SYLLABUS OF ACADEMIC DISCIPLINE
«ELECTRIC MACHINES»

Academic degree	Bachelor
Specialty	141 Electrical energetics, electrical engineering and electromechanics
Academic program	Electrical energetics, electrical engineering and electromechanics
Period of study	3, 4 semesters (6-8 terms)
Total workload	6 credits ECTS (180 hours)
Classroom workload:	
lectures:	3 hours (6 term), 2 hours (7-8 terms)
laboratory works:	1 hours
Language of study	English

Course page in E-learning platform of DniproTech:
https://do.nmu.org.ua/course/view.php?id=189

Teaching Department Electrical Engineering

Instructor:
Ivanov Oleksii Borysovych
Professor, Candidate of Technical Sciences,
Professor of the Department of Electrical Engineering

Personal page
http://vde.nmu.org.ua/ua/kafedra/ivanov.php

E-mail:
ivanov.o.b@nmu.one

1. About this course

In conditions of energy-saving technologies implementation and renewable energy sources use, development of electrical technologies such as electric machines, as means of electromechanical energy conversion, is of great importance. Use of electric machines in great degree defines technical level of many sectors of the national economy.

Progress in electrical machinery depends on electric machines theory. Understanding of electromechanical energy conversion processes is necessary as to electrical engineers as to many other professionals who are engaged in power engineering.

In discipline “Electric machines”, construction and principles of electric machines and power transformers operation are considered, explained basic phenomena taking place in this equipment. Analysis of electric machines operation, their equations and relationships between machines parameters, properties of different types of machines and transformers are explained.

2. Aim and objectives

The aim of the course – formation of competencies in the classification, design, principle of operation, features of operation, characteristics and design of electrical machines.

Course objectives:

To teach applicants for higher education:

- to determine principles of construction and functioning of electric machines as components of power, electrical and electromechanical complexes and systems;
- to solve professional tasks on designing and application electric machines;
- to take measures on technical servicing electric machines as parts of electromechanical systems, equipment of electric power stations, substations, and networks by means of relevant instructions and practical skills;
- to discover new ways for economic conversion, distribution, transmission, and use of electricity by means of electric machines and transformers.

3. Results of study

Disciplinary learning outcomes:

- to determine principle of construction and functioning of electric machines units as part of electric power, electrical, and electromechanical complexes, and systems;
- to assess working parameters of electric machines as part of electrical, electric power, and electromechanical equipment and relevant complexes and systems, and to develop measures of their energy efficiency and reliability improvement;
- to solve professional tasks on designing and maintenance of electric machines;
- to master methods of electric machines with specified properties synthesis;
- to carry out tasks of technical maintenance of electric machines as part of electromechanical systems, electric power stations, substations, systems, and networks electrical equipment by means of relevant instructions and practical skills;
- to carry out new ways for solving problems of economic conversion, distribution, transmission, and application of electrical energy by means of electric machines.

4. Course program

LECTURES
1. Transformers
1.1 Principle of operation, construction, cooling
1.2 Induced voltage and magnetization curves, magnetizing current
1.3 Electromagnetic processes in transformers
1.4 Magnetic losses in transformers
1.5 Parameters and transformer equivalent circuit for no-load mode
1.6 Transformer magnetic field, and its equations under load
1.7 Equivalent circuit of loaded transformer
1.8 Transformation of three-phase currents
1.9 Experimental determination of transformer parameters
1.10 Performance characteristics and operating modes of transformers
1.11 Transformers parallel operation
1.12 Transformers of special types
2. Issues of general theory of AC machines
2.1 Principles of energy conversion in electric machines

