National Technical University of Ukraine
"Igor Sikorsky Kyiv Polytechnic Institute"

Department of Electromechanics

ELECTRIC MACHINES

Working program of the academic discipline (Syllabus)

Details of the academic discipline	
Level of higher education	***First (undergraduate)***
Discipline	*14 "Electrical engineering"*
Specialty	*141 "Electric power engineering, electrical engineering and electromechanics"*
Educational program	*Electromechanical automation systems, electric drive and electromobility (" Electromechanical Automation Systems , Electric Drive and Electromobility)*
Discipline status	*Normative*
Form of education	*Full-time/long-distance/mixed*
Year of training, semester	*II year, spring semester*
Scope of the discipline	*1 5 0 hours / 5 ECTS credits*
Semester control/ control measures	*Exam/MKR/RR*
Class schedule	*http://roz.kpi.ua/*
Language of teaching	*Ukrainian*
Information about the head of the course / teachers	Lecturer: *Ph.D. , Assoc. Haydenko Yuriy Antonovych, 0675061948* Laboratory: *assistant . Andrii Serhiyevich Stulishenko , 0997969078* *assistant Ignatiuk Yevhen Stanislavovych, 0971125679* *assistant Oleksiy Volodymyrovych Vishnevskyi, 0633650996*
Placement of the course	https://do.ipo.kpi.ua/course/view.php?id=3188

Program of study discipline

1. Description of the educational discipline, its purpose, subject of study and learning outcomes

The program of the study discipline "Electric machines" was compiled in accordance with the bachelor's educational program "Electromechanical systems of automation, electric drive and electromobility " in the field of knowledge 14 "Electrical engineering" in the specialty 141 "Electric power engineering, electrical engineering and electromechanics".

The purpose of the academic discipline *is to form and consolidate the following competencies in students :*

General competencies: (K01-K10) Ability to abstract thinking, analysis and synthesis; ability to apply knowledge in practical situations; the ability to communicate in the state language both orally and in writing; the ability to communicate in a foreign language; the ability to search, process and analyze information from various sources; the ability to identify, pose and solve problems; ability to work in a team; ability to work autonomously ; the ability to realize one's rights and responsibilities as a member of society, to realize the values of civil (free democratic) society and the need for its sustainable development, the rule of law, the rights and freedoms of a person and a citizen in Ukraine; with the ability to preserve and multiply the moral, cultural, scientific values and achievements of society based on an understanding of the history and patterns of development of the subject area, its place in the general system of knowledge about nature and society and in the development of society, technology and technologies, to use various types and forms of motor activity for active recreation and leading a healthy lifestyle.

Professional competences: (K07, K08, K15, K19) Ability to work in a team; Ability to work autonomously ; Ability to solve practical problems involving the methods of mathematics, physics and electrical engineering; The ability to solve complex specialized tasks and practical problems related to the operation of electric machines, devices and automated electric drives; The ability to perform professional duties in compliance with the requirements of the rules of safety, labor protection, industrial sanitation and environmental protection; Awareness of the need to increase the efficiency of electric power, electrotechnical and electromechanical equipment.

The subject of the educational discipline *is construction, principles of operation, physical phenomena and processes in electric machines and transformers; typical mathematical methods of research of electric machines and transformers; main characteristics of electric machines and transformers.*

Program learning outcomes:

PR03. Know the principles of operation of electric machines, devices and automated electric drives and be able to use them to solve practical problems in professional activities.

PR07. To carry out the analysis of processes in electric power, electrotechnical and electromechanical equipment, relevant complexes and systems.

PR09. To be able to evaluate the energy efficiency and reliability of electric power, electrotechnical and electromechanical systems.

PR19. Apply suitable empirical and theoretical methods to reduce losses of electrical energy during its production, transportation, distribution and use. PR12. Understand the basic principles and tasks of technical and environmental safety of electrical engineering objects

2. Pre-requisites and post-requisites of the discipline (place in the structural and logical scheme of training according to the relevant educational program)

To successfully master the discipline, the student must possess: the theoretical basis of the disciplines "Higher Mathematics", "Physics", "Theoretical Mechanics" and "Theoretical Basics of Electrical Engineering". The discipline "Electrical machines", using the known laws of electrical engineering, presents the theory of electric machines and transformers. When studying the design and modes of operation of electric machines and transformers, knowledge of engineering graphics, electrical engineering materials, applied mechanics, electronics, the basics of metrology and electrical measurements is also required. Considerable attention was paid to the analysis of the scope of application of electric machines and their impact on the development of various industries; precedes the study of the disciplines "Theory of electric drive", "Theory of automatic control", " Electrical wiring of machines and equipment", " Electromobility ".

3. Content of the academic discipline

*The discipline is structurally divided into **7 sections** , namely:*

1. ***Introduction to the discipline "Electric Machines"*** *, which includes issues of history and modern scientific trends in the development of electromechanics, the role of a modern engineer and scientist in the development of science, the relationship between the laws of nature and society, the role and significance of electric machines in modern electrical engineering, the acceleration of scientific and technical progress, classification of electric machines, nominal data of electric machines, materials used in electrical engineering.*
2. ***Transformers*** *, which included questions about the purpose, classification and design of transformers, the basics of the theory of transformer operation at no-load, short-circuit and under load.*
3. ***General questions of the theory of alternating current machines*** *, which included questions of electromechanical energy conversion in alternating current electric machines, about EM windings of alternating current, their EMF and MRS, as well as about magnetic fields of windings of alternating current.*

