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

Department of Electromechanical Systems Automation and Electrical Drives

MODELING OF ELECTROMECHANICAL SYSTEMS

Working program of the academic discipline (Syllabus)

Details of the academic discipline	
Level of higher education	***First (undergraduate)***
Discipline	*14 "Electrical engineering"*
Specialty	*141 "Electric power engineering, electrical engineering and electromechanics"*
Educational program	*Electromechanical automation systems, electric drive and electric mobility*
Discipline status	*Mandatory*
Form of education	*daytime*
Year of training, semester	*IV year, autumn semester*
Scope of the discipline	*120 hours / 4 ECTS credits*
Semester control/ control measures	*Credit/MKR/RGR*
Class schedule	*http://rozklad.kpi.ua*
Language of teaching	*Ukrainian/English*
Information about the head of the course / teachers	*Lecturer: Dr.Sc. Kovbasa Serhii Mykolayovych, 0674351881* Practical classes: *Dr.Sc. Kovbasa Serhii Mykolayovych, 0674351881*
Placement of the course	

Program of study discipline

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

The syllabus of the educational discipline " Modeling of electromechanical systems " was compiled in accordance with the educational program "Electromechanical systems of automation, electric drive and electromobility " of bachelor's training in the specialty 141 - Electric power, electrical engineering and electromechanics.

The purpose of the educational discipline *is the acquisition by students of the following general and professional competencies : (ZK01) ability to abstract thinking, analysis and synthesis; (FC1) Ability to solve practical problems using automated design and calculation systems (CAD); (FC12) Ability to use mathematical methods and methods of automatic control theory in the study of linear and non-linear systems, conduct analysis of quality indicators, synthesize regulators, compile and analyze structural diagrams of automatic control systems; (FC13) Ability to use modeling software packages for analysis, synthesis and research of electromechanical automation systems and electric drives; (FC15) Ability to perform calculations of the mechanical part of the electric drive, mechanical transients, calculate the parameters of DC and AC motors, perform their modeling and analysis;*

(FK16) The ability to solve complex problems related to the control of automated electric drives of various technological applications with direct and alternating current electric drives.

The subject of the educational discipline *is the control algorithms of electromechanical converters of various types, as well as dynamic, static and energy indicators of the quality of electromechanical systems built on their basis, including taking into account semiconductor voltage converters.*
Program learning outcomes: *(PR03) know the principles of operation of electric machines, devices and automated electric drives and be able to use them to solve practical problems in professional activities; (PR06) apply application software, microcontrollers and microprocessor technology to solve practical problems in professional activities; (PR07) to analyze processes in electric power, electrotechnical and electromechanical equipment, relevant complexes and systems; (PR09) to be able to evaluate the energy efficiency and reliability of electric power, electrotechnical and electromechanical systems; (PR22) know and understand the basics of coordinate transformation and the principles of frequency and vector control of electromechanical systems; (PR25) know how to improve the efficiency of algorithms for controlling electric drives, electromechanical systems, the basics of electromobility theory ; (PR26) to know and understand the laws of transformation of structural diagrams, typical control laws, methods of studying the stability of linear automatic control systems; typical libraries of Simulink blocks , basics of programming in M-files.*

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

To successfully master the discipline, the student must possess the disciplines "Automated electric drive", "Electric drive", "Control of electric drives", "Theory of automatic control", "Mathematical methods in electromechanics", "Electric machines", "Nonlinear and discrete automatic control systems" Competencies, knowledge and skills acquired in the process of studying the credit module are necessary for further practice and completion of bachelor's work.

3. Content of the academic discipline

*The discipline is structurally divided into **2 sections,** namely:*

Chapter 1 . Mathematical models of elements of electromechanical systems

Topic 1.1. General information about modeling of electromechanical systems.
Topic 1.2. Models of DC motors.
Topic 1.3. Models of alternating current motors.
Topic 1.4. Generation of typical trajectories of specified signals.
Topic 1.5. Alternative packages of modeling programs.
Topic 1.6. Modeling of electromechanical systems based on DC motors .
Topic 1.7. Modeling of transistor converters of electromechanical systems in SimPowerSystems

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Topic. 1.8. Dynamic models of some technological objects. A single-mass technological object with a constant moment of inertia. Two-mass technological object with elasticity. Single-link manipulator in the vertical plane. Single-link manipulator with elasticity. Mass-elastic system.