2.2 Structure of AC machine windings
2.3 Magnetic field of mutual induction of electric machines
2.4 Flux linkage and induced voltage of Ac winding
2.5 Electromagnetic torque of electric machine, electromechanical energy conversion
3. Asynchronous machines (induction machines)
3.1. Construction of induction machines
3.2. Principle of induction machines operation
3.3. Analogy of processes in induction machine with equivalent locked rotor and in transformer
3.4. Induction machine voltage and current ratio
3.5. Equations of magnetomotive forces and currents of induction machine; no-load current
3.6. Induction machine parameters at rotating and locked rotor. Rotor current as a function of slip
3.7. Quantities and parameters of locked rotor referred to the stator side
3.8. Equations of referred induction machine with locked rotor
3.9. Equivalent locked rotor of induction machine; the machine equivalent circuits
3.10. Main set of equations of induction machine with equivalent locked rotor
3.11. Three-phase phase regulator. Three-phase voltage regulator.
3.12. Parameters, EMF and current of the rotating rotor
3.13. Main equations of an induction machine during rotor rotation.
3.14. Power flow diagram of induction motor
3.15. Efficiency of an induction machine.
3.16. Determination of the electromagnetic power and electromagnetic torque of an induction machine due to electrical losses in the rotor winding circuits.
3.17. Reducing electromagnetic processes during rotor rotation to processes in a transformer
3.18. Electromagnetic torque and characteristics of induction machine
3.19. The circular diagram of an induction machine and its use for determination of mechanical and operating characteristics. Additional features of the induction machine
3.20. Starting induction motors
3.21. Induction motors speed regulation
3.22. Operation of three-phase induction machines under non-symmetrical conditions
4. Synchronous machines
4.1. Construction of synchronous machines
4.2. Processes in synchronous machines under no-load conditions
4.3. Magnetomotive force and armature circuit parameters
4.4. Electromagnetic processes in synchronous machine under load
4.5. Losses and efficiency of synchronous generators
4.6. Electromagnetic power and torque of synchronous machines
4.7. Characteristics of synchronous generator at independent operation
4.8. Switching synchronous generator to parallel operation with power network
4.9. Processes and properties of synchronous machine at parallel operation
4.10. Synchronous motors
4.11. Synchronous compensators
5. DC machines
5.1. Construction of DC machines

5.2. Principle of operation
5.3. Armature windings. Equations of motors and generators armature winding circuit, armature current
5.4. Electromechanical energy conversion in DC machines
5.5. Rotational induced voltage in armature circuit; electromagnetic torque
5.6. Magnetic field of DC machine
5.7. Armature reaction of DC machine
5.8. Methods of weakening armature reaction in DC machines. Compensating winding
5.9. Commutation of armature current in DC machines
5.10. Generators with separate excitation
5.11. Generators with self-excitation
5.12. DC generators parallel operation
5.13. Circuitry of DC motors
5.14. Motors with separate and parallel excitation
5.15. Motors with series excitation
5.16. Compound motors
6. Special electric machines
6.1. Single-phase AC motors
6.2. Special induction machines
6.3. Asynchronous electrical machine automation devices
6.4. Special synchronous machines
6.5. Special types of DC machines
6.6. Commutator AC machines
LABORATORY LESSONS
Determination of transformer ratings and its testing
Testing of transformer under conditions of open circuit and short-circuit operation
Transformers parallel operation
Study of induction motors construction and principle
Investigation of three-phase induction motor using data of no-load and short-circuit tests
Investigation of induction motor working properties using method of direct loading
Investigation of cage induction motors starting methods
Investigation of parallel operation of synchronous generator connected to grid
Asynchronous starting and investigation of synchronous motor at field current adjustment
Investigation of dc generators
Investigation of dc motors with shunt and compound excitation

5. Technical equipment and/or software

# of work (code)	Work name	Tools, equipment, and software used in the work
EM-2/1	Determination of transformer ratings and its testing	TCO-2.5 transformer Incandescent lamp Probes Switch

		Measuring devices: • megohmmeter • AC voltmeter,15 V • AC voltmeter, 250 V
EM-2/2	Testing of transformer under conditions of open circuit and short-circuit operation	TCO-2.5 transformer Probes Switch Additional resistance of 5 kOhm - 2 pieces. Measuring devices: • ammeter 2.5… 5 A - 3 pcs • voltmeter 75… 600 V • wattmeter 5/150 - 2 pcs
EM-2/4	Transformers parallel operation	TSO-2,5 transformer - 2 pieces Probes Switch 50 A - 1 pc Switch 20 A - 4 pcs Panel for connection- 2 pieces Measuring devices: • AC ammeter, 10 A - 2 pcs • AC ammeter, 20 A - 1 pc. • voltmeter change e.g. 250 V - 2 pcs
EM-3/1	Study of induction motors construction and principle	Asynchronous motor Incandescent lamp Probes Switch Measuring devices: • AC voltmeter, 15 V - 1 pc • megohmmeter
EM-3/2	Investigation of three-phase induction motor using data of no-load and short-circuit tests	Asynchronous motor Switch Resistance 12.5 Ohms Additional resistance of 5 kOhm - 2 pieces Current transformer 15; 50/5 - 2 pcs Measuring devices: • DC voltmeter, 1… 150 V • voltmeter, 75… 600 V • ammeter 2,5… 5 A - 2 pcs • wattmeter 5A / 150V - 2 pcs
EM-3/3	Investigation of induction motor working properties using method of direct loading	The test bench with measuring instruments, starting equipment and amotor Additional resistance of 5 kOhm Tachometer Desktop measuring instruments: • voltmeter 75… 600 V

