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

Department of Automation of Electrotechnical and Mechatronic Complexes

Engineering of electrotechnical and mechatronic systems

Working program of the educational discipline (Syllabus)

Detail of educational discipline	
Level of higher education	***Second (Master's)***
Branch of knowledge	*14 Electrical engineering*
Specialty	*141 Power engineering, electrical engineering and electromechanics*
Educational program	*Engineering of intelligent electrotechnical and mechatronic complexes*
Discipline status	*Normative*
Form of education	*daytime*
Year of training, semester	*1st year, spring semester*
Scope of the discipline	*5 credits (150 hours) (36 hours - lectures, 18 hours practical works, 18 hours laboratory works)*
Semester control/ control measures	*Exam / modular control work (MCW), laboratory work*
Schedule	*roz.kpi.ua*
Language of teaching	*English*
Information about course teachers	Lecturer: Ph.D., associate professor, Anton V.Toropov, tel. 066-736-54-53, email: toropovtosha@ukr.net Practical / Seminars: Ph.D, associate professor, Anton V.Toropov, tel. 066-736-54-53, email: toropovtosha@ukr.net
Placement of course	https://classroom.google.com/c/NTU3ODQwNzM2MjM4

Program of educational discipline

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

The purpose and task of the educational discipline "Engineering of electrical and mechatronic systems" is to acquaint students with the basic provisions of consulting and investment-construction engineering. During studying process students acquire the basics of organizing design work, be familiar with the basic schemes of electric drives, methods of organizing construction, mounting and commissioning work in the development of electrotechnical complexes and mechatronic systems.

Competencies: (C13) Ability to analyze technical and economic indicators and examine design and construction solutions in the field of electric power, electrical engineering and electromechanics; (C15) Ability to understand and take into account social, ecological, ethical, economic and commercial considerations affecting the implementation of technical solutions in electric power engineering, electrical engineering and electromechanics; (C16) Ability to manage projects and evaluate their results; (C21) Ability to formulate technical requirements for developed products and technologies, determine technical conditions of operation and maintenance of new equipment, draw up technical tasks for research and development, highlight key technological parameters of developments and determine their target or normative values in the field of engineering.

Program learning outcomes: (PR01) Reproduce processes in electric power, electrotechnical and electromechanical systems using computer simulation; (PR02) Outline action plan to increase the

reliability, safety of operation and prolong the resource of electric power, electrotechnical and electromechanical equipment and corresponding complexes and systems. (PR03) Analyze processes in electric power, electrotechnical and electromechanical equipment and corresponding complexes and systems; (PR05) Possess the methods of mathematical and physical modeling of objects and processes in electric power, electrotechnical and electromechanical systems; (PR08) Consider legal and economic aspects of scientific research and innovative activities; (PR10) Justify the choice of direction and methodology of scientific research taking into account modern problems in the field of electric power, electrical engineering and electromechanics; (PR15) Perform physical and mathematical modeling, static and dynamic analyzes of structures, mechanisms, materials and processes at the design stage, investigate the reliability of systems, using modern computer tools.

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

Interdisciplinary connections: The discipline "Engineering of electrical and mechatronic systems" is taught on the basis of the material of the disciplines: "Automated electric drive of machines and installations", «Computer modeling of processes in electromechanical systems», «Digital and nonlinear systems of electric drive control», «Intelligent decision-making systems», etc., which students studied earlier or in parallel.

The knowledge and skills acquired in the process of studying the credit module "Engineering of electrical and mechatronic systems" are necessary for every specialist of this specialty who solve engineering tasks in the field of automation of electrical engineering and mechatronics and when completing a master's thesis.

3. Content of the educational discipline

The educational discipline "Engineering of electrical and mechatronic systems" consists of 5 chapters:

Chapter 1. Introduction to the discipline "Engineering of electrical and mechatronic systems"

Topic 1.1. General Information. Subject and structure of the course, methods of teaching and assessment of knowledge.

Topic 1.2. The main provisions regarding engineering activities. Basic concepts and definitions.

Chapter 2. Content of engineering

Topic 2.1. System engineering. Objects and characteristics of system engineering. Unification, aggregation and typification in system engineering.

Topic 2.2. Electrical engineering. Objects and characteristics of electrical engineering. Normative and technical documents used in electrical engineering.

