National Technical University of Ukraine
Igor Sikorsky Kyiv Polytechnic Institute "

Department of
Electromechanical Systems
Automation and Electrical
Drives

Control of electric drives

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 (normative)*
Form of education	*Daytime*
Year of training, semester	*4th year, autumn semester*
Scope of the discipline	*6 ECTS credits / 180 hours (54 hours of lectures, 18 hours of practical classes; 18 hours of laboratory work)*
Semester control/ control measures	*Examination/testing, MKR, protection of laboratory works*
Class schedule	*3 lectures (6 hours) once every 2 weeks;* *1 practical session (2 hours) once every 2 weeks;* *1 laboratory work (4 hours) once every 4 weeks.*
Language of teaching	*Ukrainian*
Information about the head of the course / teachers	*Lecturer* : *Ph.D. Peresada Serhiy Mykhailovych, 0662150169,* Practical: *Nikonenko Yevhen Oleksiyovych, 0660214977,* Laboratory : *Ph.D. Mykola Mykolayovych Zhelinskyi , 0986461034*
Placement of the course	https://do.ipo.kpi.ua/course/view.php?id=4962

Program of study discipline

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

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

The purpose of the educational discipline *is to form students of the following competencies : (ZK01) Ability to abstract thinking, analysis and synthesis; (ZK03) Ability to communicate in the state language both orally and in writing; (ZK05) Ability to search, process and analyze information from various sources; (ZK06) Ability to identify, pose and solve problems; (ZK07) Ability to work in a team; (K08) Ability to work autonomously; (FK01) Ability to solve practical problems using automated design and calculation systems (CAD); (FK02) Ability to solve practical problems involving the methods of mathematics, physics and electrical engineering; (FK05) Ability to solve complex specialized tasks and practical problems related to the operation of electric machines, devices and automated electric drive; (FK09) Awareness of the need to increase the efficiency of electric power,* *electrotechnical and electromechanical equipment; (FC10) Awareness of the need to constantly expand one's own knowledge about new technologies in electric power, electrical engineering and electromechanics; (FK12) Ability to use mathematical methods and methods of automatic control theory in the study of linear and nonlinear 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; (ФК16) 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 methods of synthesis, analysis and research of vector control systems for electromechanical energy conversion in AC electric drives, which are used in the construction of modern electric drives with asynchronous and synchronous motors in the form of algorithms for controlling the coordinates of electromechanical systems.*

Program learning outcomes, the formation and improvement of which the discipline is aimed at: *(PRN03) 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; (PRN06) Apply application software, microcontrollers and microprocessor technology to solve practical problems in professional activities ; (PRN07) To analyze processes in electric power, electrotechnical and electromechanical equipment, relevant complexes and systems; (PRN08) Choose and apply suitable methods for the analysis and synthesis of electromechanical and electric power systems with specified indicators; (PRN09) Be able to evaluate the energy efficiency and reliability of electric power, electrotechnical and electromechanical systems; (PRN10) Find the necessary information in scientific and technical literature, databases and other sources of information, evaluate it relevance and reliability; (PRN11) Communicate freely about professional problems in national and foreign languages orally and in writing, discuss the results of professional activity with specialists and non-specialists, argue one's position on debatable issues; (PRN18) To be able to learn independently, acquire new knowledge and improve the skills of working with modern equipment, measuring equipment and application software; (PRN20) Know and understand the principles of control of linear, non-linear and discrete automatic control systems; (PRN22) Know and understand the basics of coordinate transformation and the principles of frequency and vector control of electromechanical systems; (PRN25) Know ways to improve the efficiency of algorithms for controlling electric drives, electromechanical systems, the basics of electromobility theory ; (PRN26) Know and understand the laws of transformation of structural schemes, typical control laws, methods of studying the stability of linear automatic control systems; typical libraries of Simulink blocks , basics of programming in M-files; (PRN27) To know the equation of motion of an electric drive for different types of masses; methods of calculating the mechanical part of the electric drive; methods of controlling DC and AC motors; methods of selecting electric motors by power.*

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, a student must possess the educational components "Electric machines", "Electric drive", "Theory of automatic control", "Nonlinear and discrete automatic control systems", "Automated electric drive". Competences, knowledge and skills acquired during the study of the educational component are necessary for further study of the educational components "Control of electric drives. Course project ", "Management of energy conversion in renewable sources and electric vehicles" and "Electromechanical systems of typical technological applications".

