Ministry of Science and Higher Education of the Russian Federation
Federal State Autonomous Educational Institution of Higher Education
Perm National Research Polytechnic University

APPROVED BY
Pro-rector for Academic Affairs
_____ N.V. Lobov
"__" 11 2021

ACADEMIC COURSE WORKING PROGRAM

Academic course: Electrically powered mechatronic and robotic systems
(Name)

Form of education: Full-time
(Full-time / part-time / correspondence)

Level of higher education: Bachelor's program
(Bachelor's program / specialist program / Master's program)

Total labour intensiveness: 180 (5)
(Hours (CU))

Training program (degree): 15.03.06 Mechatronics and robotics
(Code and denomination of degree)

Direction: Mechatronics and Robotics
(Title of curriculum)

Perm 2021

1. General Provisions

1.1. Goals and Objectives of the Course

The goal of the course is to master the disciplinary competencies for the implementation of analysis, calculation of electric drive of mechatronic and robotic systems to provide training of bachelors able to solve the problems of design, research, adjustment and operation of modern robotic technological processes and production.

The objectives of the course are:

- to study general physical patterns inherent to drive systems and methods of regulating the coordinates of electric drives;
- to study the purpose, classification and principles of electric drive system installation and features of operation;
- to study electromechanical elements and converters of electric drive systems used in mechatronic and robotic systems;
- to form the ability to make a reasonable choice of electromechanical devices and converters applied in mechatronic and robotic systems;
- to form the skills of parameters and characteristics calculation of electromechanical systems and power elements of electric drives selection for the design of mechatronic and robotic systems.

1.2. Prescribed Objects of the Course

- the mechanical part of the electric drive;
- the electromechanical properties of the motors;
- electric drive transition modes;
- regulating the coordinates of electric drives;
- fundamentals of the heat transfer theory and motor power selection;
- power of electric drives;
- automation of electric drive control.

1.3. Starting Conditions

Unstipulated

2. Planned Results of the Course Training

Competence	Indicator's Index	Planned Results of the Course Training (to know, to be able to, to master)	Indicator of Attaining Competence which the planned results of training are correlated with	Means of Assessment
GPC-9	**IA-1$_{GPC-9}$**	**To know**: - basic schematic solutions of electric drives and mathematical description of electromechanical processes; - the structure and requirements of design documentation at each stage of designing the electric drive systems; - the arrangement, the	**Knows** the principles of construction of advanced technological equipment at mechatronic and robotic system production.	Grading test

		basic concepts, principles, regularities, electromechanical properties and characteristics of electric drive systems for carrying out comparative analysis and selection of electromechanical and power converters.		
GPC-9	**IA-2$_{GPC-9}$**	**To be able to**: - synthesize the electric drive control system and calculate the adjustment elements providing the required dynamic characteristics; - calculate parameters and form mechanical and electromechanical characteristics of the electric drive; - analyze the adjustment properties of the electric drive system; - calculate electricity losses in the steady-state and transient operation of the electric drive.	**Is able to** introduce components of engineering production technological support in the chosen subject area.	Calculation and graphic works
GPC-9	**IA-3$_{GPC-9}$**	**To master the skills** of: - fault diagnosis and detection in simple circuits of electric drive; - analytical processing of experimental research results of electromechanical operations in electric drives.	**Has mastered the skills** of introducing and mastering technological equipment in the field of mechatronics and robotics.	Report on laboratory work
RPC-2	**IA-1$_{RPC-2}$**	**To know** the basic calculation methods and principles of - energy losses and indicators of electric drive systems; - correction elements for the system regulating the electric drive coordinates; - the mechanical part of the electric drive; - transition processes in electric drive systems.	**Knows** methods of calculating individual units and devices of mechatronic and robotic systems.	Grading test