4. ***Asynchronous machines*** *, which included questions about types of design and the basics of AM theory, MRS equations and AM voltages , AM substitution schemes, energy diagrams, rotating electromagnetic moments and mechanical characteristics. In addition, special types of AM are considered, in particular, single-phase asynchronous motors and three-phase ACs operating in single-phase mode.*
5. ***Synchronous machines (SM)*** *, which included questions about the design and basics of the theory of the SM, the operation of three-phase SGs under symmetrical load, the power and electromagnetic moment of the SM. LEDs excited by permanent magnets are also considered.*
6. ***Direct current machines (DC machines)*** *, which included questions about the design, principle of operation and physical processes in direct current machines, different methods of excitation of DC machines, operation of DC machines under load, external, regulating and loading characteristics of DC motors, direct current motors (DC motors).*
7. ***Special electric machines,*** *which included questions about the design, principle of operation and main characteristics of such electric machines as: synchronous jet engines, valve -jet engines, direct current tachogenerators, executive direct current engines, universal collector engines.*

4. Educational materials and resources

Main information resources:

1. *Andrienko V.M., Kuevda V.P. Electric machines : Learn . Help - K.: NUHT, 2010. - 366 p. ISBN 978-966-612-090-1.*
2. *Vaskovsky Yu.M. , Haydenko Yu.A. , Kovalenko M.A. Mathematical modeling of electric machines with permanent magnets: Study . help for studies specialty 141 "Electroenergetics, electrical engineering and electromechanics" (Grif of the university No. 6; date 12.06.2017) K.: KPI named after Ihor Sikorskyi, 2017.– 193 p. ISBN 978-966-622-269-8;*
3. *Traction electric machines of electric rolling stock: training manual /V. M. Bezruchenko , V. K. Varchenko, V. V. Chumak. - D.: Dnipropetr Publishing House . national University of Railways transp . named after Acad. V. Lazaryan, 2003. - 252 p. - ISBN 966-8471-00-8.*
4. *Ostashevskyi M. O., Yuryeva O. Yu. Electric machines and transformers: teaching . manual Kharkiv: FOP Panov A. M., 2017. – 452 p.*
5. *Electric machines: Laboratory works [Electronic resource]: teacher . help for studies specialty 141 "Electric power engineering, electrical engineering and electromechanics", specialization "Electromechanical systems of automation and electric drive" / KPI named after Igor Sikorskyi; comp.: Yu.A. Haydenko , S.S. Tsyvinskyi . – Electronic text data (1 file: 2.07 MB). – Kyiv: KPI named after Igor Sikorskyi, 2018 - 69 p.; Url: ; Adopted by the methodological council; Protocol No. 7; Date 29.03.2018*
6. *Electric machines: Workbook for performing laboratory work [Electronic resource]: education . help for studies specialty 141 "Electric power engineering, electrical engineering and electromechanics", specialization "Electromechanical systems of automation and electric drive" / KPI named after Igor Sikorskyi; comp.: Yu.A. Haydenko , S.S. Tsyvinskyi . – Electronic text m data (1 file: 16.4 MB). – Kyiv: KPI named after Igor Sikorskyi, 2018 – 75 p.; Url: ; Adopted by the methodological council; Protocol No. 7; Date 29.03.2018*
7. *Distance course "Electric machines https://do.ipo.kpi.ua/course/view.php?id=3188*

Additional:

8. *Yatsun M.A. Electric machines. Lviv: Publishing House of Lviv Polytechnic, 2011. 464 p.*
9. *Hrabko V. V. Experimental research of electric machines. Part III. Asynchronous machines: study guide / V. V. Grabko, M. P. Rozvodyuk , S. M. Levitskyi. – Vinnytsia: VNTU, 2007. – 197 p*
10. *Electrical Machines https://books.google.com.ua/books?id=FLgMygrZDgEC&hl=uk&source=gbs.*
11. *https://books.google.com.ua/books?id=SPFKDwAAQBAJ&hl=uk&source=gbs_book_similarbooks*

Educational content

5. Methods of mastering an educational discipline (educational component)

Lecture classes

No s/p	*The name of the topic of the lecture and a list of main questions (list of didactic tools, links to information sources)*
1	**Chapter 1. Introduction to the discipline "Electric machines"** ***Topic 1. Introduction to electromechanics. Basic terms and definitions*** ○ *General concepts and definitions* ○ *Principles of electromechanics* ○ *Classification of electric machines* ○ *Advantages and disadvantages of electric machines* ○ *Classification of electric machines* ○ *Materials used in electrical engineering* ○ *Nominal data of electric machines* *literary sources: [1]p. 5-7;* *distance course "Electric machines" lecture 1* *https://do.ipo.kpi.ua/course/view.php?id=3188#section-2*
2	**Chapter 2. Transformers** ***Topic 2.1. Purpose and principle of operation of the voltage transformer*** ○ *Purpose and classification of voltage transformers* ○ *Basic nominal data of transformers* ○ *The principle of operation of a single-phase transformer* ○ *Electromagnetic relations of the transformer* *literary sources [1], p. 8-10;* *distance course "Electric machines" lecture 2* *https://do.ipo.kpi.ua/course/view.php?id=3188#section-3*
3	***Topic 2.2. Construction of voltage transformers*** ○ *Types of constructions of magnetic conductors of transformers* ○ *Types of designs of transformer windings* ○ *Advantages of oil cooling of transformers* ***Topic 2.3. Schemes and groups of connections of windings of three-phase transformers*** ○ *Schemes of connections of windings of three-phase transformers* ○ *Groups of connections of windings of three-phase transformers* ○ *Conditions for turning on transformers for parallel operation* *literary sources : [1], p. 11-27; with. 56-60.* *distance course "Electric machines" lecture 3, 4* *https://do.ipo.kpi.ua/course/view.php?id=3188#section-3*
4	***Topic 2.4. Transformer idling*** ○ *Operation of the transformer in idle mode. Basic values* ○ *Calculation of the magnetic circuit of the transformer* ○ *Phenomena occurring during the magnetization of a magnetic circuit* ○ *The influence of the winding connection scheme on the operation of three-phase transformers in the H.H. mode.* *literary sources [1], pp. 28-30.* *distance course "Electric machines" lecture 5* *https://do.ipo.kpi.ua/course/view.php?id=3188#section-3*