3. Content of the academic discipline

*The discipline is structurally divided into **12 sections** , namely:*

Chapter 1. Overview of adjustable AC drives.

Topic 1.1. Overview of automatic control systems based on EP .
Topic 1.2. Power converters for EP alternating current .
Topic 1.3. Typology of alternating current electric drives .
***Chapter 2. Mathematical description of electromechanical energy conversion processes in AC electric machines** .*

Topic 2.1. Mathematical description in two-phase variables. Substitution scheme. Equations of flux linkages, matrix of inductances, equations of electrical balance, equations of moment.
Topic 2.2. Implicit-pole and obvious-pole synchronous motors with excitation from permanent magnets. Saturation of the magnetic system in synchronous motors.
Topic 2.3. Transformation of the coordinates of the generalized electric machine. Phase transformations. Transformation of the coordinates of the generalized electric machine. Topic 2.4 . The most frequently used models of typical non-polar and positive-pole electric machines.
Chapter 3. Fundamentals of AC EMC control based on synchronous motors (SD) .

Topic 3.1. Study of the dynamic characteristics of the LED during direct start-up from the mains.
Topic 3.2. Study of dynamic characteristics during frequency control of the speed of the SD.
Topic 3.3. Dynamic characteristics of the vector speed control system of the DPS type .
Chapter 4. Fundamentals of vector control of alternating current EMC on the basis of asynchronous motors (AD).

Topic 4.1. Study of the transient processes of direct start-up of AD from the network.
Topic 4.2. Study of dynamic characteristics during frequency control of AD.
Topic 4.3. Vector control of the angular speed of AD by the type of DPS.
***Chapter 5. Vector torque control of alternating current electric machines : synchronous motor** .*

Topic 5.1. Vector control of the moment of the LED during current control .
Topic 5.2. Vector control of the LED moment when powered from a voltage source.
Chapter 6. Vector torque control of alternating current electric machines: induction motor with ideal field orientation .

Topic 6.1. Vector control of AD torque during current control under conditions of ideal field orientation .
Topic 6.2. Vector control of AD torque when powered from a voltage source under conditions of ideal field orientation .
Chapter 7. Vector torque control of alternating current electric machines: asynchronous motor with direct field orientation .

Topic 7.1. Direct vector control of AD torque based on the separation principle.
Topic 7.2. Direct vector control of AD moment under the condition of power supply from a current source .
Topic 7.3. Direct vector control of AD moment under the condition of power supply from a voltage source.
Chapter 8. Vector torque control of alternating current electric machines: induction motor with indirect field orientation .

Topic 8.1. Torque control under conditions of power supply from a current source.
Topic 8.2. Torque control under conditions of power supply from a voltage source.
Chapter 9. Vector control of angular velocity and angular position: general theory

Topic 9.1. Unified algorithm for working out angular velocity.
Topic 9.2. Unified angular position control algorithm.

Chapter 10. Vector control of the angular velocity of alternating current motors.

Topic 10.1. Vector control of the angular speed of the LED under the conditions of current supply .
Topic 10.2. Vector control of the angular speed of the LED under the condition of power supply from a voltage source.
Topic 10.3. Indirect vector control of the angular speed of AD under the condition of power from a current source.
Topic 10.4. Direct vector control of the angular speed of AD under the condition of current control.
Topic 10.5. Direct vector angular velocity control for power from a voltage source.
Topic 10.6. Indirect vector control of AD speed under conditions of power supply from a voltage source.

Chapter 11. Controlling the speed and position of various types of SD.

Topic 11 .1. Angular speed control of non-uniform pole synchronous motors with permanent magnets .
Topic 11.2. Angular speed control of permanent magnet synchronous motors with clear poles .
Topic 11.3. Angular velocity control of synchronous jet engines.
Topic 11.4. Angular position control of synchronous motors with permanent magnets.