Topic 2.3. Engineering of electromechatronic systems. Construction of automated electric drives of mechanisms, machines and complexes based on typical means. Analysis and selection of alternatives for the optimal system option. Synthesis of means of electromechatronic systems. Construction of distributed automation systems.

Topic 2.4. Business plans for the construction of new and modernization of existing electrical equipment. Business plan of an investment project. Marketing researches.

Topic 2.5. International systems of standards. Certification and licensing. Formalization of legal relations. International systems of standards. Certification of compliance with the requirements of technical regulations, provisions of standards and terms of contracts. Licensing of certain activities. Legal relations in the intellectual property market.

Chapter 3. General provisions for the design of electromechatronic systems

Topic 3.1. The main design stages. Technical tasks. Design stages and composition of projects. Technical tasks, requirements and conditions.

Topic 3.2. Technical and economic justification of project decisions. Life cycle of industrial products. Investment projects. Evaluation of the effectiveness of project solutions. Methodological recommendations on the application of indicators of economic efficiency of the investment project.

Topic 3.3. Selection of electrical equipment. Selection of electrical equipment in accordance with performance requirements and operating conditions.

Topic 3.4. Ensuring electromagnetic compatibility and reliability of electrical equipment. Higher harmonics in current and voltage curves and their influence on electrical equipment. Methods and devices for ensuring electromagnetic compatibility. Electromagnetic compatibility of electric motors with power semiconductor converters. Concepts and tasks of ensuring reliability. Estimated calculation of the reliability of electrical equipment elements. Reliability calculation taking into account the reliability of software tools.

Topic 3.5. Provision of projects. Implementation, design and completion of projects.

Chapter 4. Calculation and selection of technical and software means of electromechatronic systems

Topic 4.1. Technical means of electromechanical systems. Controlled converters for low-voltage AC drive systems and their components. High-voltage electric drives. Switching and protective equipment, reactors and filters. Soft start and braking devices. Managing and network facilities. Sensors in electric drive systems. Low-voltage complete devices.

Topic 4.2. Calculation of operating modes and selection of automated electric drives. Calculation and selection of complete electric drives and their components. Calculation of current and voltage harmonics in the power grid that powers the frequency converter. Calculation and selection of electric drives of continuous operation without recuperation of braking energy into the power grid. Calculation and selection of a cyclic electric drive with recuperation of braking energy into the power grid. The choice of electric drives taking into account the influence of operating conditions and the environment.

Topic 4.3. Software tools of electrical engineering systems. Library of programs of standard management functions. Software.

Topic 4.4. Selection of technical and software tools of automation systems. Programmable logic controllers and industrial computers. Information networks and their components. Remotes and terminals. Software for industrial computers, controllers, terminals and intelligent modules. programming of controllers for the implementation of equipment control algorithms. Programming of controllers to solve the problems of increasing the reliability of control systems.

Chapter 5. Computer technologies for designing electromechatronic systems

Topic 5.1. Design tools. Design systems. Basic methods of performing engineering and graphic works. Software analysis. Databases for designing electromechatronic systems.

Topic 5.2. Graphical and alphanumeric markings on diagrams. Formats and main inscriptions Conventional graphic designations of scheme elements and links. Alphanumeric designations of elements and devices. Formats and main captions.

4. Educational materials and resources

Primary literature:

1. Bolton, W. (2018). Mechatronics. Great Britain: Pearson Education Limited.
2. Bolton, W. (2020). Engineering Science. Great Britain: CRC Press.
3. Biemer, S. M., Kossiakoff, A., Seymour, S. J., Flanigan, D. A. (2020). Systems Engineering Principles and Practice. Great Britain: Wiley.

4. Drive Solutions Mechatronics for production and logistics. Edited by E. Kiel.–Berlin: SpringerVerlag, 2008. – 542 p.

5. The industrial communication technology handbook Edited by Richard Zurawski.: CRC Press, Taylor & Francis Group. 2005. - 879 p, ISBN 0-8493-3077-7

6. MATLAB for Engineering Applications. Edited by William J. Palm: McGraw-Hill Education, 2019. – 563p. https://www.technicalbookspdf.com/download/?file=17617

Secondary literature:

6. Alexander Kossiakoff, Samuel J. Seymour, David A. Flanigan, Steven M. Biemer. (2020) Systems Engineering Principles and Practice. John Wiley & Sons, Inc– 688p. ISBN: 978-1-119-516668