5, 6	***Topic 2.5. Fundamentals of the theory of voltage transformers*** ○ *Voltage equation of a single-phase transformer* ○ *Equation of transformer magnetomotive forces* ○ *Bringing the parameters of the secondary winding to the primary* ○ *Substitution scheme and its parameters* ○ *No-load and short-circuit characteristics* *literary sources: [1], pp. 31-46.* *distance course "Electric machines" lecture 6-8* *https://do.ipo.kpi.ua/course/view.php?id=3188#section-3*
7	***Topic 2.6. Operation of the transformer under load*** ○ *Vector transformer diagrams* ○ *Change in transformer voltage during load. External characteristics* ○ *Power losses and transformer efficiency* ○ *Energy diagrams of the transformer* *literary sources: [1], p. 47-52.* *distance course "Electric machines" lecture 9, 10* *https://do.ipo.kpi.ua/course/view.php?id=3188#section-3*
8	**Chapter 3. General questions of the theory of alternating current machines** ***Topic 3.1. General issues of the theory of electric machines*** ○ *The principle of inducing EMF* ○ *The principle of formation of electromagnetic moment* ○ *The principle of operation of a synchronous generator* ○ *The principle of operation of an asynchronous motor* *literary sources: [1], p. 81-86.* *distance course "Electric machines" lecture 11* *https://do.ipo.kpi.ua/course/view.php?id=3188#section-4*
9 - 10	***Topic 3.2. Stator windings of alternating current machines*** ○ *Requirements for stator windings. Basic concepts and terms of stator windings* ○ *EMF coil* ○ *Improvement of the shape of the EMF curve of the coil. Step shortening. Shortening factor* ○ *EMF of the coil group. Distribution coefficient* ○ *EMF phase. Winding coefficient* ○ *EMF harmonics and combating them* ○ *The main types of stator windings* ○ *Construction of a three-phase loop winding with a shortened pitch* ○ *The number of turns of the phase of the stator winding* *literary sources [1], p. 87-103.* *distance course "Electric machines" lecture 12 - 14* *https://do.ipo.kpi.ua/course/view.php?id=3188#section-4*
11	***Topic 3.3. Forms of grooves and insulation of stator windings of alternating current machines*** ○ *Forms of stator grooves* ○ *The coefficient of filling the groove with conductors* ○ *Classes of heat resistance of insulation of stator windings* *literary sources: [4] , Chapter 3, p. 149-152.* *distance course "Electric machines" lecture 15* *https://do.ipo.kpi.ua/course/view.php?id=3188#section-4*
12	***Topic 3.4. MRS of the stator winding of alternating current machines*** ○ *MRS of the stator winding (MRS of the coil, MRS of the coil group, MRS of the phase)* ○ *Graphical analysis of the MRS curve of the stator winding*

	literary sources: [1], pp. 103-107; *distance course "Electric machines" lecture 16* *https://do.ipo.kpi.ua/course/view.php?id=3188#section-4*
13	***Topic 3.5. Magnetic field of alternating current machines*** ○ *Circular, elliptical and pulsating magnetic fields* ○ *Calculation of the magnetic circuit of an unbalanced electric machine* ○ *Coefficient of magnetic saturation* *literary sources: [1], pp. 107-114.* *distance course "Electric machines" lecture 17* *https://do.ipo.kpi.ua/course/view.php?id=3188#section-4*
14	**Chapter 4. Asynchronous machines** ***Topic 4.1. Asynchronous machines. Design and modes of operation*** ○ *Design of asynchronous machines (AM). AM connection scheme to the network* ○ *Modes of operation of asynchronous machines* ○ *Advantages and disadvantages of asynchronous motors* *literary sources: [1], pp. 118-120.* *distance course "Electric machines" lecture 18* *https://do.ipo.kpi.ua/course/view.php?id=3188#section-5*
15-16	***Topic 4.2. The working process of a three-phase asynchronous motor*** ○ *Magnetic fluxes and inductive resistances of dispersion of asynchronous machines* ○ *Voltage equation of an asynchronous motor* ○ *MRS equation and induction motor currents* ○ *Bringing the parameters of the rotor winding to the stator winding* ○ *Scheme of replacement of an asynchronous motor* ○ *Vector diagram of an induction motor* ○ *Losses in an asynchronous motor. Energy diagram* ○ *Operating characteristics of an asynchronous motor* *literary sources: [1], pp. 120-136.* *distance course "Electric machines" lecture 19-21* *https://do.ipo.kpi.ua/course/view.php?id=3188#section-5*
17	***Topic 4.3. Mechanical characteristics of an asynchronous motor*** ○ *Electromagnetic moment AD* ○ *Mechanical characteristics of AD. Kloss formula* ○ *Influence of parameters on the mechanical characteristics of AD* *literary sources: [1], pp. 137-146.* *distance course "Electric machines" lecture 2 2* *https://do.ipo.kpi.ua/course/view.php?id=3188#section-5*
18	***Topic 4.4. Single-phase asynchronous capacitor motors*** ○ *Design and principle of operation of single-phase ADs* ○ *Single-phase AD connection schemes* ○ *Three-phase ADs included in a single-phase network* *literary sources: [1], pp. 174-180.* *distance course "Electric machines" lecture 23* *https://do.ipo.kpi.ua/course/view.php?id=3188#section-5*
1 9	**Chapter 5 . C asynchronous machines** ***Topic 5.1. Synchronous machines. Design and principle of operation*** ○ *Design of synchronous machines (SM). The scheme of connecting the CM to the network*