Chapter 12. Special issues.

Topic 12.1. Weakening of the field in an asynchronous electric drive.
Topic 12.2. Energy-efficient AD control on the example of direct AD torque vector control and a synchronous jet engine with maximization of the torque-current ratio. Study of dynamic modes.

4. Educational materials and resources

Basic literature

1. Basics of mechatronics [Electronic resource]: study guide for students of specialty 141 "Electric power, electrical engineering and electromechanics" / KPI named after Igor Sikorskyi; comp.: S.M. Peresada, M.V. Pushkar – Electronic text data (1 file: 1.87 MB). – Kyiv: KPI named after Igor Sikorskyi, 2020. – 137 p. – Name from the screen (access via the link https://ela.kpi.ua/handle/123456789/32203) .

2. Digital control of electromechanical systems [Electronic resource]: a textbook for students of specialty 141 "Electric power, electrical engineering and electromechanics" under the educational program "Electromechanical systems of automation, electric drive and electric mobility " / S.V. Bozhko , S.M. Peresada, M.V. Pechenyk , O.I. Tolochko; KPI named after Igor Sikorsky. – Electronic text data (1 file: 4.32 MB). – Kyiv: KPI named after Igor Sikorskyi, 2021. – 149 p. - Name from the screen (access via the link https://ela.kpi.ua/handle/123456789/51247) .

3. Control of electric drives. Course project [Electronic resource]: a study guide for students studying under the educational program "Electromechanical systems of automation, electric drive and electric mobility " / KPI named after Igor Sikorskyi; structure. S. M. Peresada, E. O. Nikonenko . – Electronic text data (1 file: 1.15 MB). – Kyiv: KPI named after Igor Sikorskyi, 2022. – 57 p. – Name from the screen (access via the link https://ela.kpi.ua/handle/123456789/48886).

4. Software and monitoring motion control systems [Electronic resource]: a textbook for students of specialty 141 "Electric power, electrical engineering and electromechanics", specialization "Electromechanical systems of automation, electric drive and electric mobility " / V.I. Teryaev , S.V. King; KPI named after Igor Sikorsky. – Electronic text data (1 file: 3.84 MB). – Kyiv: KPI named after Igor Sikorskyi, 2021. – 150 p. - Title from the screen (access via link https://ela.kpi.ua/handle/123456789/48880).

5. Automated electric drive. Part 2 [Electronic resource]: study guide for students of the educational program "Electromechanical systems of automation, electric drive and electric mobility

" specialty 141 "Electric power, electrical engineering and electromechanics" / KPI named after Igor Sikorskyi; structure. V.I. Teryaev . - Electronic text data (1 file: 7.04 MB). – Kyiv: KPI named after Igor Sikorskyi, 2022. – 204 p. - Name from the screen (access via the link https://ela.kpi.ua/handle/123456789/48821).

6. Popovych M.G., Lozinskyi O.Yu., Klepikov V.B., Matsko B.M., Peresada S.M., Teryaev V.I., Butny V.V., Misurenko V.O., Panchenko B.Ya. Electromechanical automatic control systems and electric drives: Training . manual / Edited by M.H. Popovicha, O.Yu Lozynskyi. – Kyiv: Lybid, 2005. – 680 p. ISBN 966-06-0362-2.

7. Peresada S.M., Kovbasa S.M., Krasnoshapka N.D. Indirect vector control of induction motors with properties of robustness and adaptation to changes in rotor active resistance: monograph. Kyiv: KPI named after Igor Sikorskyi, 2020. – 174 p. ISBN 978-617-7894-21-5 (access via the link https://ela.kpi.ua/handle/123456789/44255) .

8. Zahirnyak M.V., Klepikov V.B., Kovbasa S.M., Mikhalskyi V.M., Peresada S.M., Sadovoy O.V., Shapoval I.A. Energy-efficient electromechanical systems of wide technological purpose: monograph. Kyiv: NAS of Ukraine, 2018. – 310 p. ISBN 978-966-02-8403-6 (access through the link http://library.kpi.kharkov.ua/files/new_postupleniya/enelci.pdf).

