

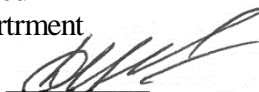
**Ministry of Education and Science of Ukraine**  
**Dnipro University of Technology**

**Department of Electrical Engineering**

**«Approved»**

Head of Department

D.V. Tsyplenkov



«31» august 2021

**The working program of academic discipline**  
**«Electric Machines»**

|                                      |   |
|--------------------------------------|---|
| Field of knowledge                   | 14 Electrical engineering   |
| Specialty.....                       | 141 Electric Power engineering, Electrical Engineering and Electromechanics |
| Level of higher education .....      | first(bachelor's)   |
| Degree.....                          | bachelor  |
| Educational and professional program | «Electric Power engineering, Electrical Engineering and Electromechanics»   |
| Status.....                          | Compulsory  |
| General volume.....                  | 6 credits (180 hours)   |
| Type of final control                | examination   |
| Terms of training .....              | 3rd and 4th semesters   |
| Language of training                 | English   |

Instructors: PhD, Professor Ivanov Olexiy Borisovich

|          |                       |  |
|----------|-----------------------|--|
| Extended | for 20__/20__ ac. yr. | ( ) «__»__ 20__yr..<br>(signature, name, date) |
|          | for 20__/20__ ac. yr. | ( ) «__»__ 20__yr.<br>(signature, name, date)  |
|          | for 20__/20__ ac. yr. | ( ) «__»__ 20__yr.<br>(signature, name, date)  |

Dnipro  
**Dnipro University of Technology**  
2021

The working program of compulsory academic discipline “Electric Machines” for students studying by bachelors’ program on specialty 141 “ Electric Power engineering, Electrical Engineering and Electromechanics” / Dnipro University of Technology, Electrical Engineering Department. – Д. : HTУ «ДП», 2020. – 16 pp.

Developed by PhD, Professor Ivanov O.B.

The working program establishes:

- The discipline goals
- Results of the discipline study based on transformation the expected results of study by the educational program
- Basic disciplines
- The discipline volume and its distribution between the forms of organization of the educational process and types of classes
- The discipline program (lesson topics)
- Algorithm of the discipline study results assessment (scales, means, procedures and assessment criteria)
- Tools, equipment, and software
- Recommended sources of information.

The working program is intended to realization the competence approach at planning the educational process, teaching the discipline, preparation students for the knowledge assessment, monitoring of educational activity, internal and external monitoring of higher education quality, and accreditation of the Educational and Professional Program in frames of the specialty.

Agreed by decision of the Scientific-Methodical Commission on specialty 141 Electric Power engineering, Electrical Engineering and Electromechanics (protocol protocol № 21/22-01 of 30.08.2021).

## CONTENTS

|  |           |
|--|-----------|
| <b>1 THE DISCIPLINE GOALS .....</b>  | <b>3</b>  |
| <b>2 EXPECTED RESULTS OF DISCIPLINE LEARNING .....</b>   | <b>3</b>  |
| <b>3 BASIC DISCIPLINES.....</b>  | <b>4</b>  |
| <b>4 THE DISCIPLINE VOLUME AND ITS DISTRIBUTION BETWEEN<br/>FOFMS OF EDUCATIONAL PROCESS AND TYPE OF CLASSES .....</b> | <b>5</b>  |
| <b>5 THE DISCIPLINE PROGRAM BY TYPES OF CLASSES .....</b>  | <b>5</b>  |
| <b>6 ASSESSMENT OF LEARNING RESULTS .....</b>  | <b>8</b>  |
| <b>6.1 Scales.....</b>   | <b>8</b>  |
| <b>6.2 Means and procedures .....</b>  | <b>9</b>  |
| <b>6.3Assessment criteria.....</b>   | <b>10</b> |
| <b>7 TOOLS EQUIPMENT, AND<br/>SOFTWARE.....</b>  | <b>11</b> |
| <b>8 RECOMMENDED SOURCES OF INFORMATION .....</b>  | <b>15</b> |