		• ammeter 2.5… 5 A • wattmeter 5A / 150V
EM-3/4	Investigation of cage induction motors starting methods	Asynchronous motor TCO-2.5 transformer Switch 50 A - 3 pcs Switch for Y/D commutation Measuring devices: • AC ammeter 100 A • AC ammeter 50 A • AC ammeter 10 A • AC voltmeter 250 V - 2 pcs
EM-4/2	Investigation of parallel operation of synchronous generator connected to grid	Synchronous generator DC motor Switch - 4 pcs Adjusting rheostat - 2 pcs Synchronization console Current transformer - 2 pcs Measuring devices: • AC ammeter 20 A • AC ammeter 3 A - 2 pcs • AC ammeter 30 A - 1 pc • DC voltmeter 300 V - 1 pc • three-phase kilo-wattmeter - 1 piece
EM-4/3	Asynchronous starting and investigation of synchronous motor at field current adjustment	Synchronous motor DC generator Equipment and devices for starting and research of synchronous motor
EM-1/2	Investigation of dc generators	Asynchronous motor DC generator Switch - 3 pcs Loading rheostat Adjusting rheostat of 1000 Ohms Measuring devices: • AC ammeter, 100 A • AC voltmeter, 250 V. • DC ammeter, 3 A • DC ammeter, 30 A • DC voltmeter, 300 V

6. Evaluation system and requirements

6.1. The academic achievements of higher education applicants based on the results of the completion of the course will be evaluated on the scale below:

Rating	Institutional
90 – 100	Excellent

74 – 89	Good
60 – 73	Satisfactory
0 – 59	Fail

The general criteria for achieving the learning outcomes correspond to the descriptions of the 6th qualification level of the NQF.

6.2. Applicants for higher education can receive a final grade in this course based on the formative assessment of their knowledge, provided that the total number of points gained from the formative testing and individual work is at least 60 points.

Maximum scores:

Differentiated test (6 term)

Theoretical part	Laboratory work			**Total**
CW.	EM 2/1	EM 2/2	EM 2/4	
36…60	9…15	12…25	6…10	**60…100**

Exam (8 term)

Theoretical part (maximum points)			Laboratory work								**Total**
CW.1	CW.2	CW.3	EM 3/1	EM 3/3	EM ¾	EM 4/2	EM 4/3	EM 1/2	EM 1/3	EM 1/4	
10	50	40	9…15	9…15	6…10	6…10	6…10	9…15	9…15	6…10	
$0.6 \cdot \sum T_i$			$0.4 \cdot \sum L.W_i$								
36…60			24…40								**60…100**

The condition for obtaining a positive grade in the course (differentiated test and/or exam) is the defense of ALL laboratory works and the completion of formative control works.

6.3. Criteria for evaluating the final work. If a higher education applicant has received less than 60 points in the formative academic assessment and / or seeks to improve the grade, a summative assessment (differentiated test in 6 term and exam in 8 term) is conducted during the control activities at the end of semester.

6.4. Criteria of laboratory work assessment. Laboratory works are accepted by tests that are taken using the Microsoft Forms Office 365. Links to the tests are provided in E-learning platform of DniproTech: https://do.nmu.org.ua/course/view.php?id=3944

7. The course policy

7.1. Policy on academic integrity. The academic integrity of higher education applicants is an important condition for mastering the learning outcomes of the course and obtaining satisfactory grades in formative and summative assessments. Academic integrity is based on the condemnation of the practices of cheating (writing with the involvement of external

sources of information other than those authorized for use), plagiarism (reproduction of published texts of other authors without proper attribution), fabrication (inventing data or facts used in the educational process). The policy on academic integrity is regulated by the Regulation on system of prevention and detection of plagiarism at the Dnipro University of Technology (https://www.nmu.org.ua/ua/content/activity/us_documents.pdf).