9. Theory of automatic control. Course work [Electronic resource]: study guide for bachelor's degree holders of the educational program "Electromechanical systems of automation, electric drive and electric mobility " specialty 141 "Electric power, electrical engineering and electromechanics" / KPI named after Igor Sikorskyi; structure. O.I. Tolochko, S.M. Peresada, B.I. Adoptee. – Electronic text data (1 file: 2.68 MB). – Kyiv: KPI named after Igor Sikorskyi, 2022. – 163 p. - Name from the screen (access via the link https://ela.kpi.ua/handle/123456789/48912) .

Additional literature

10. BK Bose . Power electronics and motor drives: advances and trends, 3rd edition , 2020. ISBN: 978-0-12-821360-5.

11. P. Krause, O. Wasynczuk and SD Sudhof . Analysis of Electric Machinery and Drive Systems. IEEE Press, 3rd edition, 2013. ISBN-13: 9781118024294 .

12. Vaez-Zadeh, Sadegh. Control of permanent magnet synchronous motors. Oxford University Press, 2018, ISBN-13: 9780198742968 .

13. SK. Sul. Control of electric machine drive systems. John Wiley & Sons, 2011, ISBN-13: 9780470590799 .

14. Electric drive theory: Textbook / Ed. M.G. Popovich Kyiv, Higher School, 1993.

15. J. Pyrhönen , V. Hrabovcová , R. S. Semken . Electrical machine drives control. An introduction. John Wiley & Sons, 2016, ISBN-13: 9781119260455 .

16. Methods of robust adaptive control of electromechanical systems with increased dynamic and energy indicators: a report on the NDR. NTUU "KPY". No. DP 0115U000381. Kyiv, 2017. 506 p.

17. Development of an energy-efficient electromechanical system of an electric bus based on an adaptive vector-controlled asynchronous electric drive with battery- supercapacitor power supply: a report on NDR / NTUU "KPI". No. DP 0117U004284. Kyiv, 2018. Volume 1. 472 p.

18. Adaptive vector control with optimization of power losses for electromechanical systems of electric vehicles with increased dynamic and energy characteristics: report on NDR / KPI named after Igor Sikorsny . – No. 2203, No. DP 0119U100170. Kyiv, 2021. 499 p.

19. Vector control of asynchronous motors with the maximization of the stator torque-current ratio. Monograph / S. M. Peresada, S. M. Kovbasa, E. O. Nikonenko , S. S. Dymko – Kyiv, KPI named after Igor Sikorskyi, 2023, -139 p. ISBN 978-617-8268-05-3. URL : https :// ela . kpi ua / handle /123456789/62017 .

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	***Introduction*** *The purpose of studying the discipline, the connection with other disciplines and its content. Development of control theory: classic, modern, ultra-modern. Methodological recommendations for studying the discipline* *Energy-efficient electromechanical systems of a wide technological purpose. Ways of increasing energy efficiency.* *Literature: synopsis of lectures.*
2	***Overview of regulated electric drives of alternating current*** *Overview of automatic control systems based on EP. Power converters for EP alternating current. Typology of alternating current electric drives. Asynchronous motors . Synchronous motors . Advantages and disadvantages of electric machines .* *Literature: synopsis of lectures.*

