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

Department of Electromechanical Systems Automation and Electrical Drives FEA

PROGRAM AND TRACKING MOTION CONTROL SYSTEMS

Work program of the discipline (Syllabus)

Реквізити навчальної дисципліни	
Level of higher education	**Second (master's)**
Branch of knowledge	*14 "Electrical Engineering"*
Specialty	*141 "Electric power engineering, electrical engineering and electromechanics"*
Educational program	*ELECTRIC POWER ENGINEERING, ELECTRICAL ENGINEERING AND ELECTROMECHANICS*
Discipline status	*Normative educational component of the training cycle*
Form of study	*Full-time education (daytime)*
Year of preparation, semester	*1 course, spring semester*
Volume of discipline	*54 hours of lectures / 4 ECTS credits*
Semester control / control activities	*Examination*
Class schedule	*http://rozklad.kpi.ua*
Language of instruction	*Ukrainian*
Information about course leader / teachers	Lecturer: *Ph.D., Assoc. Teriaiev Vitalii*
Course placement	*https://ecampus.kpi.ua/*

Curriculum of the discipline

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

The curriculum of the discipline "Program and tracking motion control systems" is compiled in accordance with the educational program "Electricity, Electrical Engineering and Electromechanics" training of Doctor of Philosophy specialty 141 - Power Engineering, Electrical Engineering and Electromechanics.

The purpose of the credit module *is to acquire knowledge on the theory and principles of technical implementation of modern tracking and software electric drives designed for mechanical engineering, transport, robotics, metalworking, production automation, military and aerospace technology.*

The subject of the discipline *includes: the principles of energy conversion in tracking electromechanical systems and the laws of control of the movement of the executive bodies of working machines. Students will study typical technological applications of tracking electromechanical systems, principles of calculation, selection of equipment and design of industrial*

electric drives, methods of improving the accuracy and element base of tracking systems, current trends and achievements in this field.

Program learning outcomes:

PH03. Analyze the processes in electrical, electrical and electromechanical equipment and related complexes and systems.

PH06. Search for sources of resource support for additional training, research and innovation.

PH07. Plan and implement research and innovative projects in the field of power engineering, electrical engineering and electromechanics.

PH09. Adhere to the principles and directions of the strategy of development of energy security of Ukraine.

PH11. Fluently communicate orally and in writing in state and foreign languages on modern scientific and technical problems of power engineering, electrical engineering and electromechanics.

PH15. To synthesize algorithms of robust and adaptive, vector control, tracking and program control of movement.

PH19. Apply energy-efficient control methods in the development of new electromechanical automation systems and electric drives, electric vehicles.

Acquired professional competencies:

ФК1. Ability to apply existing and develop new methods, techniques, technologies and procedures to solve engineering problems of power engineering, electrical engineering and electromechanics.

ФК3. Ability to analyze technical and economic indicators and examination of design decisions in the field of power engineering, electrical engineering and electromechanics.

ФК4. Ability to demonstrate knowledge and understanding of mathematical principles and methods required for use in power engineering, electrical engineering and electromechanics.

ФК7. Ability to develop plans and projects to ensure the achievement of a specific goal, taking into account all aspects of the problem to be solved, including the production, operation, maintenance and disposal of equipment of electric power, electrical and electromechanical complexes.

ФК8. Ability to demonstrate awareness and ability to use regulations, norms, rules and standards in power engineering, electrical engineering and electromechanics.

ФК11. Ability to design robust and adaptive control algorithms for electromechanical automation systems and electric drives, to develop optimal and intelligent control laws using identification and observation methods.

ФК17. Ability to perform research and development work involving the development of new and modernization of existing electromechanical automation systems and electric drives.

Prerequisites and postrequisites of the discipline (place in the structural and logical scheme of education according to the relevant educational program)

To successfully possession of the discipline, the student must have basic knowledge in physics and mathematics, theory of automatic control, elements of automated electric drive, theory of electric drive, control of electric drives, industrial electric drives and electromechanical systems. Competences, knowledge and skills acquired in the process of studying the credit module enable students and future professionals to independently create modern software and tracking electromechanical systems for a wide range of technological applications based on serial and non-standard equipment, to integrate advanced technologies into electromechanical and electrical systems. operation, modernization and maintenance of complex automation systems of industrial complexes, technological installations and systems.