### 1 THE DISCIPLINE GOALS

In the Educational and Professional Program of specialty 141 "Electric Power Engineering, Electrical Engineering and Electromechanics ", distribution of the program learning results (PLR) by type of classes is implemented. In particular, the following results are related to discipline  $\Phi 1$  «Electric Machines»:

|      |  |
|------|--|
| ИП03 | To know principles of electric machines, apparatuses, and automated electric drives operation, and to be able to use them at solving practical tasks in professional activity. |
|------|--|

**The discipline goal** is formation of competencies among future specialists in the field of compulsory discipline “Electric Machines”.

Realization of the goal requires transformation the program results of study into disciplinary results, and adequate selection of the discipline content by this criterium.

### 2 EXPECTED RESULTS OF DISCIPLINE LEARNING

| Cipher of PLR | Discipline learning results (DLR) |  |
|---------------|-----------------------------------|--|
|               | Cipher of DLR                     | contents   |
| ИП03          | ИП03.1- $\Phi 1$                  | To determine principle of construction and functioning of electric machines units as part of electric power, electrical, and electromechanical complexes, and systems.   |
|               | ИП03.2- $\Phi 1$                  | 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. |

| Cipher of PLR | Discipline learning results (DLR) |   |
|---------------|-----------------------------------|---|
|               | Cipher of DLR                     | contents  |
|               | IP03.3-Φ1                         | Solving professional tasks on designing and maintenance of electric machines.   |
|               | IP03.4-Φ1                         | To master methods of electric machines with specified properties synthesis.   |
|               | IP03.5-Φ1                         | 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. |
|               | IP03.6-Φ1                         | To carry out new ways for solving problems of economic conversion, distribution, transmission, and application of electrical energy by means of electric machines.  |

### 3 BASIC DISCIPLINES

| Discipline name                                       | Obtained study results  |
|---|---|
| Higher mathematics                                    | IP07 Carry out analysis of processes in electrical, electrical and electromechanical equipment, relevant complexes and systems.<br>IP08 Select and apply suitable methods for analysis and synthesis of electromechanical and electrical systems with specified parameters  |
| General physics                                       | IP07.1-B2 Know: basic laws and concepts of classical (including relativistic) and quantum mechanics, thermodynamics and statistical physics, electrodynamics, theory of oscillations and waves, physics of atoms, molecules, atomic nucleus and condensed state.<br>IP08.2-B2 Formulate physical ideas, solve problems, estimate quantities, operate with physical models and understand the limits of their applications |
| Computer science                                      | IP06 Use application software to solve practical problems in professional activities  |
| Fundamentals of metrology and electrical measurements | IP02.1-Φ3 Fundamentals of metrology - issues of practical application of developments in theoretical metrology and issues of metrological support<br>IP02.2-Φ3 Electrical measurement - finding (by experimental methods) the value of a physical quantity, expressed in appropriate units.   |
| Electrical materials                                  | IP07.1-B6 Analyze processes in electrical, electrical and electromechanical equipment, relevant complexes and systems, taking into account the properties of dielectric, conductive and magnetic materials<br>IP07.2-B6 Calculate the parameters of dielectric, conductive and magnetic materials used in the elements of electric power, electrical electromechanical complexes and systems.                             |
| Fundamentals of Electrical Engineering                | IP05 Know the basics of the theory of the electromagnetic field, methods of calculating electric circuits and be able to use them to solve practical problems in professional activities..  |

#### 4 THE DISCIPLINE VOLUME AND ITS DISTRIBUTION BETWEEN FORMS OF EDUCATIONAL PROCESS ORGANIZATION AND TYPES OF CLASSES

| Types of classes   | Volume, hours | Distribution between forms of educational process, hours |            |                   |            |
|--------------------|---------------|--|------------|-------------------|------------|
|                    |               | Daytime learning   |            | Distance learning |            |
|                    |               | Classroom lessons  | Self-study | Classroom lessons | Self-study |
| lectures           | 126           | 52   | 74         | -                 | -          |
| practical lessons  | –             | –  | –          | -                 | -          |
| laboratory lessons | 54            | 23   | 31         | -                 | -          |
| seminars           | –             | –  | –          | -                 | -          |
| TOTAL              | 180           | 76   | 104        | -                 | -          |