7. W.Bolton (2018) Mechatronics: Electronic control systems in mechanical and electrical engineering. Seventh edition: Pearson Education Limited – 648p. ISBN-13: 9781292250977 https://www.pearson.com/en-us/subject-catalog/p/mechatronics-electronic-control-systems-in-mechanical-and-electrical-engineering/P200000003775/9781292250977

8. International Standard IEC 61131-1 Programmable controllers –Programming languages https://webstore.iec.ch/preview/info_iec61131-1%7Bed2.0%7Den.pdf

9. International Standard IEC IEC 61800-3 Adjustable speed electrical power drive systems –EMC requirements and specific test methods https://webstore.iec.ch/p-preview/info_iec61800-3%7Bed3.0.RLV%7Den.pdf

Literature, the bibliography of which is provided with a link, can be found on the Internet. Literature, the bibliography of which does not contain references, can be found in the library of KPI named after Igor Sikorsky. Basic literature [1]-[4] is mandatory for reading. All other literary sources are optional, it is recommended to familiarize yourself with them.

Educational content

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

Strategies of active learning are applied, which are determined by the following methods and technologies: methods of problem-based learning (research method); person-oriented technologies based on such forms and methods of learning as visualization and information and communication technologies, including electronic presentations for lectures. Teaching is carried out in the form of lectures, laboratory and practical sessions.

No.l/p	***Content of educational work***
1-2	**Lecture 1.** Topic 1.1. General Information. Subject and structure of the course, methods of teaching and assessment of knowledge. **Literature:** [1,3]. **Lecture 2.** Topic 1.2. The main provisions regarding engineering activities. Basic concepts and definitions. **Literature:** [1,3].
3-4	**Lecture 3.** Topic 2.1. System engineering. Objects and characteristics of system engineering. Unification, aggregation and typification in system engineering. **Literature:** [1,4]. **Lecture 4.** Topic 2.2. Electrical engineering. Objects and characteristics of electrical engineering. Regulatory and technical documents used in electrical engineering. **Literature:** [1,2].

5-6	**Lecture 5.** Topic 2.3. Engineering of electromechatronic systems. Construction of automated electric drives of mechanisms, machines and complexes based on typical means. Analysis and selection of alternatives for the optimal system option. Synthesis of means of electromechatronic systems. Construction of distributed automation systems. **Literature:** [1,4]. **Lecture 6.** Topic 2.4. Business plans for the construction of new and modernization of existing electrical equipment. Business plan of an investment project. Marketing researches. **Literature:** [1,5].
7-8	**Lecture 7.** Topic 2.5. International systems of standards. Certification and licensing. Formalization of legal relations. Certification of compliance with the requirements of technical regulations, provisions of standards and terms of contracts. Licensing of certain activities. Legal relations in the intellectual property market. **Literature:** [1,3]. **Lecture 8.** Topic 3.1. The main design stages. Technical tasks. Design stages and composition of projects. Technical tasks, requirements and conditions. **Literature:** [1, 3].
9-10	**Lecture 9.** Topic 3.2. Technical and economic justification of project decisions. Life cycle of industrial products. Investment projects. Evaluation of the effectiveness of project solutions. Methodological recommendations on the application of indicators of economic efficiency of the investment project. **Literature:** [1,3]. **Lecture 10.** Topic 3.3. Selection of electrical equipment. Selection of electrical equipment in accordance with performance requirements and operating conditions. **Literature:** [1,3].
11-12	**Lecture 11.** Topic 3.4. Ensuring electromagnetic compatibility and reliability of electrical equipment. Higher harmonics in current and voltage curves and their influence on electrical equipment. Methods and devices for ensuring electromagnetic compatibility. Electromagnetic compatibility of electric motors with power semiconductor converters. Concepts and tasks of ensuring reliability. Estimated calculation of the reliability of electrical equipment elements. Reliability calculation taking into account the reliability of software tools. **Literature:** [1,4]. **Lecture 12.** Topic 3.5. Provision of projects. Implementation, design and completion of projects. **Literature:** [4].
13-14	**Lecture 13.** Topic 4.1. Technical means of electromechanical systems. Controlled converters for low-voltage systems of alternating current electric drives and their components. High-voltage electric drives. Switching and protective equipment, reactors and filters. Soft start and braking devices. Managing and network facilities. Sensors in electric drive systems. Low-voltage complete devices. **Literature:** [1,3]. **Lecture 14.** Topic 4.2. Calculation of operating modes and selection of automated electric drives. Calculation and selection of complete electric drives and their components. Calculation of current and voltage harmonics in the power grid that powers the frequency converter. Calculation and selection of electric drives of continuous operation without recuperation of braking energy into the power grid. Calculation and selection of a cyclic electric drive with recuperation of braking energy into the power grid. The choice of electric drives taking into account the influence of operating conditions and the environment. **Literature:** [1,3].
15-16	**Lecture 15.** Topic 4.3. Software tools of electrical engineering systems. Library of programs of standard management functions. Software for parameterization, monitoring and adjustment of electric drives. **Literature:** [1,5]. **Lecture 16.** Topic 4.4. Selection of technical and software tools of automation systems. Programmable logic controllers and industrial computers. Information networks and their

