| Subject (course) name: **Automation of Electrical Drives** | | |
|---|---|---|
| Programme: **Automation & Robotics**<br>Specialty: | | Subject code: **AiR_1S_14K**<br>Title graduate: **Engineer** |
| Type of course: **obligatory** | Course level:<br>**First-cycle studies** | Year: **II** Semester: **III**<br>Semester: **winter** |
| Form of classes:<br>**Lectures, Classes, Labs, Seminar, Project** | Number of hours per week:<br>**2L, 0, 2Lab, 0, 0** | Credit points: **4 ECTS** |

## GUIDE TO SUBJECT

### SUBJECT OBJECTIVES

C1. General knowledge in structure, principles of operation, application, properties and exploitation of electrical drives.

C2. General knowledge in laboratory stands containing automatic drive systems and general knowledge in principles of laboratory measurements using the abovementioned stands.

C3. Practical ability to connect the circuits of electrical drives as well as practical ability to conduct the laboratory measurements and formulate conclusions dealing with operating properties of the abovementioned drives.

### SUBJECT REQUIREMENTS

1. General knowledge in mechanics: moments of inertia, strength of shafts, equation of motion.
2. General knowledge in mathematics, especially in differential calculus.
3. General knowledge in electrical engineering, especially in circuit theory.
4. General knowledge in automatics: operational calculus, basic control systems, operational and spectral transmittances, time and frequency characteristics, control quality, adjusting of controllers.
5. General knowledge in electrical machines: separately excited DC motor, induction motor and synchronous motor.
6. General knowledge in power electronics: semiconductor power devices, voltage and current source inverters, rectifiers, frequency converters.
7. Ability to work independently and in team as well.
8. Ability to connect electrical circuits.
9. General ability to search in literature and internet sources.

### LERNING OUTCOMES

EK1 - Student will know structures and control methods of converters used in drives of direct current and alternating current, will be able to classify and characterize converter-fed electrical drives, will know structures and principles of operation of converter-fed electrical drives.

EK2 - Student will be able to connect laboratory circuits in order to investigate automatic electrical drives and conduct measurements according to instruction as well as formulate conclusions on the basis of the conducted measurements.

## SUBJECT CONTENT

**Form of classes - lectures**

| Topic | Hours |
|---|---|
| **W1 –** Repetition of general structures of automatic control systems. Examples of simplified control systems: block diagrams and operational transmittances. | **4** |
| **W2 –** Repetition of logarithmical frequency responses of the elementary elements: amplifier, integral, differential, inertial, oscillatory. Drawing of logarithmical frequency responses for complex systems by addition of responses of elementary elements. Frequency response of typical physical object. Adjusting of linear controllers on the basis of logarithmical frequency responses. Experimental adjusting of linear controllers. | **5** |
| **W3 –** Criteria determining the varied dynamics of drives: optimization of automatic control systems, incl. drive systems, reduced to minimization of functional in general form. Control quality coefficients. | **2** |
| **W4 –** Types, exemplary structures and control methods of converters used in drives based on DC and AC motors. Converters with intermediate DC circuits. Inverters with external and internal commutation. Voltage source inverters and current source inverters. Resonant inverters. Drive systems with AC motors. Power circuits and control circuits of the exemplary frequency converter. | **5** |
| **W5 –** Construction, principle of operations and motive properties of separately excited DC motor. Adjusting of rotational speed. Stiffness of mechanical characteristic. Determination of working point stability on mechanical characteristic. Moments of inertia of rotating elements in drive system. Frequency of drive free vibrations. Equivalent load torques and equivalent moments of inertia. Circuit mathematical model of separately excited DC motor (SEDCM). Equations written in relative units (pu.) and block diagram SEDCM. State equations. Structure and block diagram of converter-fed drive system with of SEDCM. Synthesis of error actuated control circuit for armature circuit. Optimization of dynamical properties of error actuated control circuit for rotational speed. Influence of disturbances on controlled quantity. Functional diagram of drive with SEDCM and microprocessor control. | **6** |
| **W6 –** Principles of adaptive control. Identification of parameters and state variables of drive systems. | **2** |
| **W7 –** Properties of induction motor (IM) and synchronous motor (SM). Adjusting of IM and SM rotational speed. Control methods used in drives with AC motors. Field vector oriented control method (FOC) and direct torque control method (DTC). Soft-start system for IM. Drive system with double fed machine. Permanent magnet machines: BLDCM, PMSM. Properties of converter-fed motor. Microprocessor-based vector control of IM. | **6** |
| **Total** | **30** |