	○ *Types of synchronous machines* ○ *The principle of operation of synchronous machines* ○ *Advantages and disadvantages of synchronous motors* ***Topic 5.2. Features of starting synchronous motors*** ○ *Problem and methods of starting synchronous motors* ○ *Asynchronous start of synchronous motors* *literary sources: [1], pp. 190-195; pp. 238-239.* *distance course "Electric machines" lecture 24, 25* *https://do.ipo.kpi.ua/course/view.php?id=3188#section-6*
20	***Topic 5.3. Magnetic field of synchronous machines*** ○ *The magnetic field of the excitation winding* ○ *The magnetic field of the armature winding. Anchor reaction* ○ *Parameters of the CM anchor in the established mode of operation* *literary sources: [1], pp. 195-206.* *distance course "Electric machines" lecture 26* *https://do.ipo.kpi.ua/course/view.php?id=3188#section-6*
21	***Topic 5.4. Voltage equation of synchronous machines*** ○ *Stress equation clear-polar and non-clear-polar SMs* ○ *Vector diagrams of synchronous generators* *literary sources: [1], pp. 207-211.* *distance course "Electric machines" lecture 27* *https://do.ipo.kpi.ua/course/view.php?id=3188#section-6*
22	***Topic 5.5. Characteristics of synchronous machines*** ○ *Angular characteristics of synchronous machines* ○ *U-shaped characteristics of synchronous machines* ○ *Characteristics of the idling speed of the synchronous generator (SG)* ○ *Characteristic of short circuit SG* ○ *The short-circuit ratio of SG* ○ *External characteristics of SG* ○ *Regulatory characteristics of SG* ○ *Load characteristics of SG* ○ *Operating characteristics of a synchronous motor* *literary sources: [1], pp. 212-217.* *distance course "Electric machines" lecture 28, 29* *https://do.ipo.kpi.ua/course/view.php?id=3188#section-6*
23	**Chapter 6 . DC machines** ***Topic 6.1. DC machines. Design and principle of operation*** ○ *Design of direct current collector machines* ○ *The principle of MPS operation* ○ *MPS armature winding* ○ *Advantages and disadvantages of DC motors* *literary sources: [1], pp. 272-284.* *distance course "Electric machines" lecture 30* *https://do.ipo.kpi.ua/course/view.php?id=3188#section-7*
2 4	***Topic 6.2. Electromagnetic relations and commutation in MPS*** ○ *EMF of the MPS armature winding* ○ *MPS voltage equation* ○ *MPS electromagnetic moment* ○ *Reaction of the anchor in MPS* ○ *Ways to improve commutation in MPS*

	Topic 6.3. Ways of excitation and operating mode of MPS ○ *Ways of excitation of MPS* ○ *Modes of operation of MPS* ○ *Losses and efficiency in MPS* *literary sources: [1], pp. 293-313; pp. 314-315.* *distance course "Electric machines" lecture 31, 32* *https://do.ipo.kpi.ua/course/view.php?id=3188#section-7*
25	***Topic 6.4. DC motors*** ○ *Basic DPS equations* ○ *Rotational frequency and mechanical characteristics of DPS* ○ *Operating characteristics of DPS with independent and parallel excitation* ○ *Features of DPS launch* ○ *Adjusting the rotation speed of the DPS* *literary sources: [1], pp. 326-343.* *distance course "Electric machines" lecture 33* *https://do.ipo.kpi.ua/course/view.php?id=3188#section-7*
26	***Topic 6.5. Direct current generators*** ○ *Characteristics of GPS idling* ○ *GPS short circuit characteristics* ○ *The characteristic (reactive) triangle of GPS* ○ *GPS load characteristic* ○ *External characteristics of GPS* ○ *Regulatory characteristics of GPS* ○ *The process of self-excitation in GPS with a parallel method of excitation* *literary sources: [1], pp. 314-323.* *distance course "Electric machines" lecture 34, 35* *https://do.ipo.kpi.ua/course/view.php?id=3188#section-7*
27	**Chapter 7 . Special electric machines** ***Topic 7. Special electric machines. Principle of operation and characteristics*** ○ *Fan jet engines (SRM engines)* ○ *DC tachogenerators* ○ *Executive DC motors* ○ *Universal collector engines* *literary sources: [1], pp. 324-325; pp. 344-351.* *distance course "Electric machines" lecture 36* *https://do.ipo.kpi.ua/course/view.php?id=3188#section-8*

Practical classes

The curriculum does not provide for practical classes.