#### 5 DISCIPLINE PROGRAM BY TYPE OF CLASSES

| Cipher of DLR | Type of classes and lesson topics                                    | Component's volume, hours |
|---------------|--|---------------------------|
| ΠΡ03.1-Φ1     | <b>LECTURES</b>  | <b>126</b>                |
| ΠΡ03.3-Φ1     | 1. Transformers  | <b>28</b>                 |
| ΠΡ03.4-Φ1     | 1.1 Principle of operation, construction, cooling                    |                           |
| ΠΡ03.6-Φ1     | 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 Electric machines                     | <b>8</b>                  |
|               | 2.1 Principles of energy conversion in electric machines             |                           |
|               | 2.2 Structure of AC machine windings                                 |                           |

| <b>Cipher of DLR</b> | <b>Type of classes and lesson topics</b>   | <b>Component's volume, hours</b> |
|----------------------|--|----------------------------------|
|                      | 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)  | <b>33</b>                        |
|                      | 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. Power flow diagram of induction motor  |                                  |
|                      | 3.12. Determination of electromagnetic and mechanical power and power losses using induction machine equivalent circuit                      |                                  |
|                      | 3.13. Induction motor and generator efficiency   |                                  |
|                      | 3.14. Spatial and temporal phasor diagram of induction motor and generator   |                                  |
|                      | 3.15. Other operational modes of induction machine   |                                  |
|                      | 3.16. Electromagnetic torque of induction machine  |                                  |
|                      | 3.17. Torque-slip and speed-torque characteristics of induction machines   |                                  |
|                      | 3.18. Ways of changing mechanical characteristics of induction machines  |                                  |
|                      | 3.19. Starting of induction motors   |                                  |
|                      | 3.20. Induction motors speed regulation  |                                  |
|                      | 3.21. Circle diagram of induction machine and its use for determination of the machine characteristics Додаткові моменти асинхронної машини. |                                  |
|                      | 3.22. Additional torques in induction machines   |                                  |
|                      | 3.23. Operation of three-phase induction machines under non-symmetrical conditions   |                                  |
|                      | 4. Synchronous machines  | <b>21</b>                        |
|                      | 4.1. Construction of synchronous machines  |                                  |

| <b>Cipher of DLR</b> | <b>Type of classes and lesson topics</b>  | <b>Component's volume, hours</b> |
|----------------------|---|----------------------------------|
|                      | 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  | <b>21</b>                        |
|                      | 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  | <b>15</b>                        |
|                      | 6.1. Single-phase AC motors   |                                  |
|                      | 6.2. Special induction machines   |                                  |
|                      | 6.3. Asynchronous electrical machine automation devices   |                                  |
|                      | 6.4. Special synchronous machines   |                                  |

| <b>Cipher of DLR</b> | <b>Type of classes and lesson topics</b>   | <b>Component's volume, hours</b> |
|----------------------|--|----------------------------------|
|                      | 6.5. Special types of DC machines  |                                  |
|                      | 6.6. Commutator AC machines  |                                  |
|                      | <b>LABORATORY LESSONS</b>  | <b>54</b>                        |
| ІІР03.2-Ф1           | Determination of transformer ratings and its testing                                       |                                  |
| ІІР03.5-Ф1           | 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                              |                                  |
| <b>РАЗОМ</b>         |  | <b>180</b>                       |

## 6 ASSESSMENT OF LEARNING RESULTS

Certification of students' achievement is carried out by transparent procedures based on objective criteria in accordance with the "Regulation of Dnipro University of Technology on the assessment learning results of recipients of higher education".

