

FACULTY OF ELECTRICAL  
ENGINEERING**SUBJECT CARD**

Name in Polish: **Automatyka napędu elektrycznego - zagadnienia wybrane**  
 Name in English: **Controlled Electrical Drives - selected problems**  
 Main field of study (if applicable): **Control Engineering and Robotics**  
 Specialization (if applicable): **Automation of Machines, Vehicles and Apparatus**  
 Level and form of studies: **2nd level, full-time**  
 Kind of subject: **obligatory**  
 Subject code: **ARR043218**  
 Group of courses: **NO**

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU):	30		30		
Number of hours of total student workload (CNPS):	120		60		
Form of crediting:	examination		crediting with grade		
For group of courses mark (X) final course:					
Number of ECTS points:	4		2		
including number of ECTS points for practical (P) classes :			2		
including number of ECTS points for direct teacher-student contact (BK) classes:	2.80		1.40		

**PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES**

1. Has knowledge in the control theory (basics), informatics and fundamentals of electrical drives.

**SUBJECT OBJECTIVES**

- C1. Consolidate knowledge and/or filling the knowledge gap in the field of torque control of the DC and AC (induction and PMSM) motor drives.
- C2. Familiarizing students with the extended knowledge on the application of advanced control theory methods in controlled converter-fed motor drives, including sensorless, adaptive, predictive and sliding-mode control methods.
- C3. The acquisition of practical knowledge and skills for design, testing and analysis of advanced control structures for DC and AC motor drives, including sensorless drives.
- C4. Perfecting skills for the understanding, analysis and interpretation of steady-state and transient processes in chosen controlled DC and AC drive systems.
- C5. Acquisition and fixing the social competences related to work in teams, solving engineering problems together; responsibility, honesty and fairness, observance of manners which are obligatory for academia and society.

**SUBJECT EDUCATIONAL EFFECTS***relating to knowledge:*

- PEK\_W01 Has matured knowledge on the basic torque and speed control methods of the DC motor drives and vector control methods of AC motor drives and active rectifiers (AC/DC converters).
- PEK\_W02 Has matured and in-depth knowledge on modern control methods of complex DC and AC motor drives, including basis of sensorless, adaptive, sliding and predictive control.
- PEK\_W03 Can define and describe basic control methods and structures for DC motors, induction motors, brushless DC and AC motors, and characterize their performance.

*relating to skills:*

- PEK\_U01 Can realize the simulation tests of chosen controlled electrical drive in Matlab/Simulink environment using delivered software and can make analysis of the obtained results.
- PEK\_U02 Can realize the experimental tests of chosen controlled electrical drive in laboratory set-up and can make analysis of the obtained results

*relating to social competences:*

- PEK\_K01 Student can act independently and cooperate within a group working on a complex engineering project.

## PROGRAMME CONTENT

Form of classes - lecture		Number of hours:
Lec 1	Introduction. Cascade control structure - advantages and disadvantages. PI/PID controllers - performance, design criteria. Saturation phenomenon and anti-wind-up solutions.	2
Lec 2	Vector control in converter fed drives - consolidate knowledge and/or filling the knowledge gap on the field-oriented control (DFOC, IFOC) and direct torque control (DTC-ST, DTC-SVM) of the induction motors.	2
Lec 3	Vector control in converter fed drives - consolidate knowledge and/or filling the knowledge gap on the field-oriented control (FOC) and direct torque control (DTC-ST, DTC-SVM) of the synchronous permanent magnet motors.	2
Lec 4	Vector control methods in converters (AC/DC active rectifiers) and in converter-fed AC drives - similarities to vector control methods of AC motors, specific features. Part 1.	2
Lec 5	Vector control methods in converters (AC/DC active rectifiers) and in converter-fed AC drives - similarities to vector control methods of AC motors, specific features. Part 2.	2
Lec 6	Sensorless drives - estimation methods for feedback signals of AC motor drives. State variables estimators - classification and theoretical backgrounds.	2
Lec 7	Sensorless drives - state variables estimators - classification. Design of the Luenberger observers and Kalman filter for chosen dynamical systems.	2
Lec 8	MRAS-type estimators and neural network-based estimators for AC motor drives. Application examples.	2
Lec 9	Adaptive control - classification, design, application examples.	2
Lec 10	Sliding-mode control - theoretical backgrounds. Sliding-mode control of the induction motor - direct and cascade control concepts. Part 1.	2
Lec 11	Sliding-mode control - theoretical backgrounds. Sliding-mode control of the induction motor - direct and cascade control concepts. Part 2.	2
Lec 12	Predictive control - theoretical background, predictive controller structure, performances, examples of application in power electronics and drives. Part 1.	2
Lec 13	Predictive control - theoretical background, predictive controller structure, performances, examples of application in power electronics and drives. Part 2.	2
Lec 14	Control structures for drive systems with elastic couplings: structures with additional feedbacks and with the state controller - design, performance. Control of the systems with nonlinear friction and backlash. Part 1.	2
Lec 15	Control structures for drive systems with elastic couplings: structures with additional feedbacks and with the state controller - design, performance. Control of the systems with nonlinear friction and backlash. Part 2.	2
Total hours:		<b>30</b>