Laboratory work

No s/p	*Summary of laboratory work*
1	*RESEARCH OF A THREE-PHASE TWO-WINDING TRANSFORMER* *(Lab work #1)* ***The purpose of the work** is to get acquainted with the design of the transformer, to determine the parameters and characteristics of the power transformer based on the data of studies of non-operating cycle (NH) and short circuit (KZ).* ***Program for conducting and processing research results:***

	1. Make an external inspection of T, record factory data and make a sketch of its magnetic system. 2. Measure with a megohmmeter the resistance of the insulation between the windings and on the body, as well as the resistance of the insulation of the tightening bolts on the body. 3. Measure the ohmic resistance of the transformer windings and bring the resistance to temperature. 4. Assemble the scheme. Take off and build the characteristics of HX. Determine: HX current as a percentage of the nominal current and parameters. Find the transformation factor. Determine the number of turns of the primary and secondary windings of the transformer. 5. Assemble the circuit by applying voltage to the HV winding and shorting the LV winding, remove and plot the characteristics of K3. Based on the data of the experiment, determine the parameters, the short-circuit voltage and its components. 6. Determine the induction in the rod and yoke. Using the value of XX losses (at nominal voltage), calculate the specific losses in the steel of the transformer. 7. Calculate and plot the dependence of the efficiency on the load factor for two values of the power factor. 8. According to the short-circuit parameters, determine changes in the secondary voltage at different values of the load factor for two values of cos ϕ_2. Construct external characteristics for two values of cos ϕ_2. *Literature: [5], pp. 8-15* *distance course "Electric machines"* *https://do.ipo.kpi.ua/course/view.php?id=3188*
2	*STUDY OF PARALLEL OPERATION OF TWO-WINDING THREE-PHASE TRANSFORMERS* *(Laboratory work #2)* ***The purpose of the work** is to study the concept and master the method of experimental determination of the connection group of transformer windings; to study the rules of switching on and operation when transformers are connected in parallel.* ***Program for conducting and processing research results:*** *1. Familiarize yourself with the tested transformers and write down the passport data from the factory panels in the test report. 2. Determine the connection group of the transformer windings when the secondary winding is connected in a "star" and "delta". 3. By changing the connection scheme, marking the beginnings and ends, and permuting the markings of the secondary winding clamps in a circle, get groups 8; 6; 2; 5; 11. Construct vector diagrams of linear EMFs for the specified groups of winding connections. 4. Assemble the transformer scheme and check compliance with the conditions for connecting two transformers in parallel operation. 5. Remove and plot the external characteristics of each transformer and transformers working in parallel for two cases: a) with the same voltages K3; b) at different voltages of K3.* *Literature: [5], pp. 16-22* *distance course "Electric machines"* *https://do.ipo.kpi.ua/course/view.php?id=3188*
3	*RESEARCH OF AN ASYNCHRONOUS MOTOR WITH A PHASE ROTOR* *(Lab work #3)* ***The purpose of the work** is to conduct an experiment, to obtain the parameters and characteristics of an asynchronous motor with a phase rotor.* ***Research program:*** *1. Familiarize yourself with the tested unit. Record the data of the factory panel of the asynchronous motor and the auxiliary machine. 2. Measure the ohmic resistances of the stator and rotor windings of the asynchronous motor. Record the ambient temperature.* *3. Collect the diagram, record the data of measuring devices and other equipment used during work. 4. Determine the transformation coefficient. 5. Remove characteristics of non-working stroke (NH). 6. Remove short-circuit characteristics. 7. Remove operating characteristics.* *Literature: [5], pp. 23-33* *distance course "Electric machines"*

	https://do.ipo.kpi.ua/course/view.php?id=3188
4	*RESEARCH OF AN ASYNCHRONOUS MACHINE WITH A SHORT-CIRCUITED ROTOR IN MOTOR AND GENERATOR MODES* *(Lab work #4)* ***The purpose of the work** is to conduct research, obtain the parameters and characteristics of an asynchronous machine with a short-circuited rotor in engine and generator modes.* ***Research program:*** *1. Familiarize yourself with the tested unit. Record the data of the factory panel of asynchronous and auxiliary machines. 2. Measure the ohmic resistance of the stator winding. Measure the ambient temperature. 3. Assemble a circuit for testing. Record the data of measuring devices and other equipment used in the scheme. 4. Remove the HX characteristic in engine mode. 5. Remove the operating characteristics of the asynchronous machine for the engine and generator modes.* *Literature: [2], pp. 34-41* *distance course "Electric machines"* *https://do.ipo.kpi.ua/course/view.php?id=3188*
5	*TESTING OF A THREE-PHASE SYNCHRONOUS GENERATOR IN THE AUTONOMOUS OPERATION MODE* *(Lab work #5)* ***The purpose of the work** is to experimentally determine the main operational characteristics of a synchronous generator (SG) operating in autonomous mode; study the influence of the anchor reaction and the nature of the load; familiarize yourself with the basic methods of regulating a synchronous generator in offline mode.* ***Research program:*** *1. Familiarize yourself with the data of the factory gas panels and the direct current drive motor (DC motor) of the unit under study and write them down in the workbook. 2. Determine on the stand the location of measuring devices, load, starting and adjusting rheostats related to this scheme; rewrite the data of the measuring devices with the indication of the prices of the scale divisions of each measuring device. 3. Assemble a circuit for testing. Record the data of measuring devices and other equipment used in the scheme. 4. Remove and plot the idle speed characteristics of the SG. 5. Remove and construct the short-circuit characteristic of the SG. 6. Remove and build the external characteristics of SG: a) with a purely active load; b) with an inductive load . 7. Remove and build the adjustment characteristics of SG: and) with a purely active load; b) with an inductive load. 8. Remove and construct the induction load characteristic of the SG. 9. Based on the experimental data, construct a characteristic triangle.* *Literature: [2], pp. 42-49* *distance course "Electric machines"* *https://do.ipo.kpi.ua/course/view.php?id=3188*
6	*TESTING OF A SYNCHRONOUS MOTOR* *(Laboratory work No. 6)* ***The purpose of the work** is to investigate and study the main properties of a synchronous motor (SD) , in particular, the method of asynchronous starting, operating characteristics, as well as methods of regulating reactive power.* ***Research program:*** *1. Familiarize yourself with the data of the factory panels SD and the loading direct current generator (GPS) of the unit under study and write them down in the workbook. 2. Determine on the stand the location of measuring devices, load, starting and adjusting rheostats related to this scheme; rewrite the data of the measuring devices with the indication of the prices of the scale divisions of each measuring device. 3. Assemble a circuit for testing. Record the data of measuring devices and other equipment used in the scheme. 4. Carry out asynchronous start of the synchronous motor. 5. Draw and plot the V-shaped characteristics of a synchronous motor at*