	components. Remotes and terminals. Software for industrial computers, controllers, terminals and intelligent modules. programming of controllers for the implementation of equipment control algorithms. Programming of controllers to solve the problems of increasing the reliability of control systems. **Literature:** [3,5].
17-18	**Lecture 17.** Topic 5.1. Design tools. Design systems. Basic methods of performing engineering and graphic works. Software analysis. Databases for designing electromechatronic systems **Literature:** [1,2,3]. **Lecture 18.** Graphical and alphanumeric markings on diagrams. Formats and main captions. Conventional graphic designations of scheme elements and links. Alphanumeric designations of elements and devices. Formats and main captions. **Literature:** [3,4]. **Modular control work.**

Practical lessons:

No.l/p	Content of educational work
Practical lesson No.1	Marketing research of the market in developed countries of the far and near abroad and Ukraine on the topic of cource project
Practical lesson No.2	Analysis and selection of an automated control system for the selected object on the topic of cource project
Practical lesson No.3	Selection of electrical equipment
Practical lesson No.4	Evaluation of the energy indicators of the selected electric drive control system
Practical lesson No.5	Selection of technical and software tools of automation systems
Practical lesson No.6	Synthesis of the selected control system in the Matlab environment
Practical lesson No.7	Development of an assembly diagram of an electric drive
Practical lesson No.8	Technical and economic justification of the project decision
Practical lesson No.9	Design of graphic material

Laboratory lessons:

No.l/p	Content of educational work
Laboratory lesson No.1	Investigation of a frequency-regulated AC drive with vector control based on a simulated virtual laboratory bench AS2 in the MATLAB environment.
Laboratory lesson No.2	Investigation of a frequency-regulated AC drive with flux control based on a simulated virtual laboratory bench AS3 in the MATLAB environment.
Laboratory lesson No.3	Investigation of a frequency-regulated AC drive with direct torque control based on a simulated virtual laboratory bench AS4 in the MATLAB environment.
Laboratory lesson No.4	Investigation of regulated synchronous drive with excitation control on the basis of simulated virtual laboratory bench AS5 in the MATLAB environment
Practical lesson No.5	Investigation of a frequency-regulated PM synchronous drive with vector control based on a simulated virtual laboratory bench AS6 in the MATLAB environment.
Laboratory lesson No.6	Investigation of brushless DC drive on the basis of simulated virtual laboratory bench AS7 in the MATLAB environment

Laboratory lesson No.7	Investigation of a DC electric drive system with a reversible single-phase controlled thyristor converter on the basis of a simulated virtual laboratory bench DC2 in the MATLAB environment
Laboratory lesson No.8	Investigation of a DC electric drive system with a reversible three-phase controlled thyristor converter based on a simulated virtual laboratory bench DC4 in the MATLAB environment
Laboratory lesson No.9	Investigation of a DC electric drive system with a reversible pulse-width converter based on a simulated virtual laboratory bench DC7 in the MATLAB environment

6. Independent work of the student

Independent work of the student involves:
preparation for classroom lessons - 52 hours;
preparation for the modular control work - 2 hours;
preparation for the exam - 24 hours

Policy and control

7. Policy of educational discipline (educational component)

At the time of each lesson, both lecture and practical, the student must have the Zoom application installed on the device from which he works (in the case of distance learning), and the course "Engineering of electrotechnical and mechatronic systems " must be opened on the "Google Classroom" platform (the access code to the course to students at the first lesson according to the schedule should be given). Syllabus; lecture material; tasks for each practical session; variants of modular control work; tests to be completed after lectures; methodical recommendations for practical lessons and calculation graphic work; variants of exam work are posted on the "Google Classroom" platform and in the "KPI Electronic Campus" system.