The achieved competences level regarding to the expected one, that is identified during the assessment procedures, displays factual students' study result on the discipline.

### 6.1 Scales

Assessment educational achievements of Dnipro University of Technology students' is carried out by the rating (100-point) and the converting scales. The last is needed for conversion of scores obtained by recipients of higher education of different higher educational institutions due to absence of officially approved national scale.

#### *Scales for assessment of educational achievements of Dnipro University of Technology students*

| <b>Rating scale</b> | <b>Institutional scale</b> |
|---------------------|----------------------------|
| 90...100            | відмінно / Excellent       |
| 74...89             | добре / Good               |
| 60...73             | задовільно / Satisfactory  |
| 0...59              | незадовільно / Fail        |

Credits of the academic discipline are certified if a student obtains the total score not less than 60 points. The less score is considered as an academic debt that must be



retaken according to Regulations of Dnipro University of Technology on the Organization of the Educational Process.

## 6.2 Means and procedures

Content of diagnostics means is aimed to monitoring knowledges, skills, communication ability, autonomy, and responsibility of a student at representation his/her study results according to NQF toward the 6<sup>th</sup> qualification level in relation to established by the working program of academic discipline requirements.

At the assessment procedure, a student must carry out tasks aimed only to demonstration of the discipline study results (Section 2).

Diagnostic means given students at current and final monitoring procedures in the form of tasks must be formed as concretized initial data and the way of demonstration of the disciplinary study results.

Diagnostic means (control tasks) for current and final monitoring procedures are approved by a head of the department.

Types of diagnostics means and procedures of assessment for current and final monitoring the discipline are given below.

### *Diagnostic means and procedures of assessment*

| CURRENT MONITORING |                                 |   | FINAL MONITORING        |  |
|--------------------|---------------------------------|---|-------------------------|--|
| Type of lessons    | Means of monitoring             | Procedures                                      | Means of monitoring     | Procedures   |
| Lectures           | Control task for each the topic | completing the assignment during the lecture    | Integrated control work | Determination of average weighted result of current monitoring |
| Laboratory lessons | Control task for each the topic | completing the assignment during the lesson     |                         | Carrying out a control work during the exam                    |
|                    | or individual task              | completing the assignment during the self-study |                         |  |

During the current monitoring, lectures are assessed by determination quality of fulfilment the concretized tasks. Laboratory work is assessed by quality of fulfillment the control or individual tasks.

When content of definite type of lessons includes several components of qualification level description, the integrated score can be determined considering the weight factors that are assigned by an instructor.

When level of current monitoring results on all lesson types is not less than 60 points, the final control is performed without a student participation by determination an average weighted score based on the obtained current scores.

Regardless of results of the current monitoring, each the student has the right to carry out the integrated control work which includes the tasks covering the key discipline study results.

Number of concretized integrated tasks should meet the time allocated for its fulfillment. Number of the integrated task options must provide the task individualization.

A score for the integrated control task is determined as an average score for the task components (i.e., the concretized tasks) and is the final

A score for the integrated control task can be also determined considering the weight factors for the task components which are set by the department for each a component of qualification description level of the integrated control task.

### 6.3 Criteria

Factual results of a student's learning are identified and measured relative to the results expected at the assessment procedure with the help of criteria describing actions of a student on demonstration his/her study results.

For assessment control tasks during current control at lectures and practical lessons, the material assimilation factor, that adapts the scores to the rating scale, is used as a criterium:

$$O_i = 100 a/m,$$

where  $a$  – the number of proper answers or essential operations with regards to the solution standard;  $m$  – the total number of questions or essential reference operations.

Individual tasks and integrated control works are assessed using criteria characterizing the relationship between requirements to competence levels and indices by the rating scale.

Criteria content is based on competence characteristics defined by NQF for the bachelors' level of higher education which is given below.