Content of the discipline

The discipline is structurally divided into 4 sections, namely:
Section 1. Principles of building tracking and software control systems
Topic 1.1 Tracking and software control systems. Terms and definitions, classification, generalized functional diagram
Topic 1.2 Error images, quality factor, technical requirements and design stages of software and tracking electric drives
Topic 1.3 Mathematical description of the tracking electric drive at standard settings
Topic 1.4 Methods of improving the accuracy of tracking and software electric drives

Section 2. Hardware of CNC systems
Topic 2.1 The principle of construction and structure of the CNC system
Topic 2.2 Program input unit
Topic 2.3 Control of information entry
Topic 2.4 Buffer memory block
Topic 2.5 Code converters

Section 3. Programming of CNC systems
Topic 3.1 Source coding systems
Topic 3.2 Programming of geometric information
Topic 3.3 Programming of technological information

Section 4. Features of use of stepper motors in systems with numerical program control
Topic 4.1 Characteristics and applications of stepper motors
Topic 4.2 Types of stepper motors
Topic 4.3 Hybrid stepper motors
Topic 4.4 Features of operating modes of stepper motors
Topic 4.5 Holding torque and operating torque of the stepper motor
Topic 4.6 Formation of transients

Section 5. Information and measuring elements of tracking and software electric drives
Topic 5.1 Position sensors of tracking electric drives
Topic 5.2 Means of connecting digital and analog systems, interface
Topic 5.3 Digital-to-analog and analog-to-digital converters
Topic 5.4 Means of forming transients and improving the accuracy of dynamic modes

Навчальні матеріали та ресурси

Main information resources:

1. *Suk-Hwan Suh, Seong-Kyoon Kang, Dae-Hyuk Chung, Ian Stroud Theory and Design of CNC Systems / Springer-Verlag London Limited, 2008. – 477 p.*
2. *Tan K.K. Precision Motion Control: Design and Implementation. Precision Motion Control / K.K. Tan, T.H. Lee, S. Huang. – London: Springer, 2008. – 272 p.*
3. *Sabanovic A. Motion Control Systems / A. Sabanovic. – Wiley-IEEE Press, 2011. – 352 p.*
4. *Advances in High-Performance Motion Control of Mechatronic Systems / eds. T. Yamaguchi, M. Hirata, C.K. Pang. – Boca Raton, Florida: CRC Press, 2013. – 337 p.*
5. *Thyer G.E. Computer Numerical Control of Machine Tools, Second Edition / G.E. Thyer. – Oxford ; Boston: Butterworth-Heinemann, 1991. – 256 p.*
6. *Evans K. Programming of CNC Machines / K. Evans. – New York: Industrial Press, Inc., 2007. –*

500 p.

7. *Ловыгин А. А., Теверовский Л. В. Современный станок с ЧПУ и CAD/CAM-система. – М.: ДМК Пресс, 2015. – 280 с.*
8. *Сосонкин В.Л., Мартинов Г.М. Системы числового программного управления: Учеб. пособие. - М.: Логос, 2005. - 296 с.*

Supporting literature

9. *Черков Е.А., Кузьмин В.П. Комплектний электропривод станков с ЧПУ. Горький, 1989.*
10. *Головенков Е.А., Сирочкин С.В. Основи автоматики и автоматического регулирования станков с программным управлением. – М. :Машиностроение, 1988. – 288 с.*
11. *Методичні вказівки до виконання курсової роботи з дисципліни «Системи програмного керування електроприводами і промисловими установками». Розділ 1. Синтез цифрового регулятора положення електроприводу подачі верстата з ЧПК/ Укладачі В.Ф. Кудін, І.О. Коваленко. – К.:КПІ. – 1995.*
12. *Кенио Такаши Шаговые двигатели и их микропроцессорные системы управления: Пер. с англ., М.: Энергоатомиздат, 1987 — 199с.*