During studying of discipline "Computer control of technological processes, experiments, equipment", students are obliged to adhere to the general moral principles and rules of ethical behavior specified in the Code of Honor of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute". The deadlines for the completion of each task in the discipline " Engineering of electrotechnical and mechatronic systems" on the "Google Classroom" platform are specified. The presence of students of higher education at practical classes is mandatory. Lessons missed for valid reasons ought to be made up.

All students, without exception, are obliged to comply with the requirements of the Regulations on the Academic Plagiarism Prevention System at the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute". Types of control and rating system for evaluating learning outcomes (RSE).

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

Current control: MCW is carried out before the calendar control at a lecture session in the presence of the teacher (15 points), 9 laboratory sessions (5 points per laboratory session = 5 x 9 = 45). MCW is performed in the form of an answer to a theoretical question from the lecture material. At the end of the classtime, the work on the MCW stops and cannot be rewritten. MCW is estimated at 15 points according to the following criteria:

- "excellent" - a complete answer (at least 90% of the required information), relevant justifications and a personal opinion are provided - 14-15 points;

- "good" - a sufficiently complete answer (at least 75% of the required information), which is completed in accordance with the requirements for the "skills" level or contains minor inaccuracies - 9-13 points;

- "satisfactory" - an incomplete answer (at least 60% of the required information), completed in accordance with the requirements for the "stereotypical" level and containing some errors - 3-8 points;

- "unsatisfactory" - unsatisfactory answer - 0 points.

Tasks within the framework of the laboratory session are evaluated in 5 points according to the following criteria:

- "excellent" - fully completed work (at least 90% of the required information), appropriate justifications and personal opinion provided - 5 points;

- "good" - the work contains certain inaccuracies (at least 75% of the required information), the provided justifications are not complete enough - 4 points;

- "satisfactory" - the work contains significant inaccuracies (at least 60% of the required information), the work is performed in accordance with the requirements for the "stereotypical" level and contains significant errors - 3 points;

- "unsatisfactory" - the algorithm proposed in the work is unworkable or there are gross inaccuracies in the developed electrical circuit - 0 points.

Calendar control: is carried out twice a semester as a monitoring of the current state of fulfillment of the syllabus requirements. The condition for a positive first and second calendar control is to obtain at least 50% of the maximum possible rating at the time of the corresponding calendar control.

Semester control: : exam.

Conditions for admission to the semester control: completed MCW and practical classes.

RC(max) = 15 + 45 = 60 points

RC(min) = 3 + 27 = 30 points

At the exam, students perform a written test. The exam paper is valued at 40 points. The control task of this work consists of two theoretical questions from the list provided in the appendix to the syllabus and task. Each question is valued at 13 points (task of 14 points) according to the following criteria:

- "excellent" - a complete answer (at least 90% of the required information), relevant justifications and a personal opinion are provided - 13-14 points;

- "good" - a sufficiently complete answer (at least 75% of the required information), completed in accordance with the requirements for the "skills" level or containing minor inaccuracies - 11-12 points;

- "satisfactory" - an incomplete answer (at least 60% of the required information), completed in accordance with the requirements for the "stereotypical" level and containing some errors - 10 points;

- "unsatisfactory" - unsatisfactory answer - 0 points.

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

Number of points	Rating
100-95	Excellent
94-85	Very good
84-75	Good
74-65	Satisfactory
64-60	Enough
Less than 60	Unsatisfactory
The conditions of admission are not fulfilled	Not allowed

9. Additional information on the discipline (educational component)

The list of questions submitted for semester control is given in the appendix to the syllabus.

A student of higher education has the opportunity to take an online course(s) on one or more topics provided by the work program of the academic discipline. The applicant can choose an online course independently or on the recommendation of a teacher, for example, the "Introduction to Systems Engineering" course on the Coursera platform. 1 hour of the course is valued at 0.83 points. The maximum number of hours that can be credited based on the results of non-formal education is 12 hours, accordingly the maximum number of points for such results is 10 points.

