Subject (course) name: **Electrical machines**		
Programme: **Automation & Robotics** Specialty:		Subject code: **AiR_1S_8K**
		Title graduate: **Engineer**
Type of course: **obligatory**	Course level: **First-cycle studies**	Year: **II** Semester: **III** Semester: **winter**
Form of classes: **Lectures, Classes, Labs, Seminar, Project**	Number of hours per week: **2L, 1C, 2Lab, 0, 0**	Credit points: **5 ECTS**

GUIDE TO SUBJECT

SUBJECT OBJECTIVES

C1. General knowledge in construction, principles of operation, application, static properties and operating structures of electrical machines.

C2. Particular knowledge in calculation problems dealing with transformers and induction machines.

C3. General knowledge in laboratory stands containing electrical machines and general knowledge in principles of laboratory measurements using the abovementioned stands.

C4. Practical ability to connect the circuits including electrical machines windings as well as practical ability to conduct the laboratory measurements and formulate conclusions dealing with operating properties of the abovementioned machines.

SUBJECT REQUIREMENTS

1. General knowledge in mechanics.
2. General knowledge in mathematics, especially in differential calculus.
3. General knowledge in electrical engineering, especially in circuit theory.
4. Ability to work independently and in team as well.
5. Ability to connect electrical circuits.
6. General ability to search in literature and internet sources.

LERNING OUTCOMES

EK1 - Student will know classification of electrical machines, their construction, principles of operation, problems of losses and efficiency, motive properties and static characteristics.

EK2 - Student will be able to solve calculation problems dealing with the selected electrical machines.

EK3 - Student will be able to connect laboratory circuits in order to investigate electrical machines 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 – Construction of transformer. Cores and windings. Principles of operation. Basic dependencies for transformer operation.	**2**
W2 – Equations and equivalent circuit of transformer. Phasor diagrams.	**2**

W3 – No-load state of transformer: equivalent circuit, characteristics, power losses. Nonlinearity of magnetic circuit; higher harmonics.	**2**
W4 – Short-circuit state of transformer: equivalent circuit, diagrams, short-circuit voltage.	**2**
W5 – Operation of transformer: external characteristics, voltage variability, power losses and efficiency of transformer.	**2**
W6 – Transforming in 3-phase circuits. Connections of 3-phase windings.	**2**
W7 – Asymmetric loads. Symmetrical components method.	**2**
W8 – Parallel operation of transformers and determination of connection group.	**2**
W9 – Construction of induction machines (IM): stator and rotor of squirrel-cage IM and slip-ring IM, windings, teeth, slots. Deep-slot IM.	**2**
W10 – Magnetic induction distribution in air-gap at: lumped or distributed winding (conducting direct or alternating current). Dimensional-time function of induction. Diameter and chord windings. Minimization of 3-rd harmonic. Rotating field.	**2**
W11 – Equations and equivalent circuit of IM. Comparison between equivalent diagrams of transformer and IM.	**2**
W12 – Idle running and short-circuit state of IM. Power and loss balance.	**2**
W13 – Electromagnetic torque. Critical torque and slip. Mechanical characteristic and its parameters. Influence of IM working parameters on mechanical characteristic.	**2**
W14 – Starting and braking of IM.	**2**
W15 – Adjusting of IM rotational speed.	**2**
Total	**30**

Form of classes – classes

Topic	Hours
C1,2,3 – Influence of feeding voltage, cross-section of core, frequency and number of winding turns on crosswise parameters of transformer equivalent circuit with nonlinear magnetic circuit.	**1** **1** **1**
C4 – Calculation of equivalent circuit parameters on the basis of short-circuit and idle running measurements or catalogue data.	**1**
C5 – Influence of frequency or number of winding turns on longitudinal parameters of transformer equivalent circuit.	**1**
C6 – Calculation of unit number of transformer windings turns. Influence of air-gap on magnetizing current.	**1**
L7 – Determination of connection group of 3-phase transformer	**1**
L8 – Voltage variability of transformer	**1**
L9,10 – Electromotive forces induced in windings of induction machines.	**1+1**
L11,12 – IM power and loss balance.	**1+1**
L13,14 – Motive properties of IM	**1+1**
L15 – Completion of the classes	**1**
Total	**15**