RPC-2	**IA-2$_{RPC-2}$**	**To be able to** - apply methods and tools for elements calculation and selection of the designed electric drive; - develop electrical circuits (functional diagram, schematic diagram, and external connection diagram) of the designed electric drive on the selected element base; - analyze the technical requirements of the electric drive and to make rational schematic and technical decisions on its design.	**Is able to** apply techniques and tools for designing individual units and devices of mechatronic and robotic systems.	Calculation and graphic works
RPC-2	**IA-3$_{RPC-2}$**	**To master the skills** of: - using standard means of measuring and computing technology for calculating static characteristics, transition processes, load diagrams and power indicators of electric drives; - modern methods of calculation and means of computer technology used in designing the electric drive systems; - power selection and type of electric motor and controlled converter for the electric drive system.	**Has mastered the skills** of applying standard measuring and computer equipment in designing and calculating individual units and devices of mechatronic and robotic systems.	Report on practical work

3. Full time and forms of academic work

Form of academic work	Hours in all	Distribution in hours according to semesters
		Number of semester
		8
1. Holding classes (including results monitoring) in the form: 1.1.Contact classwork, including:	54	54
- lectures (L)	24	24
- laboratory work (LW)	16	16
- practice, seminars and/or other seminar-type work (PW)	10	10
- control of self-work (CSW)	4	4
- test		
1.2. Students' self-work (SSW)	126	126
2. Intermediate attestation		
Exam		
Grading test	9	9
Test (Credit)		
Course Project (CP)		
Course Work (CW)		
Workload in hours	180	180

4. Course contents

Name of the units with the course outline	Full time of classroom activity in hours according to the forms			Full time of extracurricular work in hours according to the forms
	L	LW	PW	SSW
8th semester				
Introduction	1	0	0	0
Basic concepts, terms and definitions. The subject and objectives of the discipline. Generalized structures and examples of modern drives of mechatronic and robotic systems. Examples of mechatronic and robotic systems, their classification and requirements for the electric drive. Development of the automated drive theory. Prospects of mechatronic and robotic systems development in Russia and the world.				
Unit 1. Fundamentals of electric drive mechanics	4	0	4	20
Topic 1. General structure of the electric drive and its mechanical part. General structural block diagram of electric drive, its purpose, and functions. Basic diagrams of electric drives of different purposes. Types of electric drives. Kinematic diagram. Forces and moments in the electric drive system. Mechanical characteristics of production mechanisms. Topic 2. Moments of inertia and moments of resistance reduction to the engine shaft, equation of the electric drive motion.				

Reduction of parameters to the design speed and calculation schemes of the mechanical part of the electric drive. Purposes of the reductions. Equations of motion and modes of electric drive operation as a dynamic system. Topic 3. Mechatronic and robotic systems transfer functions. Gearboxes (cylindrical, conical, worm, planetary), screw gears (sliding screw-nut, rolling screw-nut), rack and gear drive, belt and cable transmission, chain and toothed belt transmission, wave gear. Gear elements (ratchet, hinges, clutch).				
Unit 2. Electromechanical properties and characteristics of DC and AC motors	4	4	2	18
Topic 4. Electromechanical properties and characteristics of DC motors (DCM). The basic characteristics of DCM applied in mechatronic and robotic systems. Natural and artificial mechanical characteristics. Equations and characteristics calculation. DCM brake modes (regenerative, back connection, dynamic). Topic 5. Electromechanical properties and characteristics of induction motor (IM). The basic characteristics of IM applied in mechatronic and robotic systems. Parameters of the IM substitution scheme and basic mathematics for rotor current, slip, electromagnetic moment, and critical moment. Natural and artificial mechanical and electromechanical characteristics of IM. Kloss formula and calculation of mechanical characteristics. IM brake modes (regenerative, back connection, dynamic). Topic 6. Stepper motor (SM). Operating principle. Design features of electric drives with SM. Advantages and disadvantages of electric drives with SM.				
Unit 3. Control of electric drives coordinates.	4	4	2	18
Topic 7. Concept of electric drive and its coordinate control. Goals and objectives of coordinates control (variables). Basic methods of coordinate control, their indicators and characteristics. Concept of systems "Controlled modulated converter". Topic 8. Thyristor converter system. Schematic diagram of the thyristor converter system. Static mechanical characteristics, operating modes. Speed control, braking. Main technical and economic indicators. Topic 9. Speed control of electric drives with DC motors. Basic indicators of control and application of different methods. Topic 10. Speed frequency control of induction electric drive. Laws of frequency control. Systems of frequency control with static frequency converter.				