Textbooks and manuals

13. *Системы управления электроприводов: Учебник для высших учебных заведений. - Под ред. В.М.Терехова. 2-е изд. - М.: Издательский центр «Академия», 2006. - 304 с.*
14. *Белов М.П., Новиков А.Д., Рассудов Л.Н. Автоматизированный электропривод типовых производственных механизмов и технологических комплексов: Учебник для высших учебных заведений. - 3-е изд. - М.: Академия, 2007. - 576 с.*
15. *Расчет и конструирование элементов электропривода: Учебное пособие / В.С.Янковенко, С.С. Арсенюк, В.С.Царик. - М.: Энергоатомиздат, 1997. – 320 с.*
16. *Гусев Н.В., Букреев В.Г. Системы цифрового управления многокоординатными следящими электроприводами: Учебное пособие / Н.В. Гусев, В.Г. Букреев – Томск: Изд-во Томского политехнического университета, 2007. – 213 с.*
17. *URL: http://elprivod.nmu.org.ua/files/automaticED/Гусев%20системы%20управления%20следЭП.pdf*
18. *Теория автоматизированного электропривода: Учеб. пособие для вузов / М.Г.Чиликин, В.И.Ключев, А.С.Сандлер. – М.:Энергия, 1979. – 616 с.*
19. *Динамика следящих приводов: Учеб. пособие для втузов / Б.И.Петров, В.А.Полковников и др.; Под ред. Л.В.Рабиновича. – М:. Машиностроение, 1982. – 496 с.*

Educational content

1. Methods of mastering the discipline (educational component)

Lectures

№ lect.	*Title of lecture topics and list of main issues (list of teaching aids, references)*
1	*Section 1 Introduction. Principles of building tracking and software control systems* *Topic 1.1 Tracking and software control systems. Terms and definitions, classification, generalized functional diagram* *Software and tracking electric drives. Classification, definition. Generalized functional diagram of EMC position control. Options for implementing the position contour. Typical types of loads, setting actions and errors of tracking electric drives.* *Literature: 13, p. 234-296; 14, p. 164-180.*
2	*Topic 1.2 Error images, quality factor, technical requirements and design stages of software and tracking electric drives* *Representation of errors in control and perturbation actions, quality factor of the following electric drive. Technical requirements and design stages of software and tracking electric drives.* *Literature: 13, p. 234-296; 14, p. 164-180; 16, 23-33; 18, p. 7-11.*
3	*Topic 1.3 Mathematical description of the tracking electric drive at standard settings* *Mathematical description of the tracking electric drive at standard settings for technical and symmetrical optimum. Calculation of parameters of links of a contour of adjustment of position. Errors at standard influences.* *Literature: 17, p. 472-497.*
4 *5* *6* *7* *8* *9*	*Topic 1.4 Methods of improving the accuracy of tracking and software electric drives* *Improving the accuracy of automatic control systems based on increasing the gain and the order of astatism.* *Invariance. Application of combined control in tracking electric drives.* *Use of corrective feedback in tracking electric drives.* *Multi-channel control in speed- and position-adjustable electric drives.* *Application of sliding control.* *Application of adaptive control.* *Literature: 16, p. 155-165; 17, p. 472-497; 18, p. 224-254.*
10	*Section 2 Hardware of numerical program control systems* *Topic 2.1 The principle of construction and structure of the contour system of CNC* *Functional diagram of the CNC contour system. The program reading unit.* *Literature: 1, p. 6-8, p. 33-66, 8, p. 55-121.*
11	*Topic 2.2 Program input unit* *Functions of program input, information control, code conversion.* *Literature: 6, p. 35-81; 1, p. 62-66.*
12	*Topic 2.3 Control of information input* *Control tasks. Two stages of control. Parity control. Address structure control. Hardware control. Software control.* *Literature: 6, p. 69-72; 6, p. 34-37.*
13	*Topic 2.4 Buffer memory block* *Functional diagram of BBP. Address register. Memory cells.*