	constant useful power. 6. Remove and construct the operating characteristics of a synchronous motor . *Literature: [2], pp. 50-56* *distance course "Electric machines"* *https://do.ipo.kpi.ua/course/view.php?id=3188*
7	*TESTING OF A DIRECT CURRENT GENERATOR WITH INDEPENDENT EXCITATION* *(Laboratory work No. 7)* ***The purpose of the work** is to get acquainted with the design of a direct current machine, to investigate the working properties of a direct current generator (DCG) with independent excitation.* ***Research program:*** *1. Familiarize yourself with the data of the factory shields of the direct current generator (GPS) and the drive motor of the unit under study and write them down in the workbook. 2. Determine on the stand the location of measuring devices, load, starting and adjusting rheostats related to this scheme; rewrite the data of the measuring devices with the indication of the prices of the scale divisions of each measuring device. 3. Assemble a circuit for testing. Record the data of measuring devices and other equipment used in the scheme. 4. Take off and build the characteristic of idle speed. 5. Remove and construct the short circuit characteristic. 6. Based on the characteristics of idling and short circuit, construct a characteristic triangle. 7. Remove and build external characteristics at: a) voltage drop; b) to increase the voltage. 8. Remove and build the control characteristic. 9. Remove and construct load characteristics.* *Literature: [2], pp. 57-62* *distance course "Electric machines"* *https://do.ipo.kpi.ua/course/view.php?id=3188*
8	*OF A PARALLEL AND MIXED DIRECT CURRENT MOTOR* *(Laboratory work No. 8)* ***The purpose of the work** is to investigate the operating properties of a DC motor with parallel and mixed excitation.* ***Research program:*** *1. Get acquainted with the data of the factory shields of the direct current motor (DC) and the load generator of the unit under study and write them down in the workbook. 2. Determine on the stand the location of measuring devices, load, starting and adjusting rheostats related to this scheme; rewrite the data of the measuring devices with the indication of the prices of the scale divisions of each measuring device. 3. Assemble a circuit for testing. Record the data of measuring devices and other equipment used in the scheme. 4. Take off and build the characteristic of idle speed. 5. Remove and construct the operating characteristics of the DPS: a) according to the parallel excitation scheme;* *b) according to the scheme of mixed excitation with coordinated switching on of the windings. 6. Remove and build the DPS control characteristic.* *Literature: [2], pp. 63-68* *distance course "Electric machines"* *https://do.ipo.kpi.ua/course/view.php?id=3188*

6. Student's independent work

No. z/p	*Type of independent work*	*Number hours of SRS*
1	*Preparation for classroom classes*	*8*
2	*Calculations based on primary data obtained in laboratory classes*	*32*

3	*Execution of calculation and graphic works*	*15*
4	*Preparation for MKR*	*7*
5	*Preparation for the exam*	*10*

Policy and control

7. Policy of academic discipline (educational component)

The system of requirements that the teacher sets before the student:

- *rules for attending classes: in accordance with Order 1-273 dated 14.09.2020, it is prohibited to evaluate the presence or absence of the winner at the classroom class, including the awarding of incentive or penalty points. According to the RSO of this discipline, points are awarded for the relevant types of educational activity in lectures and practical classes. Completion of laboratory work in the discipline is a mandatory condition for admission to the exam;*
- *rules of behavior in classes: the student has the opportunity to receive points for the appropriate types of educational activity in lectures and practical classes, provided for by the RSO of the discipline. The use of means of communication to search for information on the teacher's Google Drive, on the Internet, in a distance course on the Sikorsky platform is carried out on the condition that the teacher instructs;*
- *rules for the protection of laboratory work: both individual protection of laboratory work and collective protection (as part of a team, the composition of which is determined at the first laboratory session) are allowed. In both cases, the individual answers of each student are evaluated.*
- *rules for the protection of individual tasks : the protection of the calculated work (RR) from the discipline is carried out individually and only in the case when the student does not agree with the points awarded based on the results of the RR check (provided that the calendar plan for the RR execution is followed);*
- *rules for assigning incentive and penalty points: incentive and penalty points are not included in the main scale of RSO, and their sum does not exceed 10% of the starting scale. Incentive points are awarded for participation in faculty and institute olympiads in the discipline "Electric machines", participation in faculty and institute scientific conferences. Penalty points are awarded for untimely completion of RR and untimely protection of laboratory works.*
- *policy of deadlines and rescheduling: untimely completion of RR and untimely protection of laboratory work involve the accrual of penalty points. If the student did not pass or did not appear for the MKR, his result is evaluated at 0 points. There is no provision for rescheduling the defense of laboratory work and MKR results;*
- *policy on academic integrity: the Code of Honor of the National Technical University of Ukraine "Kyiv Polytechnic Institute" https://kpi.ua/files/honorcode.pdf establishes general moral principles, rules of ethical behavior of individuals and provides a policy of academic integrity for persons working and studying at the university, which they should be guided by in their activities, including when studying and preparing control measures in the discipline "Electric machines";*
- *when using digital means of communication with the teacher (mobile communication, e-mail, correspondence on forums and social networks , etc.), it is necessary to observe generally accepted ethical norms, in particular, be polite and limit communication to the working hours of the teacher.*