Topic 11. AC electric drive with valve motor. Concept of valve motor. Function of rotor position sensor (RPS), its principle arrangement and operation. Static mechanical characteristics of valve motor. Algorithm of valves operation. The field of valve motor application.				
Unit 4. Electric motor cooling and heating, selection of the its power	3	0	1	18
Topic 12. Motor cooling and heating in different modes of operation. The concept of load diagrams of mechanisms and motors. Rated operating modes of electric motors (S1-S8). Electric motor cooling and heating in continuous duty (S1), short-time (S2) and intermittent periodic duty (S3) of operation modes. Topic 13. Methods of checking the limit load of electric motors. Calculations and selection of motors and other electrical equipment at the design of electric drives. Preliminary selection of electric motors by power. Check of the motor limit load by the method of average losses. Determination of losses and efficiency of the electric motor under rate and non-rate load. Check of the limit load with methods of equivalent values (current, moment, power). Topic 14. Selection of electric motors by power. Selection of electric motors by power for operation in modes S1, S2, and S3. Selection of converters.				
Unit 5. Power of electric drives	2	0	1	16
Topic 15. Energy losses in the steady state of electric drives. The concept of electric drive power. Energy losses in the steady state of an unregulated and regulated electric drive. Basic mathematics of energy losses in electric drives with DC and AC motors. Topic 16. Energy losses in electric drive transitions and methods to reduce energy losses. Power losses at transient state in unregulated and regulated electric drives. Reducing energy losses.				
Unit 6. Electromechanical transient processes	3	4	0	18
Topic 17. General information on electric drive transient modes. The concept of transient processes of electric drives, factors affecting the transient process, classification of transient processes, and methods of analysis. The equations of electromechanical transient process of electric drive with linear mechanical characteristic at w0=const and Mc=const. Topic 18. Transient processes of electric drive with linear speed-torque characteristic at values of w0 and Mc in different operation modes.				
Unit 7. Automated electric drive control in open and closed systems.	3	4	0	18
Topic 19. Automated modes of electric drive in open-				

circuit systems. Automation of starting, braking, and reverse processes of electric drives in open-circuit systems. Typical units of automated control systems for starting, braking and reversing of DC and AC motors. Topic 20. Closed-loop systems of "Controlled modulated converter" with different feedbacks. Construction and structural schemes principles of closed-loop systems of thyristor converter, thyristor frequency converter-asynchronous motor with feedbacks of speed, current and EMF. Schematic diagrams and static mechanical characteristics. Topic 21. Elements of automated electric drives design. Choice of electric drive system. Technical requirements and specifications. Ratings of typical electrical equipment. Climatic modification.				
Total with regard to 8th semester	24	16	10	126
Total with regard to the course	**24**	**16**	**10**	**126**

Topics of exemplary practical works

Sl. №	**Topic of practical works**
1.	Design scheme synthesis and definition of the mechanical part of the electric drive
2.	Parameters and characteristics calculation of an electric drive with the DC motor of separate excitation
3.	Parameters and characteristics calculation of AC electric drive with asynchronous motor
4.	Calculation of controlled electric drive installation with the DC motor in the thyristor converter system
5.	Calculation of controlled electric drive installation with the AC motor in the thyristor frequency converter-asynchronous motor
6.	Loss evaluation in the steady-state and transient operation modes of the electric drive
7.	Motor heating, its selection according to power.

Topics of exemplary laboratory works

Sl. №	Topic of laboratory works
1.	Study of the static characteristics of a DC motor electric drive
2.	Study of static characteristics of electric drive with three-phase asynchronous motor
3.	Study of the static characteristics of the DC thyristor converter system
4.	Study of static characteristics of open-loop system "Frequency converter-asynchronous motor"
5.	Study of closed-loop system "Frequency converter-asynchronous motor"
6.	Study of electromechanical transient processes in a DC electric drive

5. Organizational and Pedagogical Conditions

5.1. Educational Technologies Used for Competences Formation

Holding lectures in the discipline is based on the active method of training in the process of which students are not passive but active participants of the lesson answering questions of the teacher. Teacher's questions are aimed at activating the process of learning material as well as at the development of logical thinking. The questions stimulating associative thinking and connecting new material with the previous one are formulated by the teacher in advance.