Chapter 2. Modeling of electromechanical systems based on AC motors

Topic 2.1. Simulation of the frequency control algorithm of an asynchronous motor.
Topic 2.2. Modeling of the system of indirect vector control of asynchronous motors : standard vector control.
Topic 2.3. Modeling of the system of indirect vector control of asynchronous motors : control with compensations of cross connections .
Topic 2.4. Modeling of the direct vector control system.
Topic 2.5. Modeling of vector control systems in the field weakening mode.

Topic 2.6. Study of the robustness of vector control systems.
Topic 2.7. Modeling of vector control systems for permanent magnet synchronous motors.
Topic 2.8. Modeling of torque control systems and the torque vector module .
Topic 2.9. Modeling of angular position control systems.
Topic 2.10. Modeling taking into account the limitations of regulators and elements of electromechanical systems.

4. Educational materials and resources

1. H. Abu-Rub High performance control of AC drives with MATLAB/ Simulink models /H. Abu Rub , A. Iqbal , J. Guzinski . // John Wiley & Sons . -2012. -492 p.
2. Cherny O. P. Modeling of electromechanical systems: Textbook / Cherny O. P., Lugovoi A. V., Rodkin D. Y. , Sisyuk G. Yu., Sadovoy O. V. – Kremenchuk. -2001. -376 p.
3. Ostroverkhov M. Ya., Pyzhov V. M. Modeling of electromechanical systems in "SIMULINK" / Education . a guide for students of higher technical institutions. -K.: VD " Stylos ", 2008. -528 p.
4. Theory of an electric drive / Ed. M.G. Popovicha. - K.: V ischa shkola, 1993.-494 p.
5. Theory of mechatronic systems – 1: Methodological instructions for performing computational and graphic work for correspondence students of the training direction 6.050702 – "Electromechanics" specialty "Electromechanical systems of automation and electric drive" / Compilation: S. M. Peresada, S. M. Kovbasa . -K.: NTUU "KPI", 2011. -96 p.
6. Automation of electromechanical systems-2. Synopsis of lectures for students of the field of training 6.050702 – "Electromechanics" of the specialty "Electromechanical systems of automation and electric drive" / Compilation: S. M. Peresada,–K.: department. AEMS-EP NTUU "KPI", 2014 - 90 p.
7. Krashnan , R. Electric motor drives : modeling , analysis and control /R. Krishnan // Prentice Hall . - 2001. 653 p.
8. Bose BK Power Electronics and Variable Frequency Drives . -IEEE Press , 1997. -639p.

Educational content

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

Lecture classes

No s/p	*The name of the topic of the lecture and a list of main questions (list of didactic tools, links to information sources)*
1	*Topic 1.1. General information about modeling of electromechanical systems.*
2	*Topic 1.2. Models of DC motors.*
3	*Topic 1.3. Models of alternating current motors.*
4	*Topic 1.4. Generation of typical trajectories of specified signals.*
5	*Topic 1.5. Alternative packages of modeling programs.*
6	*Topic 1.6. Modeling of electromechanical systems based on DC motors.*
7	*Topic 1.7. Modeling of transistor converters of electromechanical systems in SimPowerSystems .*
8	*Topic. 1.8. Dynamic models of some technological objects. A single-mass technological object with a constant moment of inertia. Two-mass technological object with elasticity. Single-link manipulator in the vertical plane. Single-link manipulator with elasticity. Mass-elastic system.*
9	*Topic 2.1. Simulation of the frequency control algorithm of an asynchronous motor.*
10	*Topic 2.2. Modeling of the system of indirect vector control of induction motors: standard vector control*

11	Topic 2.3. Modeling of the system of indirect vector control of asynchronous motors: control with compensations of cross connections .
12	Topic 2.4. Modeling of the direct vector control system.
13	Topic 2.5. Modeling of vector control systems in the field weakening mode.
14	Topic 2.6. Study of the robustness of vector control systems.
15	Topic 2.7. Modeling of vector control systems for permanent magnet synchronous motors.
16	Topic 2.8. Modeling of torque control systems and the flux coupling vector module .
17	Topic 2.9. Modeling of angular position control systems.
18	Topic 2.10. Modeling taking into account the limitations of regulators and elements of electromechanical systems.