	Literature: 1, p. 19-31.
14	*Topic 2.5 Code converters* *Interpreters. Functions of interpreters* *Literature: 1, p. 33-69.*
15	*Section 3 Features of the use of stepper motors in systems with numerical program control* *Topic 3.1 Characteristics and applications of stepper motors* *Features of design and application of stepper motors. Approaches to the choice of stepper motors. Reliability of stepper motors.* *Literature: 12, p. 45-49, p. 6-16.*
16	*Section 3 Features of the use of stepper motors in systems with numerical program control* *Topic 3.1 Characteristics and applications of stepper motors* *Features of design and application of stepper motors. Approaches to the choice of stepper motors. Reliability of stepper motors.* *Literature: 12, p. 45-49, p. 6-16.*
17	*Topic 3.3 Hybrid stepper motors* *Number of steps per revolution. Typical torque and speed values. Hybrid engine design. Bipolar and unipolar motors.* *Literature: 12, p. 55-61; 12, p. 44-54.*
18	*Topic 3.4 Features of stepper motor modes* *Full-step and half-step modes. Causes of moment oscillations and methods of their elimination. Ways to accelerate the current drop in the windings. Micro step mode.* *Literature: 12, p. 16, p. 44-51.*
19	*Topic 3.5 The torque and operating torque of the stepper motor* *Factors that determine the torque of the stepper motor. Influence of dead zones on positioning accuracy. Providing sinusoidal current phases. Sources of positioning errors.* *Literature: 12, p. 69-75.*
20	*Topic 3.6 Formation of transients* *Engine torque. Features of acceleration and braking of the engine. Maximum start speed. Acceleration mode selection criterion.* *Literature: 12, p. 58-68.*
21 *22* *23*	*Section 4 Information and measuring elements of tracking and software electric drives* *Topic 4.1 Position sensors of tracking electric drives* *Position sensors for tracking electric drives: classification, requirements, accuracy classes, basic parameters, static characteristics and dynamic properties. Coordination of sensor characteristics with subsequent devices.* *Potentiometric and inductive sensors of angular and linear movement.* *Electromachine position sensors based on selsins and rotating transformers. Linear inductosin. Principle of operation, amplitude and phase modes.* *Optical sensors of angular and linear movement.* *Pulse and digital position sensors. Literature: 16, p. 40-52.*
24	*Topic 4.2 Means of connecting digital and analog systems, interface* *Means of connection of digital and analog systems in tracking and software electric drives, elements of the communication interface.* *Literature: 14, 16.*
25	*Topic 4.3 Digital-to-analog and analog-to-digital converters* *Purpose and principles of construction of digital-to-analog and analog-to-digital*

26	*converters (number-pulse, with time conversion, compensatory)* *Literature: 13, p. 256-260.*
27	*Topic 4.4 Means of forming transients and improving the accuracy of static and dynamic modes* *Intensity sensors, perturbation sensors, parabolic position regulator* *Literature: 17, p. 497-525.*

Independent work of student

№	*Type of independent work*	*Volume of hours independent work*
1	*Preparation for classroom work*	*15*
2	*Preparation for laboratory classes*	*18*
3	*Preparation for modular control work*	*5*
4	*Preparation for the test*	*10*
	Together	*48*

Policy and control

Course policy (educational component)

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

• rules for attending classes: in accordance with Order 1-273 of 14.09.2020, it is prohibited to assess the presence or absence of the applicant in the classroom, including the accrual of incentive or penalty points. According to the RSO of this discipline, points are awarded for the relevant types of educational activity in lectures and practical classes;

• rules of conduct in the classroom: the student has the opportunity to receive points for the relevant types of learning activities in the lectures provided by the RSO discipline. The use of means of communication to search for information on the teacher's Google drive, on the Internet, in a distance course on the Sikorsky platform is carried out under the guidance of the teacher;

• policy of deadlines and rearrangements: if the student did not pass or did not appear at the MCR (without good reason), his result is evaluated at 0 points;

• policy on academic integrity: The Code of Honor of the National Technical University of Ukraine "Kyiv Polytechnic Institute" https://kpi.ua/files/honorcode.pdf establishes general moral principles, rules of ethical conduct of individuals and provides a policy of academic integrity for employees and study at the university, which they should be guided in their activities, including the study and preparation of control measures in the discipline of "Automated electric drive";

• when using digital means of communication with the teacher (mobile communication, e-mail, correspondence on forums and social networks, etc.) it is necessary to adhere to generally accepted ethical norms, in particular to be polite and limit communication during the teacher's working hours.

3. Types of control and rating system for assessing learning outcomes (RSO)

Current control: *express polls at lectures, MCR.*

Calendar control: *conducted twice a semester as a monitoring of the current state of compliance with the requirements of the syllabus.*

Semester control: *examination.*

Conditions of admission to semester control: *semester rating more than 30 points.*

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

Number of balls	Rating
95-100	Excellent
85-94	Very good
75-84	Good
65-74	Satisfactory
60-64	Sufficiently
Less 60	Unsatisfactory
Less 30	Not admitted

The general rating assessment *of the student for work in a semester consists of the points received on:*

1. Answers during express interviews at lectures. The weight score is 1. The maximum number of points for all 27 lectures is 27 points. Points are awarded for 1 lecture according to the following criteria:

- active work in class and full lecture notes - 1 point for each lecture;

- passive participation in the lesson, incomplete lecture notes - 0.5 points for each lecture;

- missed lecture without good reason with mandatory presentation of lecture notes - 0.2 points;

- missed lecture for a good reason with the obligatory presentation of the lecture syllabus - 1 point;

2. Execution and protection of laboratory works.

The weight score is 3. The maximum number of points for all 4 laboratory works is 12 (6 points of practice and 6 points for defense).