Practical lessons are held by realization of the method based on active training: problem areas are determined, groups are formed. The following aims are pursued in the process of practical education: use of definite disciplines knowledge and creative methods in solving problems and decision-making; students' skill-building of teamwork, interpersonal communication and development of leadership skills; consolidation of the basic theoretical knowledge.

Laboratory classes are based on an interactive learning method in which students communicate not only with the teacher but also with each other. At the same time, students' activity in the learning process dominates. The teacher's place in interactive classes is reduced to orienting students' activities to achievement of the goals of studies.

Interactive lectures, group discussions, role-playing games, training sessions, and analysis of situations and simulation models are used in academic studies.

5.2. Students' Manual for the Course Study

Learning the course, it is advisable for students to implement the following recommendations:

1. Learning of the discipline should be done systematically.
2. After learning one of the course units with the help of the text-book or lecture notes it is recommended to reproduce the basic terms, definitions, notions of the unit from memory.
3. Special attention should be paid to the reports on practical studies and individual complex tasks for self-work.
4. The topics list for individual study is given by the teacher at the lectures. The teacher also provides students with literary sources (first of all, new ones in the periodical scientific literature) for a more detailed under-standing of the issues presented at the lectures.

6. List of Teaching Materials and Information Supply for Students' Self work in the Discipline

6.1. Paper-based courseware

Sl.№	Bibliographic entry (author, title, mode of publication, place, publishing house, year of publication, number of pages)	Number of copies in the library
1. Basic literature		
1.	Isermann Rolf Mechatronic Systems Fundamentals: Springer London, 2005, 624 p.	
2.	Hughes Austin, Drury Bill Electric Motors and Drives: Fundamentals, Types and Applications: Newnes; 4th edition, 2013, 440 p.	
2. Additional literature		
2.1. Educational and scientific literature		
1.	Krishnan R. Electric Motor Drives: Modeling, Analysis, and Control: Pearson; 1st edition, 2001, 656 p.	
2.	De Doncker Rik W., Pulle Duco W.J., Veltman André Advanced Electrical Drives: Analysis, Modeling, Control: Springer; 2nd edition, 2020, 644 p.	
2.2. Standardized and Technical literature		
3. Students' manual in mastering discipline		
4. Teaching and learning materials for students' self-work		

6.2. Electronic Courseware

Kind of literature	Name of training tool	Reference to information resource	Accessibility of EBN (Internet/local net; authorized free access)

6.3. License and Free Distributed Software used in the Course Educational Process

Type of Software	Software branding
Operating systems	Windows 10 (Azure Dev Tools for Teaching)
Office applications	Microsoft Office Professional 2007, license 42661567

6.4. Modern Professional Databases and Inquiry Systems Used in the Course Educational Process

Branding	Reference to information resource
Scientific electronic library database (eLIBRARY.RU)	https://elibrary.ru/
Scientific Library of Perm National Research Polytechnic University	http://lib.pstu.ru/
Lan' Electronic library system	https://e.lanbook.com/
IPR books Electronic library system	http ://www.iprbookshop.ru/
Information resources of the Network ConsultantPlus	http://www.consultant.ru/
Information and Reference System of Regulatory and Technical Documentation "Technical Expert: Norms, Rules, Standards and Legislation of Russia"	https://техэксперт.сайт/

7. Logistics of the Course Educational Process

Type of classes	Name of the necessary basic equipment	Number of units
Laboratory class	Laboratory facilities "Electric machines and electric drive. Asynchronous squirrel-cage electric motor, DC generator 1.5 kW"	1
Laboratory class	Laboratory facilities "Electric machines and electric drive. Three-phase asynchronous electric motor, DC generator 1.5 kW"	1
Laboratory class	Laboratory facilities "Electromechanical systems, electric drive, electric drive theory"	1
Lecture	Projector, laptop, screen, marker board	1
Practical class	Marker board	1

8. Fund of the Course Evaluating Tools

Described in a separate document