Practical classes

No s/p	Name of the subject of the lesson and list of main questions
1	Research of electromechanical properties of direct current motors by the method of mathematical modeling.
2	Research of electromechanical properties of asynchronous motors
3	Research of electromechanical systems when working out typical control actions by the method of mathematical modeling
4	Study of the system of subordinate control of coordinates of a direct current motor
5	Study of the system of subordinate control of coordinates of a direct current motor with compensation of disturbing influences and task signals
6	Study of the frequency control system of asynchronous motors
7	Research of systems of indirect vector control of asynchronous motors by the method of mathematical modeling.
8	Research of the direct vector control system by the method of mathematical modeling.
9	Study of the system of vector control of the coordinates of a synchronous motor with permanent magnets by the method of mathematical modeling.
10	Study of the influence of restrictions on the processes of controlling mechanical and electrical coordinates of electromechanical systems
11	Research of electromechanical systems in the mode of field weakening
12	Study of angular position control systems by the method of mathematical modeling.
13	Study of the robustness properties of vector control systems by the method of mathematical modeling.
14	Study of control processes of power semiconductor converters
15	Study of the operation of observers of the flux coupling vector of an asynchronous motor
16	Experimental study of systems of frequency and vector control of an asynchronous motor
17	Modular control work
18	Test

Calculation and graphic work (RGR)

Students perform computational and graphic work, which consists in studying the properties of the robustness of the rotor magnetic flux observer to parametric disturbances. For this, each student is given the observer's equations in accordance with the option, as well as the type of asynchronous motor for which research must be performed. In the processes of RGR implementation, students acquire skills in creating a simulation program, setting up observers and researching their properties using mathematical modeling.

6. Student's independent work

No. z/p	Type of independent work	Number hours of SRS
1	Preparation for classroom classes	23
2	Implementation and protection of RGR	15
3	Preparation for MKR	4
4	Preparation for the test	6

6. Control works

The purpose of the tests is to consolidate and verify theoretical knowledge from the credit module, students to acquire practical skills of independent problem solving.

When studying a credit module, one modular control paper (MKR) is given. Tests are conducted in practical classes. Each student receives an individual task to which he answers in writing. The topic of the control works is devoted to the analysis of the graphs of transient processes and the establishment of properties and quality indicators of AC motor control systems based on them. In the modular control work, the student must answer short questions based on the variant of graphs of transient processes.

Policy and control

7. Policy of academic discipline (educational component)

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

- *rules for attending classes: in accordance with Order 1-273 dated 14.09.2020, it is prohibited to evaluate the presence or absence of the winner at the classroom class, including the awarding of incentive or penalty points. According to the RSO of this discipline, points are awarded for the relevant types of educational activity in lectures and practical classes.*
- *rules of behavior in classes: the student has the opportunity to receive points for the appropriate types of educational activity in lectures and practical classes, provided for by the RSO of the discipline. The use of means of communication to search for information on the teacher's Google Drive, on the Internet, in a distance course on the Sikorsky platform is carried out on the condition that the teacher instructs;*
- *policy of deadlines and rescheduling: if a student did not pass or did not appear at the MKR (without a valid reason), his result is evaluated at 0 points. Recompilation of MKR results is not provided for;*
- *policy on academic integrity: the Code of Honor of the National Technical University of Ukraine "Kyiv Polytechnic Institute" https://kpi.ua/files/honorcode.pdf establishes general moral principles, rules of ethical behavior of individuals and provides a policy of academic integrity for persons working and studying at the university, which they should be guided by in their activities, including when studying and preparing control measures in the discipline "Modeling of electromechanical systems";*
- *when using digital means of communication with the teacher (mobile communication, e-mail, correspondence on forums and social networks, etc.), it is necessary to observe generally accepted ethical norms, in particular, to be polite and limit communication to the working hours of the teacher.*