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 – 3-phase transformer	**2**
L3 – Flat linear IM	**2**
L4 – DC shunt generator	**2**
L5 – Circular diagram of slip-ring motor	**2**
L6,7 – Performance of overdue or unfinished classes of the first series	**2+2**
L8 – Synchronous motor.	**2**
L9 – Cooperation of 3-phase transformers.	**2**
L10 – DC shunt motor	**2**
L11 – Determination of characteristics of IM using respective losses method	**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. Classes – solving exercises
3. Laboratory – connection of circuits and measurements on laboratory stands

EDUCATIONAL TOOLS

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

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

F1. Evaluation of preparation for classes on the basis of exercise solving ability
F2. 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. Evaluation of mastering the teaching material dealing with classes on the basis of class-tests
P3. 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 classes laboratory	30 15 30	75	3
Preparation for tutorials (reading literature), preparation for tests	20	50	2
Preparation for laboratory classes	5		
Preparation for exercise classes	5		
Preparation of reports from laboratory classes	5		
Preparation for completion of laboratory classes	5		
Preparation for completion of exercise classes	10		
Total		**125**	**5**

A. BASIC READING

1. Plamitzer A.M., Electrical machines (in Polish), WNT Warszawa, 1986
2. Bajorek Z., Electrical machines theory (in Polish), PWN Warszawa, 1982
3. Latek W., Electrical machines theory (in Polish), WNT Warszawa 1987
4. Popenda A., Transformers and induction machines in exercises (in Polish), Wydawnictwo Politechniki Częstochowskiej, Częstochowa 2009
5. Antal L., Janta T., Zieliński P., Electrical machines. Laboratory classes (in Polish), Wydawnictwo Politechniki Wrocławskiej, 2001

B. FURTHER READING

1. Turowski J., Electrical machines theory. Machines of alternating current (in Polish), Wydawnictwo Politechniki Łódzkiej, Łódź 1984
2. Praca zbiorowa, Exercises on electric al machines (in Polish), WNT Warszawa, 1976
3. Popenda A., Laboratory classes on electrical machines fundations (in Polish), Wydawnictwo Politechniki Częstochowskiej, Częstochowa 2009

Learning objectives	In relation to the learning outcomes specified for the field of study	Subject objectives	Study methods	Methods of assessment
EK1	KAR1A_W13	C1, C3	Lecture	P1
EK2	KAR1A_W13	C2	Classes	F1, P2
EK3	KAR1A_U09 KAR1A_U15 KAR1A_K03	C3, C4	Laboratory	F2, P3

II. EVALUATION

Grade	Outcome
EK1	**Student knows classification of electrical machines, their construction, principles of operation, problems of losses and efficiency, motive properties and static characteristics**
2 (F)	Student does not know construction, principles of operation and general problems of losses and efficiency of electrical machines, has incomplete knowledge dealing with motive properties of electrical machines, does not know majority of static characteristics and time dependencies of electrical machines.
3 (E)	Student is able to classify electrical machines, has knowledge dealing with motive properties of electrical machines and knows their static characteristics and time dependencies.
4 (C)	Student is able to classify electrical machines, knows their construction, principles of operation and problems of losses and efficiency, has knowledge dealing with motive properties of electrical machines and knows their static characteristics and time dependencies.
5 (A)	Student is able to classify electrical machines, knows their construction, understands principles of operation and problems of losses and efficiency, has knowledge dealing with motive properties of electrical machines, is able to derive and use dependencies and formulas, knows and is able to explain static characteristics and time dependencies of electrical machines.
EK2	**Student is able to solve calculation problems dealing with the selected electrical machines**
2 (F)	Student is not able to solve any calculation problems dealing with the selected electrical machines.
3 (E)	Student is able to solve some calculation problems dealing with the selected electrical machines.
4 (C)	Student is able to solve majority of calculation problems dealing with the selected electrical machines.
5 (A)	Student is able to solve all or almost all calculation problems dealing with the selected electrical machines.
EK3	**Student is able to connect laboratory circuits in order to investigate electrical machines 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.czest.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.czest.pl
3. Terms and conditions of credit courses will be provided to students during the first lecture