**Form of classes – laboratory**

| Topic | Hours |
|---|---|
| **L1** – Introduction: training in occupational health, safety and fire protection, preparation oneself for classes, technique of class performance, report from class | **2** |
| **L2** – Scalar-controlled AC drive | **2** |
| **L3** – Vector-controlled AC drive | **2** |
| **L4** – Digital DC drive | **2** |
| **L5** – BLDCM control system | **2** |
| **L6,7** – Performance of overdue or unfinished classes of the first series | **2+2** |
| **L8** – PMSM control system | **2** |
| **L9** – Soft-start system for IM | **2** |
| **L10** – Wind power station with synchronous generator | **2** |
| **L11** – Determination of mechanical characteristic of pulse-fed DC motor | **2** |
| **L12,13** – Performance of overdue or unfinished classes of the second series | **2+2** |
| **L14,15** – Completion of laboratory classes | **2+2** |
| **Total** | **30** |

## STUDY METHODS

| |
|---|
| **1.** Lectures using multimedia presentations |
| **2.** Laboratory – connection of circuits and measurements on laboratory stands |

## EDUCATIONAL TOOLS

| |
|---|
| **1.** Audiovisual equipment, lectures in electronic version |
| **2.** Laboratory stands with electrical drive sets - teamwork |
| **3.** Textbooks and handbooks, educational materials, instructions for laboratory classes |

**METHODS OF ASSESMENT (F – Forming, P – Summary)**

| |
|---|
| **F1.** Evaluation of preparation for laboratory classes (positive result = permission to perform of class) |
| **P1.** Evaluation of mastering the teaching material dealing with lectures on the basis of control test |
| **P2.** Verification of correctness of calculations, worked out results and formulated conclusions on the basis of reports from laboratory classes |

## STUDENT WORKLOAD

| Form of activity | Averaged workload (hours) | | |
|---|---|---|---|
| | [h] | ∑ [h] | ECTS |
| Participation in class activities lecture<br>laboratory | 30<br>30 | 60 | 2 |
| Preparation for tutorials (reading literature), preparation for tests | 25 | 40 | 2 |
| Preparation for laboratory classes | 5 | | |
| Preparation of reports from laboratory classes | 5 | | |
| Preparation for completion of laboratory classes | 5 | | |
| **Total** | | **100** | **4** |

### A. BASIC READING

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|---|
| **1.** Tunia H., Kaźmierkowski M., Converter-fed drive automatics (in Polish), PWN Warszawa, 1987 |
| **2.** Tunia H., Winiarski B., Power electronics in questions and answers (in Polish), WNT Warszawa, 1996 |
| **3.** Orłowska-Kowalska T., Sensorless drive systems with induction motors (in Polish), Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław, 2003 |
| **4.** Tietze U., Schenk Ch., Semiconductor systems, chapter: Electronic controllers, Polish edition: WNT Warszawa, 2009 |
| **5.** Kaczorek T., Control theory fundamentals (in Polish), WNT Warszawa, 2005 |

### B. FURTHER READING

| |
|---|
| **1.** Grunwald Z., Electric drives (in Polish), WNT Warszawa, 1987 |
| **2.** Popenda A., Modelling and simulation of dynamical operating states of drive systems for polymerization reactors with specially designed induction motors (in Polish), Wyd. Politechniki Częstochowskiej, 2011 |

| Learning objectives | In relation to the learning outcomes specified for the field of study | Subject objectives | Study methods | Methods of assessment |
|---|---|---|---|---|
| EK1 | KAR1A_W05<br>KAR1A_W13<br>KAR1A_W15 | C1 | Lecture | P1 |
| EK2 | KAR1A_U09<br>KAR1A_U15 | C2, C3 | Laboratory | F1, P2 |