#### ***General criteria of achievement learning results for the 6th qualification level by the NQF***

|  | <b>Requirements for knowledge, skills, communication, autonomy and responsibility</b>  | <b>Indicator evaluation</b> |
|--|--|-----------------------------|
| <b><i>Skills</i></b>   |  |                             |
| ♦ specialized conceptual knowledge acquired in the process of learning and / or professional activity at the level of the latest achievements, which are the basis for | The answer is excellent - correct, wrapped, meaningful. Characterizes the provision of:<br>- specialized conceptual knowledge at the levels of new and previous achievements;<br>- critical understanding of the problem in teaching and / or professional activities and at the border of subject areas | 95-100                      |
|  | The answer contains minor errors or omissions  | 90-94                       |
|  | The answer is correct, but has some inaccuracies   | 85-89                       |

|  | <b>Requirements for knowledge, skills, communication, autonomy and responsibility</b>  | <b>Indicator evaluation</b> |
|--|--|-----------------------------|
| original thinking and innovation, in particular in the context of research;<br>♦ critical understanding of problems in teaching and / or professional activities and at the boundaries of subject areas  | The answer is correct, but has some inaccuracies and is insufficiently substantiated   | 80-84                       |
|  | The answer is correct, but has some inaccuracies, insufficiently substantiated and meaningful  | 74-79                       |
|  | The answer is fragmentary  | 70-73                       |
|  | The answer shows the student's vague ideas about the object of study   | 65-69                       |
|  | The level of knowledge is minimally satisfactory   | 60-64                       |
|  | The level of knowledge is unsatisfactory   | <60                         |
| <b>Skills</b>  |  |                             |
| ♦ solving complex problems and problems that require updating and integration of knowledge, often in conditions of incomplete / insufficient information and conflicting requirements;<br>♦ conducting research and / or innovation activities | The answer characterizes the ability to:<br>- identify problems;<br>- formulate hypotheses;<br>- solve problems;<br>- update knowledge;<br>- integrate knowledge;<br>- to carry out innovative activity;<br>- to carry out scientific activity | 95-100                      |
|  | The answer characterizes the ability to apply knowledge in practice with minor errors  | 90-94                       |
|  | The answer characterizes the ability to apply knowledge in practice, but has some inaccuracies in the implementation of one requirement  | 85-89                       |
|  | The answer characterizes the ability to apply knowledge in practice, but has some inaccuracies in the implementation of the two requirements   | 80-84                       |
|  | The answer characterizes the ability to apply knowledge in practice, but has some inaccuracies in the implementation of the three requirements   | 74-79                       |
|  | The answer characterizes the ability to apply knowledge in practice, but has some inaccuracies in the implementation of the four requirements  | 70-73                       |
|  | The answer characterizes the ability to apply knowledge in practice when performing tasks on the model   | 65-69                       |
|  | The answer characterizes the ability to apply knowledge in performing tasks on the model, but with inaccuracies  | 60-64                       |
|  | The level of skills is unsatisfactory  | <60                         |
| <b>Communication</b>   |  |                             |
| ♦ clear and unambiguous communication of own conclusions, as well as knowledge and explanations that substantiate them, to specialists and non-specialists, in   | Clarity of the answer (report). Language:<br>- correct;<br>- clean;<br>- clear;<br>- accurate;<br>- logical;<br>- expressive;<br>- concise.<br>Communication strategy:   | 95-100                      |