If a higher education applicant violates academic integrity (cheating, plagiarism, fabrication), the assignment is graded unsatisfactory and must be repeated. In this case, the instructor reserves the right to change the topic of the assignment.

7.2. Communication policy. Applicants for higher education must have an activated corporate university email.

All written questions to the instructors regarding the course should be sent to the university email.

7.3. Policy on retakes. Assignments that are submitted late without valid reasons will be evaluated at a lower grade. Retakes of the summative assessment are allowed with the permission of the dean's office if there are valid reasons (e.g., sick leave).

7.4. Class attendance. Attendance at classes is mandatory for full-time applicants for higher education. Valid reasons for absence from classes are illness, participation in university events, and academic mobility, which must be confirmed by documents. A higher education applicant must notify the instructor either personally or through the leader of the academic group about the absence from class and the reasons for the absence.

If a course learner is ill, it is recommended that he or she stays at home and studies in the E-learning platform of DniproTech. Learners whose health condition is unsatisfactory and may affect the health of others will be asked to leave the class (such absence will be considered as an absence due to illness).

Practical classes are not repeated; these activities cannot be completed during the consultation.

For objective reasons (e.g. international mobility), studies may take place online with the consent of the course instructor.

7.5 Evaluation appeal policy. If a higher education applicant does not agree with the evaluation of his/her knowledge, he/she may appeal the grade assigned by the instructor in a prescribed manner.

7.6. Bonuses. Students, who did not miss classes without good reasons, carried out and passed laboratory works before beginning the week of pre-sessional monitoring events and have current scores for theoretical and laboratory parts of the discipline not less 74 points, obtain additional **4 bonus points** to the total final score for the semester. Additional 4 bonus points are given also to students taking part in student scientific circle of department of electrical engineering and presented results of their scientific work at a student scientific conference or at competition of students' scientific works.

8 Рекомендовані джерела інформації

1. Gerhard Hennenberger.Electrical machines I. Basics, Design, Function, Operation: Aachen University, 2002, - 207 pp.

2. Ivanov, O.B., Shkrabets, F.P., Zawilak, Jan. (2011)."Electrical generators driven by renewable energy systems", Wroclaw University of Technology, Wroclaw – 169 p.

3. Іванов О.Б., Ципленков Д. В. Проектування трифазних асинхронних двигунів: Навчальний посібник для студентів, що навчаються за спеціальністю 141

«Електроенергетика, електротехніка та електромеханіка» (англійською мовою). – Д.: Національний технічний університет «Дніпровська політехніка», 2020. – 111с. іл.

4. Півняк Г.Г., Довгань В.П., Шкрабець Ф.П. Електричні машини: Навчальний посібник. – Дніпропетровськ: Національний гірничий університет, 2003. – 327 с.

5. Бєлікова Л. Я., Шевченко В. П. Електричні машини: Навчальний посібник. – Одеса: Наука і техніка, 2012. – 480 с.

6. Яцун Я.А. Електричні машини: Підручник. – Львів: Видавництво Львівської політехніки, 2011. – 464 с.

7. Collection of methodical materials for laboratory work on discipline "Electric machines" (section "DC Machines") for students studying specialty 141 “Electrical energetics, electrical engineering and electromechanics” / O.B. Ivanov, D.V. Tsyplenkov; Dnipro University of Technology – D.: DniproTech, 2021. – 40 p.

8. Collection of methodical materials for laboratory work on discipline "Electric machines" (section "Transformers") for students studying specialty 141 “Electrical energetics, electrical engineering and electromechanics” / O.B. Ivanov, D.V. Tsyplenkov; Dnipro University of Technology – D.: DniproTech, 2021. – 32 p.

9. Collection of methodical materials for laboratory work on discipline "Electric machines" (section "Induction machines") for students studying specialty 141 “Electrical energetics, electrical engineering and electromechanics” / O.B. Ivanov, D.V. Tsyplenkov; Dnipro University of Technology – D.: DniproTech, 2021. – 20 p.

10. Collection of methodical materials for laboratory work on discipline "Electric machines" (section "Synchronous Machines") for students studying specialty 141 “Electrical energetics, electrical engineering and electromechanics” / O.B. Ivanov, D.V. Tsyplenkov; Dnipro University of Technology – D.: DniproTech, 2021. – 20 p.