Completion of the task of laboratory work is estimated at 1.5 points.

The defense of one laboratory work is estimated at 1.5 points.

Criteria for evaluating laboratory work:

- "excellent" (3 points) - the protocol is prepared without errors, the synthesis of all tasks is performed and all schemes are presented, the task is collected and meets the conditions of the task, the answers to the questions are clear and meaningful.

- "good" (2 points) - the protocol is prepared with some inaccuracies, the synthesis of all problems is performed and all schemes are presented, the problem is collected with some minor errors, the answers to the questions have minor errors.

- "satisfactory" (1 point) - the protocol is prepared with errors, the synthesis of all problems is performed and all schemes with some errors are presented, the problem is collected with some insignificant errors, the answers to the questions are unclear and have significant errors.

- "unsatisfactory" (0 points) - the protocol is prepared with errors, not all tasks are synthesized and not all schemes with some errors are presented, the task is not collected or does not work, the answers to the questions are incorrect. Laboratory work requires additional work.

3. Calculation and graphic work:

The weight score is 8. Scoring by RGR is carried out according to the following criteria:

- "excellent", not less than 90% of the required information - 8 points;

- "good", not less than 75% of the required information - 5-7 points;

- "satisfactory", not less than 60% of the required information and minor errors - 3-4 points;

- "unsatisfactory", less than 60% of the required information or significant errors - 0-2 points.

4. Modular control work:

The weight score is equal to 3. The calculation of points for MCR is carried out according to the following criteria:

- "excellent", complete answer (not less than 90% of the required information) - 3 points;
- "good", a sufficiently complete answer (not less than 75% of the required information), or a complete answer with minor inaccuracies - 2 points;
- "satisfactory", incomplete answer (not less than 60% of the required information) and minor errors - 1 point;
- "unsatisfactory", unsatisfactory answer (does not meet the requirements for 3 points) or absence during the work - 0 points.

***Calendar control** is based on the current rating. The condition of positive attestation is the value of the current student rating not less than 50% of the maximum possible at the time of attestation.*

The form of semester control is an exam

The maximum amount of points is 50. A necessary condition for admission to the exam is a complete syllabus of lectures, completed and defended laboratory work.
Exam evaluation criteria
- "excellent", complete answer, not less than 95% of the required information (complete, error-free solution of the problem) - 45 - 50 points;
- "very good", a fairly complete answer, at least 85% of the required information or minor inaccuracies (complete solution of the problem with minor inaccuracies) - 35-44 points;
- "good", a fairly complete answer, at least 75% of the required information or minor inaccuracies (complete solution of the problem with minor inaccuracies) - 25-34 points;
- "satisfactory", incomplete answer, not less than 65% of the required information and some errors (the task is performed with certain shortcomings) - 15-24 points;
- "enough", incomplete answer, but not less than 60% of the required information and some errors (the task is performed with significant shortcomings) - 10 - 14 points;
- "unsatisfactory", the answer does not meet the conditions "satisfactory" - 0 points.

Additional information on the discipline (educational component)

List of topics that are submitted for semester control

1. Tracking and software control systems. Terms and definitions, classification, generalized functional diagram
2. Error representation, quality factor, technical requirements and design stages of software and tracking electric drives
3. Mathematical description of the tracking electric drive at standard settings
4. Methods of improving the accuracy of tracking and software electric drives
5. The principle of construction and structure of the CNC system
6. Program input unit
7. Control of input of information
8. Buffer memory unit
9. Code converters
10. Coding systems for source information
11. Programming of geometric information
12. Programming of technological information
13. Characteristics and applications of stepper motors
14. Types of stepper motors
15. Hybrid stepper motors
16. Features of modes of operation of stepper motors

17. Holding torque and operating torque of the stepper motor
18. Formation of transients
19. Position sensors of tracking electric drives
20. Means of connection of digital and analog systems, interface
21. Digital-to-analog and analog-to-digital converters
22. Means of forming transients and improving the accuracy of dynamic modes

Work program of the discipline (syllabus):

Compiled by Associate Professor of Automation of Electromechanical Systems and Electric Drive FEA **Teriaiev Vitalii**

Approved by the Department of Automation of Electromechanical Systems and Electric Drive FEA (protocol № 12 from 30.06.2020)

Approved by the Methodical Commission of the faculty (protocol № __ from _____)