static load resistances
5. Evaluation of the inverter output voltage waveforms for the step resistive load increase and decrease.
6. Calculation and measurement of the power factor for the standard non-linear RC rectifier load
7. Matlab/Simulink simulation of linear, dynamic linear and static non-linear loads (demonstration using ready simulation schemas)
8. Measurements of the inverter with the output transformer (demonstration).

Laboratory excercise 4 hours
Increasing the inverter DC input voltage - using impedance networks with discontinuous input current (DIC) and continuous current drawn from a DC voltage source (CIC).
1. Basic calculations of Z-Source network parameters
2. Simulation of the inverter with the Z-Source network in the Matlab/Simulink program (demonstration using ready simulation diagrams).
3. Observation of current and voltage waveforms in the Z-Source experimental model.
4. Measurements of the THDVOUT distortion coefficient dependence, the efficiency dependence and the real voltage gain as a function of the shoot-through time of the inverter with the Z-Source impedance network (ZSI – Z-Source Inverter).
5. Repetition of measurements for the qZ-Source impedance network.

Laboratory excercise 4 hours
Dynamic properties of the voltage source inverter. The measurement of the Bode plots of control function of the voltage source inverter and the adjustment of the control systems.
Własności dynamiczne falowników napięcia. Pomiar charakterystyk częstotliwościowych funkcji sterowania falownika napięcia i dobór układów regulacji
1. Scaling voltage and output current measurements of the inverter
2. Measurements of the Bode plots of the inverter control transfer function
3. Selection of the PI-SISO regulator parameters using the Matlab program.
3. Simulation of the inverter operation with the PI-SISO regulator, deadbeat-MISO, version of the Passivity-Based-Control-MISO controller (eg IPBC2) in the Matlab/Simulink program (demonstration using ready simulation schemas).
4. Implementation of PI-SISO, deadbeat-MISO and PBC-MISO regulators in the laboratory model and evaluation of their effectiveness for standard loads
5. Analysis of the influence of the input impedance network on Bode plots of the inverter

Laboratory excercise 3 hours
Three-phase inverters PWM and SVM control based on Clarke transform. Analysis of the control voltages in PWM and SVM control. Analysis of the phase and line to line voltages in PWM and SVM control.

Number of hours of classes with direct participation of academic teachers or other persons teaching courses and students
Contact hours
Lecture: 15h
Laboratory: 15h
Lecture credit: 2h
Project credit: 2h

Student's own work
Preparation for lecture credit: 5h
Laboratory raports preparation: 20h
Total workload: 59h
Number of ECTS credits: 2
including
Number of ECTS credits covered by the study programme to be earned as part of the courses taught with the direct participation of academic teachers or other persons teaching courses and students: 1.36

Bibliography:

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[3] M. H. Rashid “Power Electronics Handbook”, Elsevier - , 2017
[4] M. K. Kazimierczuk “High-Frequency Magnetic Components”, ISBN: 978-1-118-71779-0, John Wiley & Sons, 2013

[5] F. L. Luo, Hong Ye, M. Rashid “Digital Power Electronics and Applications”, ISBN: 0-1208-8757-6, Elsevier Academic Press, 2005
[6] Y. Yang, K. A. Kim, F. Blaabjerg, A. Sangwongwanich "Advances in Grid-Connected Photovoltaic Power Conversion Systems", Woodhead Publishing Series in Energy, 2019.
[7] U. Tieze, Ch Schenk, E. Gamm “Electronic Circuits Handbook for Design and Application”, Springer 2008
[8] R. Erickson “Fundamentals of Power Electronics”, Kluwer Academic Publishers New York, Boston, Dordrecht, London, Moscow, 2004
[9] N. Mohan „Power Electronics and drives” MNPERE, Minneapolis, USA, 2003.
[10] Z. Rymarski „Jednofazowe i trójfazowe inwertery napięcia stosowane w systemach UPS”, Monografia habilitacyjna, Wydawnictwo Politechniki Śląskiej, 2010
[11] “Transformer UPS vs. Transformerless” UPS EmersonNetworkPower.com, 2018
[12] IEC 62040-1:2017 Uninterruptible power systems (UPS) - Part 1: Safety requirements
[13] IEC 62040-3:2011 Uninterruptible power systems (UPS). Part 3: Method of specifying the performance and test requirements
[14] EN 50160-2002 Voltage Characteristics in Public Distribution Systems
[15] IEEE Std 519-2014 - IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems
[16] IEC 61000-2-2 Ed. 2.2 b:2018 - Electromagnetic compatibility (EMC) - Environment - Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems
[17] IEC 61000-3-2:2018 Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current ≤16 A per phase)
[18] IEEE Standard 446 (Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications - Orange Book)
[19] Z. Rymarski, K. Bernacki: “Drawbacks of impedance networks”, International Journal of Circuit Theory and Applications 2018, vol. 46 issue 3, pp. 612-628, DOI: 10.1002/cta.2395, IF=1.571.

Learning outcomes:

K2A_W07
Design of the low and medium power supply systems based on the up-to-date European standards and definitions

K2A_U06

Assessment methods and assessment criteria:

Lectures - Partial written tests (or in electronic form) or the final collective written test (or computer test).
Passing criteria: minimum 50% of the maximum score of points.
Laboratory - Creating four laboratory reports and submission of them with discussion.

Element of course groups in various terms:

Course group description	First term	Last term
missing group description in English (MakAu>SM1-E-19)	2020/2021-L	

Course credits in various terms:

<without a specific program>

Type of credits	Number	First term	Last term
European Credit Transfer System (ECTS)	2	2020/2021-L	