3-4	***Mathematical description of processes of electromechanical conversion of energy in alternating current electric machines.*** *Mathematical description in two-phase variables. Substitution scheme. Equations of flux linkages, matrix of inductances, equations of electrical balance, equations of moment.* *Implicit-pole synchronous motors with excitation from permanent magnets. Transformation of the coordinates of the generalized electric machine. Phase transformations. Transformation of the coordinates of the generalized electric machine.* *The most commonly used models of typical non-single-pole electric machines. Models of asynchronous and synchronous motors.* *Literature: synopsis of lectures.*
5-6	***Basics of control of alternating current EMC on the basis of synchronous motors (SD).*** *Study of the dynamic characteristics of the LED during direct start-up from the mains.* *Study of dynamic characteristics during frequency control of the speed of the SD.* *Dynamic characteristics of the vector speed control system of the DPS type.* *Literature: synopsis of lectures.*
7-8	***Fundamentals of vector control of alternating current EMC on the basis of asynchronous motors (AD).*** *Study of the transient processes of direct start-up of AD from the network.* *Study of dynamic characteristics during frequency control of AD.* *Vector control of the angular speed of AD by the type of DPS.* *Literature: synopsis of lectures.*
9-10	***Vector torque control of alternating current electric machines: synchronous motor.*** *Vector control of the moment of the LED during current control.* *Vector control of the LED moment when powered from a voltage source.* *Literature: synopsis of lectures.*
11-12	***Torque Vector Control of Alternating Current Electric Machines: Induction Motor at Ideal field orientation*** *Vector control of AD torque with current control and ideal field orientation .* *Vector control of AD torque with power from a voltage source and ideal field orientation .* *Literature: synopsis of lectures.*
13-14	***Vector torque control of alternating current electric machines: asynchronous motor with direct field orientation*** *Direct vector control of AD torque based on the separation principle.* *Direct vector control of AD moment under the condition of power supply from a current source.* *Direct vector control of AD moment under the condition of power supply from a voltage source.* *Literature: synopsis of lectures.*
15-16	***Vector torque control of alternating current electric machines: induction motor with indirect field orientation .*** *Torque control under conditions of power supply from a current source.* *Torque control under conditions of power supply from a voltage source.* *Literature: synopsis of lectures.*
17-18	***Vector control of angular velocity and angular position: general theory*** *Unified algorithm for working out the angular velocity.* *Unified angular position control algorithm.* *Literature: synopsis of lectures.*
19-21	***Vector control of angular velocity of alternating current motors.*** *Vector control of the angular speed of the LED under the conditions of current supply.*

	Vector control of the angular speed of the LED under the condition of power supply from a voltage source. Indirect vector control of the angular speed of AD under the condition of power from a current source. Direct vector control of the angular speed of AD under the condition of current control. Direct vector angular velocity control for power from a voltage source. Indirect vector control of AD speed under conditions of power supply from a voltage source. *Literature: synopsis of lectures.*
22-23	***Control of the speed and position of different types of LED.*** *Angular velocity control of non-uniform pole synchronous motors with permanent magnets. Angular speed control of permanent magnet synchronous motors with clear poles . Speed control of synchronous jet engines. Angular position control of non-equal-pole synchronous motors with permanent magnets.* *Literature: synopsis of lectures.*
24-25	***Special questions*** *Observers of the rotor flux coupling vector of reduced and full order. Observer of reduced-order rotor flux coupling vector. Study of dynamic modes of the observer.* *Literature: synopsis of lectures.*
26-27	***Special questions*** *Energy-efficient AD control on the example of direct AD torque vector control with maximization of the torque-current ratio. Study of dynamic modes. Weakening of the field in the electric drive.* *Literature: synopsis of lectures.*

Practical classes

No s/p	*Name of the subject of the lesson and list of main questions*
1	*Compilation of the model in the Simnon software environment and the study of transient processes in the RL-circuit and DPS with independent excitation.*
2-3	*Calculation of parameters of models of three-phase alternating current motors and calculation of given trajectories of the 1st, 2nd and 3rd order.*
4-5	*Study of the differences in torque control systems of explicit and implicit pole SPDMs.*
6-7	*Study of systems of working out the torque and flux coupling for an asynchronous electric drive with direct and indirect vector control.*
8-9	*Study of the system of working out the position on the basis of non-equipolar SDPM.* *Modular control work*