|   | <b>Requirements for knowledge, skills, communication, autonomy and responsibility</b>   | <b>Indicator evaluation</b> |
|---|---|-----------------------------|
| particular to students;<br>♦ use of foreign languages in professional activities  | <ul style="list-style-type: none"> <li>- consistent and consistent development of thought;</li> <li>- the presence of logical own judgments;</li> <li>- relevant reasoning and its compliance with the defended provisions;</li> <li>- correct structure of the answer (report);</li> <li>- correct answers to questions;</li> <li>- appropriate technique for answering questions;</li> <li>- ability to draw conclusions and formulate proposals;</li> <li>- - use of foreign languages in professional activities</li> </ul>   |                             |
|   | Sufficient clarity of the answer (report) and appropriate communication strategy with minor flaws   | 90-94                       |
|   | Good clarity of the answer (report) and appropriate communication strategy (three requirements in total are not realized)   | 85-89                       |
|   | Good clarity of response (report) and appropriate communication strategy (four requirements not implemented in total)   | 80-84                       |
|   | Good comprehensibility of the answer (report) and appropriate communication strategy (five requirements in total are not fulfilled)   | 74-79                       |
|   | Satisfactory clarity of response (report) and appropriate communication strategy (seven requirements not implemented in total)  | 70-73                       |
|   | Satisfactory comprehensibility of the answer (report) and communication strategy with errors (a total of nine requirements are not implemented)   | 65-69                       |
|   | Satisfactory comprehensibility of the answer (report) and communication strategy with errors (a total of 10 requirements are not implemented)   | 60-64                       |
|   | The level of communication is unsatisfactory  | <60                         |
| <b><i>Autonomy and responsibility</i></b>   |   |                             |
| ♦ responsibility for the development of professional knowledge and practices, assessment of the strategic development of the team;<br>♦ ability to further study, which is largely autonomous and independent | Excellent competence: <ul style="list-style-type: none"> <li>- use of principles and methods of organizing team activities;</li> <li>- effective distribution of powers in the team structure;</li> <li>- maintaining a balanced relationship with team members (responsibility for the relationship);</li> <li>- stress resistance;</li> <li>- self-regulation;</li> <li>- work activity in extreme situations;</li> <li>- high level of personal attitude to the case;</li> <li>- mastery of all types of educational activities;</li> <li>- appropriate level of fundamental knowledge;</li> <li>- - the appropriate level of formation of general educational skills and abilities</li> </ul> | 95-100                      |
|   | Confident mastery of the competencies of autonomy and responsibility with minor flaws   | 90-94                       |
|   | Good mastery of autonomy and responsibility competencies (two requirements not met)   | 85-89                       |

|  | <b>Requirements for knowledge, skills, communication, autonomy and responsibility</b>         | <b>Indicator evaluation</b> |
|--|---|-----------------------------|
|  | Good mastery of autonomy and responsibility competencies (three requirements not met)         | 80-84                       |
|  | Good mastery of autonomy and responsibility competencies (four requirements not met)          | 74-79                       |
|  | Satisfactory mastery of autonomy and responsibility competencies (five requirements not met)  | 70-73                       |
|  | Satisfactory ownership of autonomy and responsibility competencies (six requirements not met) | 65-69                       |
|  | Satisfactory mastery of autonomy and responsibility competencies (fragmentary level)          | 60-64                       |
|  | The level of autonomy and responsibility is unsatisfactory                                    | <60                         |

## 7 ІНСТРУМЕНТИ, ОБЛАДНАННЯ ТА ПРОГРАМНЕ ЗАБЕЗПЕЧЕННЯ

| # of work (cipher) | Work name   | Tools, equipment, and software used in the work   |
|--------------------|---|---|
| EM-2/1             | Determination of transformer ratings and its testing                                | TCO-2.5 transformer<br>Incandescent lamp<br>Probes<br>Switch<br>Measuring devices: <ul style="list-style-type: none"> <li>• megohmmeter</li> <li>• AC voltmeter, 15 V</li> <li>• AC voltmeter, 250 V</li> </ul>   |
| EM-2/2             | Testing of transformer under conditions of open circuit and short-circuit operation | TCO-2.5 transformer<br>Probes<br>Switch<br>Additional resistance of 5 kOhm - 2 pieces.<br>Measuring devices: <ul style="list-style-type: none"> <li>• ammeter 2.5... 5 A - 3 pcs</li> <li>• voltmeter 75... 600 V</li> <li>• wattmeter 5/150 - 2 pcs</li> </ul>   |
| EM-2/4             | Transformers parallel operation   | TSO-2,5 transformer - 2 pieces<br>Probes<br>Switch 50 A - 1 pc<br>Switch 20 A - 4 pcs<br>Panel for connection- 2 pieces<br>Measuring devices: <ul style="list-style-type: none"> <li>• AC ammeter, 10 A - 2 pcs</li> <li>• AC ammeter, 20 A - 1 pc.</li> <li>• voltmeter change e.g. 250 V - 2 pcs</li> </ul> |
| EM-3/1             | Study of induction motors construction and principle                                | Asynchronous motor<br>Incandescent lamp<br>Probes<br>Switch<br>Measuring devices: <ul style="list-style-type: none"> <li>• AC voltmeter, 15 V - 1 pc</li> </ul>   |