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

Current control *: express survey, MKR, implementation and protection of practical classes and RGR.*
Calendar control *: is carried out twice a semester as a monitoring of the current state of meeting the requirements of the syllabus .*
Semester control: *assessment.*
Conditions for admission to the semester control *: semester rating of more than 30 points and completed and protected RGR.*
Table of correspondence of rating points to grades on the university scale:

Number of points	Rating
95-100	Perfectly
85-94	Very good
75-84	Good
65-74	Satisfactorily
60-64	Enough
Less than 60	Unsatisfactorily
Less than 30	Not allowed

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

- *answers during express surveys at lectures;*
- *performance and protection of tasks of practical classes;*
- *performance and protection of calculation and graphic work;*
- *execution of modular control work (MCR).*

Express survey at lectures	Tasks of practical classes	RGR	MKR
18	32	20	30

Answers during express surveys at lectures

*Weighted point 1. The maximum number of points in all lectures is 1 point * 18 = 18 points .*
Evaluation criteria

- *correct answers to individual questions from the spot - 1 point;*
- *partially correct answer - 0.5 points;*
- *incorrect answer - 0 points;*

Practical classes

Weight score -2.
*The maximum number of points for all practical classes is 2 points * 16 = 32 points.*
Evaluation criteria

- *correctly completed task and timely submitted report - 2 points;*
- *incomplete completion of the task, untimely submission of the report - 1 point;*
- *task not completed, report not submitted - 0 points.*

Calculation and graphic work

The weight score is 20.
The maximum number of points for the RGR is 20.
Evaluation criteria

implementation and registration

- *the results of the performed studies are correct and properly formatted - 11 - 12 points;*
- *minor errors in calculations and/or design deficiencies 9-10 points;*
- *questionable research results and/or poor design 5-8 points;*
- *incorrect research results - 0 points.*

protection of the RGR

at the defense, the student is asked four questions, the correct answer to each of which is estimated at 2 two points - up to 8 points in total.

Modular control work

The MKR weight score is 30.
The maximum score for MKR is 30.

Evaluation criteria

On the modular test, the student must answer 15 short questions, the correct answer to each of which is estimated at 2 points, a partial answer - 1 point, no answer or an incorrect answer - 0 points.

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

The form of semester control is credit

The maximum number of points is 100. A necessary condition for admission to the credit is a semester rating of more than 30 points and completed and protected RGR . In order to receive credit from the credit module "automatically", you must have a rating of at least 60 points, as well as fulfill the conditions for admission to the credit.
Students who have a rating of less than 60 points at the end of the semester, as well as those who want to improve their grade in the ECTS system, take a credit test. At the same time, the points scored by the student are canceled, and the grade for the credit test is final.
The credit work consists of two parts. The first part consists in setting up a simulation program to study the dynamic, static and energy characteristics of the vector control system for given engine parameters and test conditions. The second part consists in answering 10 short questions about the quality indicators of the investigated vector control system.

Evaluation criteria for credit test work

- *the simulation program starts and is operational and shows correct results for the system under study - 10 points;*
- *the engine parameters are entered correctly - 10 points;*
- *the test conditions are configured correctly - 10 points;*
- *correct answer to each of ten questions - 7 points.*

9. Additional information on the discipline (educational component)

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

Working program of the academic discipline (syllabus):

Compiled by an associate professor of the Department of Automation of Electromechanical Systems and Electric Drives of the FEA , Ph.D. S. M. Kovbasa

Approved by the Department of Automation of Electromechanical Systems and Electric Drives of the FEA (Protocol No. 6 dated January 22 , 2024)

Agreed by the Methodical Commission of the faculty [1](protocol No. 5 dated 01.29.2024)

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