Laboratory work

No s/p	*Summary of laboratory work*
1	***Study of static and dynamic modes of the speed and position control system of a synchronous motor based on the Indradrive C control and conversion device (Laboratory work #1)*** ***The purpose of the work*** *is to study the capabilities of the IndraDrive C converter, to study the static and dynamic characteristics of the speed and position control system of the synchronous motor.* ***Program for conducting and processing research results:*** *1. Familiarize yourself with the structure of the laboratory installation, the purpose of its elements. 2. Calculate the parameters of the nominal operating mode of the loader. 3. Configure the converter IndraDrive using the IndraWorks software component . 4. Remove the family of static mechanical and electromechanical characteristics of the electric drive for given speeds according to the option. 5. Take the graphs of the transient processes of the electric drive for the start-up and loading modes in the speed control mode with the settings of the speed and position regulators according to the option. 6. Take graphs of the transient processes of the electric drive for the start-up mode and load application in the position control mode with the settings of the speed and position regulators according to the option. 7. Perform mathematical modeling of transient processes from clauses 4 and 5 in the Simnon software environment using the SMPMW and SMPMTET simulation programs. 8. Compare the results obtained experimentally and during modeling and draw conclusions from the obtained results. 9. Draw conclusions on the work and draw up a report.*
2	***Study of static and dynamic characteristics of the vector control system of the angular speed of an asynchronous motor based on the NORD AC 530E converter (Laboratory work #2)*** ***The purpose of the work*** *is a comparative study of the dynamic and static characteristics of the AD angular speed control system in an electromechanical system with a NORD converter.* ***Program for conducting and processing research results:*** *1. Familiarize yourself with the laboratory installation, signaling, control and management bodies, setting parameters of the researched control algorithms, process visualization software. Understand the purpose of the main functional blocks of the system. 2. In accordance with the variant of the task, remove the mechanical characteristics of the control system: - when using the sensorless vector control algorithm; - when using the vector control algorithm with a speed sensor. 3. In accordance with the variant of the task, remove transient processes of adjustable coordinates of the system: - when using the sensorless vector control algorithm; - when using the vector control algorithm with a speed sensor. 4. Remove static characteristics when working with a vector control algorithm with and without a speed sensor. 5. To perform a study of the dynamic characteristics of the vector control algorithm for driving and generator load moments, as well as for P- and PI-regulators of angular velocity. 6. Draw conclusions and draw up a report.*
3	***Study of static and dynamic characteristics of the vector control system of an asynchronous motor built on the basis of the ACS-550 converter with angular velocity measurement and in sensorless mode (Laboratory work No. 3)*** ***The purpose of the work*** *is a comparative study of the dynamic and static characteristics of electromechanical systems based on ACS-550 converters operating in vector control modes with and without an angular speed sensor, as well as in frequency control mode.* ***Research program:***

	1. Obtain permission to perform work. Familiarize yourself with the laboratory installation and its diagrams, connect the converters (loading to the machine under study) to the computer and set the initial settings. 2. Install the frequency control algorithm in the converter under study. Carry out a study of the dynamic behavior of the frequency control system of an asynchronous motor during the following sequence of control operations: motor excitation, acceleration to a given speed, application of the nominal load moment. Carry out a study for a given speed with the application of a loading and generator load moment. On the basis of the conducted tests, evaluate the quality of transient processes, the static error of the angular velocity adjustment, and the achieved adjustment range. 3. Complete the task from item 2 for the speed frequency control algorithm with slip compensation. 4. Complete the task from item 2 for the speed frequency control algorithm with voltage drop compensation on the active resistance of the stator (IR- compensation). 5. Perform an identification test to determine the electrical and mechanical parameters of AD, as well as adjust the parameters of the regulators. Re-identification test must be carried out when changing algorithms. 6. Install the vector control algorithm with angular velocity measurement in the converter. Repeat the tests from point 2 and supplement them with a test at zero set angular velocity. To analyze the indicators of the quality of angular speed control and compare them with those obtained for frequency control. 7. Install the vector control algorithm in the converter without measuring the angular velocity. Repeat the tests of item 2 for the loading moment of the load. Determine the minimum angular speed at which stable operation of the system is ensured. To draw conclusions about the quality indicators of angular velocity regulation and the range of regulation. 8. To formalize the research results and draw conclusions on the work, in which to display the identified differences between the frequency and vector control systems (with and without measurement of angular velocity). Give examples of mechanisms in which it is advisable to apply each of the studied algorithms for controlling an asynchronous motor.
4	***Study of static and dynamic characteristics of an asynchronous electric drive based on the ACS-800 converter using the DTC algorithm with angular velocity measurement and in sensorless mode*** ***(Laboratory work #4)*** ***The purpose of the work*** *is a comparative study of the dynamic and static characteristics of electromechanical systems based on ACS-800 converters, which work in vector control modes with a speed sensor, without angular velocity measurement, as well as in frequency control mode.* ***Research program:*** *1. Obtain permission to perform work. Familiarize yourself with the laboratory setup and its diagrams, connect the converter (the machine under study) to the computer and set the initial settings. 2. Install the frequency control algorithm in the converter under study. Carry out a study of the dynamic behavior of the frequency control system of an asynchronous motor during the following sequence of control operations: motor excitation, acceleration to a given speed, application of the nominal load moment. Carry out a study for a given speed with the application of a loading and generator load moment. On the basis of the conducted tests, evaluate the quality of transient processes, the static error of the angular speed adjustment and the achieved adjustment range. 3. Complete the task from point 2 for the algorithm of frequency control of the speed with compensation of the voltage drop on the active resistance of the stator. 4. Perform an identification test to determine the electrical and mechanical parameters of the asynchronous motor, as well as adjust the parameters of the regulators. 5. Install the vector control algorithm in the converter without measuring the angular velocity. Repeat the tests of item 2 for the loading moment of the load. Determine*