Working program of the educational discipline (syllabus):

Developed by: Associate Professor of the Department of Automation of Electrical and Mechatronic Complexes, Ph.D., Anton V. Toropov

Approved by: Department of Automation of Electrical and Mechatronic Complexes. (Protocol No.17 from 31.05.23).

Agreed by: Methodical Commission of Educational and scientific institute of energy saving and energy management (Protocol No.9 from 22.06.23).

Appendix to the syllabus of the educational component of the course «Engineering of electrical and mechatronic systems»

The list of tasks submitted for semester control

1 1. Explain the concepts of engineering and electromechatronics.

2. Formulate the main types of activities in the implementation of engineering of electromechatronic systems (electric drives and automation systems).

3. List the possible types of engineering activities for young specialists.

4. Reveal the meaning of the following generally accepted terms: stage of creation, product, production, production, plant (factory), enterprise, firm, organization.

5. List the objects of system engineering; the main stages of the process of development and production of products and production.

6. List the main functions of the customer, developer and manufacturer.

7. Give examples of methods of unification, aggregation and typification in system engineering.

8. Formulate the main objects and components of electrical engineering.

9. Formulate the main provisions that must be followed when implementing power equipment projects; the procedure for solving design issues in accordance with the technical specifications.

10. What do the main regulatory documents used in electrical engineering regulate?

11. Give options for creating automated electric drives; principles of construction of modern automated technological complexes (typical structure).

12. Reveal the general issues of calculation, selection and design of automated electric drives.

13. Explain the main options for implementing projects to modernize existing equipment in automated electric drives.

14. List the main requirements for the analysis and selection of the optimal option of an electromechatronic system.

15. Explain the concept of synthesis of means of electromechatronic systems (electric drives and automation systems).

16. Explain the main stages, goals and results of creating distributed automation systems.

17. Give an example of a scheme of means of a modern complex automation system.

18. Explain the purpose and structure of a business plan for an investment project.

19. Explain the content of marketing research.

20. Explain the concept of standard; goals of standardization.

21. Provide the basic concepts and regulations regarding certification.

22. Explain the concept of licensing of certain activities.

23. Give examples of the organizational structure of modern engineering firms.

24. Explain the concepts of agreements and contracts, their content.

25. Explain the concept of intellectual property protection in conditions of competition: patent, objects of patent law, patent owner, commercial secret. Legal relations in the intellectual property market.

26. List the design stages and composition of projects: technical proposal, sketch project, technical project, working design documentation. Nomenclature of design documents.

27. Explain the concepts: technical tasks, requirements and conditions (purpose and content).

28. List the stages and stages of the life cycle of industrial products.

29. Explain the concept of investment projects. Evaluation of the effectiveness of project solutions based on the system of interrelated indicators.

30. List the stages of choosing electrical equipment in accordance with performance requirements and operating conditions.

31. Higher harmonics in current and voltage curves, their influence on electrical equipment; basic measures to ensure electromagnetic compatibility.

32. Provide indicators of the quality of electricity; harmonic composition of current and voltage; damage from higher harmonics for electrical equipment.

33. Explain the methods and devices for ensuring electromagnetic compatibility.

34. Explain the concept of electromechanical compatibility of electric motors with semiconductor converters.

35. List the main concepts and tasks of ensuring the reliability of electromechatronic systems.

36. Explain the concept of estimated calculation of the level of reliability of electrical equipment.

37. Controlled converters for low-voltage electric drive systems and their components.

38. High-voltage electric drives: scope of application; basic technical solutions in practical implementation.

39. Switching and protective equipment, chokes and filters: purpose; general and local connection schemes.

40. Methods of modernization of existing direct current drives: general approaches; example of a typical scheme.

41. Cables and wiring: basic provisions; an example of a general connection scheme. Sensors in electric drive systems.

42. Give the calculation and selection of complete electric drives and their components: the relevance of the task, the main factors and how they can be solved.

43. Determination of current and voltage harmonics in an electrical network with frequency converters.

44. Calculation and selection of electric drives of continuous operation without recuperation of braking energy into the network.

45. Electric drives of cyclic action with recuperation of braking energy into the network.

46. Rules for execution of drawings and schemes. Examples of drawings.

47. Electrical structural and functional diagrams. Implementation examples.

48. Features of implementation of principle schemes. An example of the execution of the scheme of the automation system.

49. Schemes of automated single-motor and multi-motor electric drives: execution order and examples.

50. Circuit diagrams, connection and location: execution order and examples.