## II. EVALUATION

| Grade | Outcome |
|---|---|
| **EK1** | **Student knows structures and control methods of converters used in drives of direct current and alternating current, is able to classify and characterize converter-fed electrical drives, knows structures and principles of operation of converter-fed electrical drives** |
| 2 (F) | Student has only general knowledge in automatic control, adjusting of controllers and control quality or has not this knowledge. |
| 3 (E) | Student has general knowledge in: automatic control, adjusting of controllers and control quality. Student knows examples of the simplified control systems with electrical motors, knows their block diagrams and operational transmittances. Student knows structures of converters used in DC and AC drives. Student knows structure and block diagram of converter-fed DC drive with control circuit for armature current and rotational speed. Student knows basic properties of AC motors and methods of rotational speed adjusting. |
| 4 (C) | Student has general knowledge in: automatic control, adjusting of controllers and control quality. Student knows examples of the simplified control systems with electrical motors, knows their block |

| | |
|---|---|
| | diagrams and operational transmittances. Student is able to draw logarithmical frequency responses of complex physical objects on the basis of operational transmittances, is able to define and describe mathematically typical physical object and adjust linear controller on the basis of logarithmical frequency responses or experimentally. Student knows criteria determining varied dynamics of drives. Student knows circuit mathematical models of DC motor, knows structure and block diagram of converter-fed DC drive. Student knows properties of AC motors and methods of rotational speed adjusting, knows one vector control method of AC motor: FOC or DTC. Student knows and is able to characterize: soft-start, drive system with DFM, BLDCM and PMSM-based drive systems. Student knows and is able to characterize functional diagram of DC and AC drive with microprocessor control. |
| 5 (A) | Student has general knowledge in: automatic control, adjusting of controllers and control quality. Student knows examples of the simplified control systems with electrical motors, knows their block diagrams and operational transmittances. Student is able to draw logarithmical frequency responses of complex physical objects on the basis of operational transmittances, is able to define and describe mathematically typical physical object and adjust linear controller on the basis of logarithmical frequency responses or experimentally. Student knows criteria determining varied dynamics of drives. Student knows circuit mathematical models of DC motor, knows structure and block diagram of converter-fed DC drive. Student knows problems of synthesis and optimization of closed control circuits for armature current and rotational speed. Student knows structures and principles of operation of inverters used in AC drive systems. Student knows properties of AC motors and methods of rotational speed adjusting, knows vector control methods of AC motor: FOC and DTC. Student knows and is able to characterize: soft-start, drive system with DFM, BLDCM and PMSM-based drive systems. Student knows and is able to characterize functional diagram of DC and AC drive with microprocessor control. |
| **EK2** | **Student is able to connect laboratory circuits in order to investigate automatic electrical drives and conduct measurements according to instruction as well as formulate conclusions on the basis of the conducted measurements.** |
| 2 (F) | Student comes offhand, disturbs the other participants of team, is not to able or does not want to connect laboratory circuits, does not participate in performance of measurements. Also student that was not permit to laboratory classes or has not performed three or more from eight scheduled classes as a consequence of non-preparation, delay or absence. |
| 3 (E) | Student is prepared for laboratory classes but has problem in connection of laboratory circuits and performance of measurements. Also student that fulfils criteria for mark 4 but has not performed one or two laboratory classes. |
| 4 (C) | Student is prepared for laboratory classes, participates in connection of laboratory circuits and performance of measurements, has performed all scheduled classes, in general is able to formulate logical conclusions on the basis of performed measurements. |
| 5 (A) | Student is prepared for laboratory classes, actively participates in classes, is the leader in connection of laboratory circuits and performance of measurements, has performed all scheduled classes, is able to formulate logical conclusions on the basis of performed measurements. |

## III. OTHER USEFUL INFORMATION

1. All information for students on the schedule are available on the notice board and on the website: www.el.pcz.pl
2. Information on the consultation shall be provided to students during the first lecture and will be placed on the website www.el.pcz.pl
3. Terms and conditions of credit courses will be provided to students during the first lecture