Form of classes - laboratory		Number of hours:
Lab 1	Introduction. Modeling of basic drive system elements using Matlab/Simulink -repetition.	2
Lab 2	Simulation tests of the cascade control structure for chosen dynamical object. Application of different design methods for the PI/PID controllers. Anti-windup systems.	2
Lab 3	Testing of the PWM techniques, including space vector modulator SVM for a voltage inverter-fed induction motor.	2
Lab 4	Testing of the vector control methods for the induction motor - comparison of the FOC and DTC methods. Part 1.	2
Lab 5	Testing of the vector control methods for the induction motor - comparison of the FOC and DTC methods. Part 2.	2
Lab 6	Testing of the vector control method for AC/DC converter and the induction motor drive system with active rectifier.	2
Lab 7	Testing of the sensorless induction motor drives with chosen flux and speed estimators. Part 1.	2
Lab 8	Testing of the sensorless induction motor drives with chosen flux and speed estimators. Part 2.	2
Lab 9	Testing of the adaptive control structure for the DC motor drive.	2
Lab 10	Testing of the adaptive control structure for the AC motor drive.	2
Lab 11	Testing of the sliding-mode control structure for the induction motor drive.	2
Lab 12	Testing of the predictive control structures for electrical drive.	2
Lab 13	Testing of the chosen control structures of the driver system with elastic coupling - PI/PID controllers.	2
Lab 14	Testing of the chosen control structures of the driver system with elastic coupling - state controller.	2
Lab 15	Additional term. Crediting with grade.	2
Total hours:		<b>30</b>

**TEACHING TOOLS USED**

- N1. Lecture with multimedia tools combined with classical lecture (problem oriented).  
 N2. Consultations.  
 N3. Laboratory exercises in student groups; testing of student knowledge with short test before laboratory exercises.  
 N4. Assessment of the laboratory exercises by reports.

**EVALUATION OF SUBJECT EDUCATIONAL EFFECTS ACHIEVEMENT**

<b>Evaluation</b> <i>F – forming (during semester) P – concluding (at semester end)</i>	<b>Educational effect number</b>	<b>Way of evaluating educational effect achievement</b>
F1(W)	PEK_W01 PEK_W02 PEK_W03	Participation in lectures.
F2(W)	PEK_W01 PEK_W02 PEK_W03	Final exam.
P(W)	$P=0,1 \cdot F1 + 0,9 \cdot F2$	
F1(L)	PEK_U01 PEK_U02 PEK_K01	Activity during laboratory exercises (including grades obtaining during short tests).
F2(L)	PEK_U01 PEK_U02 PEK_K01	Preparation of the report.
P(L)	$P=0,3 \cdot F1 + 0,7 \cdot F2$	

**PRIMARY AND SECONDARY LITERATURE****PRIMARY LITERATURE:**

- [1] Kaźmierkowski M.P., Tunia H., Automatyka napędu przekształtnikowego. PWN, 1987  
 [2] Orłowska-Kowalska T., Bezczytnikowe układy napędowe z silnikami indukcyjnymi. Oficyna Wydawnicza P.Wr., Wrocław, 2003  
 [3] Orłowska-Kowalska T., Automatyka napędu elektrycznego - podstawy. Oficyna Wydawnicza P.Wr., Wrocław, w druku  
 [4] Szabat K., Struktury sterowania elektrycznych układów napędowych z połączeniami sprzężystymi, Oficyna Wyd. P.Wr., Wrocław, 2008  
 [5] Zawirski K., Deskur J., Kaczmarek T., Automatyka napędu elektrycznego, Wyd. Polit. Poznańskiej, 2012  
 [6] T. Kaczorek, A. Dzieliński, W Dobrowolski, R. Łopatka. Podstawy teorii sterowania, WNT, 2005  
 [7] P. Tatjewski, Sterowanie zaawansowane obiektów przemysłowych. Struktury i algorytmy, Exit 2000

**SECONDARY LITERATURE:**

- [1] P. Vas, Sensorless Vector and Direct Torque Control, Oxford University Press, 1998  
 [2] M.D. Murphy, F.G.Turnbull, Power Electronic Control of AC Drives, Pergamon Press, Oxford, 1988  
 [3] W. Leonhard, Control of Electrical Drives, Springer Verlag, 1990  
 [4] K. Ogata, Modern Control Engineering

**SUBJECT SUPERVISOR**

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MATRIX OF CORRELATION BETWEEN EDUCATIONAL EFFECTS FOR SUBJECT  
**ARR043218 - Controlled Electrical Drives - selected problems**  
AND EDUCATIONAL EFFECTS FOR MAIN FIELD OF STUDY **Control Engineering and Robotics**  
AND SPECIALIZATION **Automation of Machines, Vehicles and Apparatus**

Subject educational effect	Correlation between subject educational effect and educational effects defined for main field of study and specialization (if applicable)	Subject objectives	Programme content	Teaching tool number
PEK_W01	S2AMPU_W01	C.1	Lec1 Lec2 Lec3	N.1 N.2
PEK_W02	S2AMPU_W01	C.2	Lec4 Lec5 Lec6 Lec7 Lec8 Lec9 Lec10 Lec11 Lec12 Lec13 Lec14 Lec15	N.1 N.2
PEK_W03	S2AMPU_W01	C.1 C.2	Lec1 Lec2 Lec3 Lec4 Lec5 Lec6 Lec7 Lec8 Lec9 Lec10 Lec11 Lec12 Lec13 Lec14 Lec15	N.1 N.2
PEK_U01	S2AMPU_U01	C.3 C.4	Lab1 Lab2 Lab3 Lab4 Lab5 Lab6 Lab7 Lab8 Lab9 Lab10 Lab11 Lab12 Lab13 Lab14 Lab15	N.3 N.4
PEK_U02	S2AMPU_U01	C.3 C.4	Lab1 Lab2 Lab3 Lab4 Lab5 Lab6 Lab7 Lab8 Lab9 Lab10 Lab11 Lab12 Lab13 Lab14 Lab15	N.3 N.4
PEK_K01	K2AiR_K06 K2AiR_K07	C.5	Lab1 Lab2 Lab3 Lab4 Lab5 Lab6 Lab7 Lab8 Lab9 Lab10 Lab11 Lab12 Lab13 Lab14 Lab15	N.3 N.4