8. Types of control and rating system for evaluating learning outcomes (RSO)

Current control *: Calculation work, MKR.*

Calendar control *: is carried out twice a semester as a monitoring of the current state of meeting the requirements of the syllabus .*

Semester control *: exam*

Conditions for admission to the semester control *: minimum positive grades for calculation and graphic work and MKR, enrollment of all laboratory work, semester rating of at least 30 points.*

Table of correspondence of rating points to grades on the university scale:

Number of points	*Rating*
100-95	*Perfectly*
94-85	*Very good*
84-75	*Good*
74-65	*Satisfactorily*
64-60	*Enough*
Less than 60	*Unsatisfactorily*
Admission conditions not met	*Not allowed*

The student's overall rating after the end of the semester consists of points obtained for:

- *execution and protection **of 8** laboratory works;*
- *performance of **2** calculation works (RR) within the framework of an individual task;*
- *execution of one modular control work (MKR).*

Laboratory work	***Calculation works***	***MKR***	***Rs***	***R_E***	***R***
40	*10*	*10*	*60*	*40*	*100*

Performance and protection of laboratory work

*Weight score – **5** .*

*The maximum number of points for all laboratory works is equal to **5 ×8 = 40 points** .*

Evaluation criteria

- *complete performance of the experimental part of the work, accurate processing of experimental data, high-quality design of the protocol and full response in the defense of the work - **5 points** ;*
- *fulfillment of the previous item with such shortcomings as: processing of experimental data with minor errors or poor design of the protocol - **4 points** ;*
- *significant errors in experimental data but complete understanding of the topic and material of laboratory work - **2 ... 3 points** ;*
- *incomplete or inaccurate answer when defending the work and poor preparation of the protocol - **1 point** ;*
- *laboratory work in general is not protected with the existing formalized protocol - **0 points.***

Individual semester task (RR)

*Weight score – **5** .*

*The maximum number of points for completing the RR is **5 ×2 = 10 points** .*

Evaluation criteria

- *complete, accurate and timely execution - **5 points** ;*
- *the calculation is inaccurate, there are some insignificant errors - **3...4 points** ;*
- *the calculation is incomplete, there are some significant errors - **1...2 points** ;*
- *the calculation is incorrect - **0 points** ;*
- *3 weeks are allocated for the execution of the RR from the moment of issuing the task; submission of the RR after the set deadline implies the accrual of a penalty point of **-1** for each week beyond the set deadline.*

Modular control work

*Weight score is **10** .*
*The maximum score for MKR is **10 ×1 = 10 points** .*

Evaluation criteria

- *Complete and accurate execution - **10 points** .*
- *The answers are inaccurate, there are some insignificant errors - **6...9 points** .*
- *The answers are incomplete, there are some significant errors - **1...5 points** .*
- *Incorrect answers - **0 points** .*

Calendar control is based on the current rating. A condition for a positive assessment is the value of the student's current rating of at least 50% of the maximum possible at the time of assessment.

The form of semester control is an exam

The examination paper consists of two theoretical questions.

*If the current rating is $r_c \geq 0.6R$, i.e. **60 points or more** - at the request of the student, the rating point r_c can be credited automatically without taking the exam.*

*If the current rating r_c is within **(0.3 ... 0.59)*R** , i.e. **30 ... 59 points** - the student must complete the examination work.*

*The maximum number of exam points is $R_E = 40$ **points***

Evaluation criteria of the exam

- *complete and correct performance of the task; comprehensive and logical answers to all questions (if necessary, and additional ones) - $R_E = 35...40$ **points** ;*
- *when answering questions, the student makes some mistakes, but can correct them with the help of the teacher; knows the definition of the main concepts and values of the discipline, in general understands the physical essence of physical processes in the studied objects - $R_E = 25...34$ **points** .*
- *the student partially answers the exam questions, shows knowledge, but does not sufficiently understand the physical essence of electromagnetic processes of energy conversion. The answers are inconsistent and unclear - $R_E = 15...24$ **points** .*
- *in the answer, the student makes significant mistakes, shows a lack of understanding of the physical essence of electromagnetic processes, cannot correct mistakes with the help of the teacher. The answers are incorrect, and in some cases do not correspond to the essence of the question - $R_E < 15$ **points** .*

9. Additional information on the discipline (educational component)

List of topics (questions) that are submitted for semester control

1. *Purpose of electric machines and transformers. Classification of electric machines.*
2. *Principles of electromechanics. Purpose and classification of transformers.*