	the minimum angular speed at which stable operation of the system is ensured. To draw conclusions about the quality indicators of angular velocity regulation and the range of regulation. 6. Install a vector control algorithm with a speed sensor in the converter. Repeat the tests performed for frequency control in point 2, and supplement them with a test at a set speed equal to 10% of the nominal speed. To analyze the indicators of the quality of angular speed control and compare them with those obtained for frequency control. 7. To formalize the results of research and draw conclusions on the work, in which to display the identified differences between frequency and vector control systems (with and without measurement of angular velocity).

6. Student's independent work

No. z/p	*Type of independent work*	*Number of hours of SRS*
1	*Preparation for classroom classes*	*30*
2	*Calculations based on primary data obtained in laboratory classes*	*12*
3	*Preparation for practical classes and homework*	*8*
4	*Preparation for MKR*	*10*
5	*Preparation for the exam*	*30*

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: it is forbidden to evaluate the presence or absence of the winner in 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 "Control of electric drives";*
- *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 *: exercises in lectures and practical classes, testing, MKR, performance of tasks for practical classes, performance and defense of laboratory works.*

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

Semester control: *exam.*

***Conditions for admission to semester control** : completed and defended laboratory work, completed tasks for practical classes, semester rating of more than 25 points.*

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
The conditions for admission to the semester control have not been met	Not allowed

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

- *testing for each lecture session;*
- *execution and protection of tasks for practical classes;*
- *performance and protection of laboratory work;*
- *execution of modular control work (MCR);*
- *exam answers.*

Testing by lectures	Practical classes	Laboratory work	MKR	Exam
27	8	8	7	50

Testing on the materials of lecture classes

***Weighted point 1.** The maximum number of points for testing is 1 point * 27 lectures = = 27 points.*

Testing is conducted in the Moodle distance learning system and is available within 5 working days after the end of the current lecture or lecture module. In some cases, the term of passing the test can be extended by the lecturer.

Each test contains 8-10 questions of different formats (short answer, simulation tasks).

Evaluation criteria

- *the task was solved correctly - 1 point;*
- *the task was solved partially correctly - 0.6 points;*
- *the task was solved incorrectly or not solved - 0 points.*

Practical classes

***Weighted point 1.** The maximum number of points for testing is 1 point * 8 lessons = = 9 points.*

, students together with the teacher solve tasks according to the subject of the practical class . After each practical session, students receive a homework assignment that must be solved and submitted to the teacher for review before the start of the next session (usually this is 2 weeks, but sometimes this time can be changed by the teacher in some specific cases).