|        |  |  |
|--------|--|--|
|        |  | <ul style="list-style-type: none"> <li>• megohmmeter</li> </ul>  |
| EM-3/2 | Investigation of three-phase induction motor using data of no-load and short-circuit tests | Asynchronous motor<br>Switch<br>Resistance 12.5 Ohms<br>Additional resistance of 5 kOhm - 2 pieces<br>Current transformer 15; 50/5 - 2 pcs<br>Measuring devices: <ul style="list-style-type: none"> <li>• DC voltmeter, 1... 150 V</li> <li>• voltmeter, 75... 600 V</li> <li>• ammeter 2,5... 5 A - 2 pcs</li> <li>• wattmeter 5A / 150V - 2 pcs</li> </ul>                                   |
| EM-3/3 | Investigation of induction motor working properties using method of direct loading         | The test bench with measuring instruments, starting equipment and amotor<br>Additional resistance of 5 kOhm<br>Tachometer<br>Desktop measuring instruments: <ul style="list-style-type: none"> <li>• voltmeter 75... 600 V</li> <li>• ammeter 2.5... 5 A</li> <li>• wattmeter 5A / 150V</li> </ul>   |
| EM-3/4 | Investigation of cage induction motors starting methods                                    | Asynchronous motor<br>TCO-2.5 transformer<br>Switch 50 A - 3 pcs<br>Switch for Y/D commutation<br>Measuring devices: <ul style="list-style-type: none"> <li>• AC ammeter 100 A</li> <li>• AC ammeter 50 A</li> <li>• AC ammeter 10 A</li> <li>• AC voltmeter 250 V - 2 pcs</li> </ul>  |
| EM-4/2 | Investigation of parallel operation of synchronous generator connected to grid             | Synchronous generator<br>DC motor<br>Switch - 4 pcs<br>Adjusting rheostat - 2 pcs<br>Synchronization console<br>Current transformer - 2 pcs<br>Measuring devices: <ul style="list-style-type: none"> <li>• AC ammeter 20 A</li> <li>• AC ammeter 3 A - 2 pcs</li> <li>• AC ammeter 30 A - 1 pc</li> <li>• DC voltmeter 300 V - 1 pc</li> <li>• three-phase kilo-wattmeter - 1 piece</li> </ul> |
| EM-4/3 | Asynchronous starting and investigation of synchronous motor at field current adjustment   | Synchronous motor<br>DC generator<br>Equipment and devices for starting and research of synchronous motor  |
| EM-1/2 | Investigation of dc generators   | Asynchronous motor<br>DC generator<br>Switch - 3 pcs<br>Loading rheostat<br>Adjusting rheostat of 1000 Ohms<br>Measuring devices: <ul style="list-style-type: none"> <li>• AC ammeter, 100 A</li> </ul>  |

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|  |  | <ul style="list-style-type: none"> <li>• AC voltmeter, 250 V.</li> <li>• DC ammeter, 3 A</li> <li>• DC ammeter, 30 A</li> <li>• DC voltmeter, 300 V</li> </ul> |
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## 8 RECOMMENDED SOURCE OF INFORMATION

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Розробник  
Іванов Олексій Борисович

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