3. *Principle of operation and electromagnetic relations of transformers.*
4. *Construction of voltage transformer. Types and designs of the magnetic circuit.*
5. *Schemes and groups of connections of windings of three-phase transformers.*
6. *Features of calculating the magnetic circuit of the transformer.*
7. *Phenomena that occur during magnetization of the magnet wire of the transformer.*
8. *The influence of the winding connection scheme on the operation of three-phase transformers.*
9. *Equations of transformer voltages , magnetomotive forces and currents.*
10. *Substitution scheme and vector diagram of the transformer.*
11. *Short-circuit and no-load characteristics of the transformer.*
12. *Transformer losses and efficiency. Energy diagram.*
13. *External characteristics of transformers.*
14. *Conditions for turning on transformers for parallel operation.*
15. *The main types of windings and grooves of the stator of alternating current machines. Insulation classes of stator windings of alternating current machines.*
16. *EMF of the coil of the stator winding of alternating current machines. Ways to reduce higher EMF harmonics .*
17. *EMF of the coil group of the stator winding of alternating current machines. Distribution coefficient.*
18. *Phase emf of the stator windings of alternating current machines.*
19. *EMF harmonics and combating them.*
20. *MRS of the stator winding of alternating current machines.*
21. *Concept of circular, elliptical and pulsating magnetic field of alternating current machines. Conditions for creating a circular field.*
22. *MRS of the air gap of an alternating current machine. Air gap coefficient.*
23. *MRS of ferromagnetic sections of an alternating current machine. Saturation factor.*
24. *Design and principle of operation of an asynchronous motor.*
25. *Modes of operation of an asynchronous machine.*
26. *Magnetic fluxes and inductive resistances of dissipation of an asynchronous machine.*
27. *Voltage equation of an asynchronous motor.*
28. *Equation of magnetomotive forces and currents of an asynchronous motor.*
29. *Bringing the parameters of the rotor winding to the stator winding of an asynchronous machine. Values of the parameters of the asynchronous motor replacement scheme.*
30. *Substitution scheme and vector diagram of an asynchronous motor with a short-circuited rotor (for the nominal mode).*
31. *Losses and efficiency of an asynchronous motor. Energy diagram.*
32. *Electromagnetic torque and mechanical characteristics of an asynchronous motor.*
33. *The maximum and starting moments AD. Critical slip. Kloss formula.*
34. *Operating characteristics of an asynchronous motor.*
35. *Experiment and characteristics of idle speed of an asynchronous motor. Scheme of replacement of AD in idle mode.*
36. *Experiment and short-circuit characteristics of an asynchronous motor. Scheme of replacing AD in short-circuit mode.*
37. *Scheme of starting an asynchronous capacitor motor. Operation of a three-phase asynchronous motor from a single-phase network.*
38. *Design and principle of operation of a synchronous generator.*
39. *Types of synchronous machines and their structural differences.*
40. *The problem of starting synchronous motors. Asynchronous startup method.*
41. *The magnetic field of excitation of synchronous machines.*
42. *Armature reaction of synchronous machines.*
43. *Voltage equation of synchronous machines. Vector diagrams of a synchronous generator with an active-inductive and active-capacitive load.*
44. *Characteristics of short circuit and idling of synchronous machines.*

45. *External, adjustment and loading characteristics of synchronous machines.*
46. *Angular characteristics of clear-pole and implicit-pole synchronous machines.*
47. *Operating characteristics of synchronous motors.*
48. *U-shaped characteristics of synchronous machines.*
49. *Design, advantages and disadvantages of a direct current machine (DC).*
50. *Principle of operation and methods of excitation of MPS.*
51. *EMF of the armature winding and MPS voltage equation.*
52. *Electromagnetic moment and mechanical characteristics of DPS.*
53. *Armature reaction of DC machines.*
54. *The reasons for the increase in sparking under the brushes and ways to improve commutation in MPS.*
55. *Features of DPS launch.*
56. *Regulation of the rotation speed of the direct current motor.*
57. *Modes of operation of MPS.*
58. *Losses and efficiency in MPS.*
59. *Operating characteristics of DPS with independent and parallel method of excitation.*
60. *No-load and short-circuit characteristics of GPS with independent excitation. Determination of the saturation coefficient. Characteristic (reactive) triangle.*
61. *External characteristics of GPS with independent, parallel, series and mixed excitation.*
62. *Regulatory characteristic of GPS with independent, parallel and mixed excitation (matched and opposed).*
63. *Load characteristic of GPS with independent and parallel independent, parallel and mixed coherent excitation.*
64. *The process of self-excitation in GPS with a parallel method of excitation.*
65. *Design and characteristics of valve jet engines (SRM engines) .*
66. *DC tachogenerators (design, principle of operation, characteristics).*
67. *Executive DC motors (design features, principle of operation, characteristics).*
68. *Universal collector engine (design, principle of operation, time dependence of torque).*

Certificates of completion of distance or online courses on the relevant subject may be credited subject to the fulfillment of the requirements specified in *ORDER NO. 7-177 DATED 01.10.2020 ON APPROVAL OF THE REGULATION ON RECOGNITION IN KPI NAMED AFTER IHOR SIKORSKYI OF LEARNING RESULTS ACQUIRED IN NON-FORMAL/ INFORMAL EDUCATION*

Working program of the academic discipline (syllabus):

Compiled by an associate professor of the Department of Electromechanics of the FEA, Ph.D. , Assoc. Haydenko Yu. A.

Approved by the Department of Electromechanics of the FEA (Protocol No. 10 of 19.05.2023)

Agreed by the Methodical Commission of the faculty [1](protocol No. 10 of June 20 , 2024)

[1] Methodical council of the university – for general university disciplines.