Evaluation criteria

- *the homework was solved correctly - 1 point;*
- *the homework was solved with minor errors - 0.6..0.9 points;*

– *homework is solved with significant errors - it is returned for revision.*

WARNING! *Solving and submitting all homework assignments is a condition for admission to the exam. Students who have not passed the homework at the time of the consultation before the exam are not allowed to take the main exam and are preparing for a retake.*

WARNING! *In order to be allowed to retake the exam, you must hand in all homework assignments for practical classes within the deadline set by the teacher.*

Laboratory work

Weight score. *The maximum number of points for all laboratory works is 2 points * 4 works = 8 points.*

Criteria for evaluating laboratory work:

– *the defense task was solved correctly - 2 points;*

– *the defense task was solved partially correctly - 1.2-1.8 points;*

– *the task was solved incorrectly or not solved, the laboratory work was not performed or the protocol was not presented - it is returned for practice or revision.*

WARNING! *Defense of all laboratory work is a condition for admission to the exam. Students who, at the time of the consultation before the exam, have not defended the laboratory work, are not allowed to take the main exam and are preparing for a retake.*

WARNING! *In order to be allowed to retake the exam, it is necessary to pass all laboratory work debts within the deadline set by the teacher.*

Modular control work

Weight score – 7.

The student completes 2 tasks in the modular control work. In task 1, it is necessary to synthesize a vector control algorithm, as well as conduct simulation of the control system with this algorithm. In the second (individual) task, additional research should be conducted.

Evaluation criteria for modular test work:

– *the synthesis of the control algorithm was correctly performed, the simulation was carried out, the individual task was completed - 7 points;*

– *the synthesis of the control algorithm was correctly performed, the simulation was carried out, the individual task was not completed - 5 points;*

– *the synthesis of the control algorithm was correctly performed, the simulation was not performed, the individual task was not performed - 4 points;*

– *the synthesis was performed with errors, the program was not completed - 0 points.*

Calendar control

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 score required to obtain a positive calendar control is made known to the students by the teacher no later than 2 weeks before the start of the calendar control.

Additional (bonus) points

The rating system provides additional points for completing additional tasks. One student cannot receive more than 5 bonus points in a semester. Bonus points can be obtained for active participation in lectures and practical classes.

The form of semester control is an exam

The maximum number of points for work in the semester is 50. A necessary condition for admission to the exam is completed and defended laboratory work, completed tasks for practical classes, a semester rating of at least 25 points.

The exam includes two components: theoretical and practical. ***The theoretical component*** *is aimed at checking students' knowledge acquired as a result of studying the educational component in the form of vector control algorithm synthesis. The maximum number of points for this task is 25 points.* ***The practical component*** *involves checking acquired modeling skills. Each student is given a* *separate task, according to the conditions of which it is necessary to conduct a study of the dynamic and static characteristics of the vector control system. The maximum number of points per problem is 25 points.*

The theoretical question assessment system:
– *"excellent", complete answer (at least 90% of the required information) - 23-25 points;*
– *"good", a sufficiently complete answer (at least 75% of the required information), or a complete answer with minor inaccuracies - 19-22 points;*
– *"satisfactory", incomplete answer (at least 60% of the required information) and minor errors - 15-18 points;*
– *"unsatisfactory", unsatisfactory answer (less than 60% of the required information) - 0 points.*
Evaluation system of the practical task:
– *"excellent", complete problem-free solution - 23-25 points;*
– *"good", complete solution of the task with insignificant inaccuracies - 19-22 points;*
– *"satisfactory", the task was completed with certain shortcomings - 15-18 points;*
– *"unsatisfactory", task not completed - 0 points.*

9. Additional information on the discipline (educational component)

The study of the discipline is carried out by solving specific problems. It is desirable that students use computers during lectures to demonstrate theoretical concepts and their practical application.
It is assumed that all considered examples of the use of algorithms for vector control of electromechanical objects will be investigated by the method of mathematical modeling using modeling programs provided to students.

All topics and examples covered during the semester are presented for the exam.

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 the professor of the department of automation of electromechanical systems and electric drive FEA, Doctor of Technical Sciences . Transplantation of S.M. and assistant of the department of automation of electromechanical systems and electric drive FEA, assistant . Nikonenko E.O.

Approved by the Department of Automation of Electromechanical Systems and Electric Drives of the FEA (Protocol No. 15 dated 06.13.2024)

Agreed by the Methodical Commission of the faculty (protocol No. 10 dated 06/20/2024)