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

Department of Automation of Electrical and Mechatronic Complexes

Control technologies for electrical complexes and mechatronic systems

Working program of the academic discipline (Syllabus)

Details of the discipline	
Level of higher education	***Second (Master's)***
Field of Knowledge	*G Engineering, Manufacturing and Construction*
Speciality	*G3 Electrical Engineering*
Educational program	*Control technologies for electrical complexes and mechatronic systems*
Discipline status	*Custom*
Form of study	*Full-time (daytime)*
Year of study, semester	*1st year, spring semester*
Scope of discipline	*4 credits / 120 hours*
Semester control / control measures	*Test*
Class schedule	*http://rozklad.kpi.ua/*
Language of instruction	*English*
Information about the Course Lecturer / Instructions	Lecturer and practical classes: *Ph.D., Assoc. Prof. Leonid Kulakovskyi; e-mail: kulakovskiyl@ukr.net; Tel. +38-097-453-65-46 (08:00 – 16:00)*
Course placement	

Program of the discipline

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

The syllabus of the educational component "Control Technologies of Electrical Complexes and Mechatronic Systems" is compiled in accordance with the educational program for the masters study "Engineering of Intelligent Electrotechnical And Mechatronic Complexes" of specialty 141 – Electric Power Engineering, Electrical Engineering and Electromechanics.

The purpose of the discipline is to form and consolidate the following competencies in students:

Professional Competencies (PC): (PC01) Ability to apply existing and develop new methods, techniques, technologies, and procedures to solve engineering problems of Electric Power Engineering, Electrotechnics and Electromechanics; (PC09) Ability to use software for computer modeling, computer-aided design, computer-aided manufacturing, and computer-aided development or design of elements of electric power, electrotechnical, and electromechanical systems.; (PC12) Ability to develop intelligent solutions to increase the efficiency of electrical and mechatronic systems.

The subject of study of this discipline gives the student the knowledge and skills necessary to solve the problems of developing new modes, algorithms for the operation of electrical and mechatronic complexes and practical skills in building digital control systems for technological processes and electromechanical equipment using programmable logic controllers.

Program learning outcomes (PLO), the formation and improvement of which the discipline is aimed at: (PLO13) To master new versions or new software designed for computer modeling of objects and processes in electric power, electrical and electro-mechanical systems; (PLO16) Select and integrate the

element base of intelligent solutions for electromechanical and mechatronic systems, including intelligent technologies for controlling electric and hydraulic drives, protection and automation of technological processes; (PLO17) to create intelligent technologies for automated control and monitoring of electromechanical equipment's technical condition based on programmable logic controllers.

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

Interdisciplinary connections: The discipline "Control Technologies of Electrical Complexes and Mechatronic Systems", is taught on the basis of the material of the educational components "Computer control of technological processes, experiments, equipment", "Modeling of electrical and mechatronic systems", "Theory of automatic control of electrical complexes and mechatronic systems", "Engineering of electrotechnical and mechatronic systems ".

3. Content of the discipline

Chapter 1. Low-level programmable logic controllers. Layout, configuration, connectivity

Topic 1.1. Basic information about programmable logic controllers. Especially the use of Siemens controllers compare to other controllers.

Topic 1.2. Configuration of inputs and outputs of programmable logic controllers.

Topic 1.3. Diagrams for connecting typical devices of automation systems to programmable logic controllers.

Chapter 2. Data types in SIMATIC S7 series controllers, data addressing, operands, labels and parameters.

Topic 2.1. Data types. Assignment of bit data types.

Topic 2.2. Operands and labels

Topic 2.3. Typical processor architecture S7. State word (flag register). Indirect addressing.

Topic 2.4. Types of parameters.

Chapter 3. Technology of process control by the LD (Ladder Diagram) programming language of controllers.

Topic 3.1. Software elements of relay logic

Topic 3.2. Software control with LAD.

Chapter 4. Technology of process control by the FBD (Functional Block Diagram) programming language of controllers.

Topic 4.1. Programming binary logical operations with FBD.

Topic 4.2. Programming standard boxes with FBD.

Chapter 5. Technology of process control by the SCL (Structured Control Language) programming language of controllers.

Topic 5.1. Programming binary logical operations using SCL. Programming memory functions with SCL.

Chapter 6. Technology of process control by the STL (Statement list) and S7-GRAPH sequential control programming language of controllers

Topic 6.1. STL operator structure.

Topic 6.2. Processing of a binary logical operation, step of the operation.

Topic 6.3. Elements of a sequential control.

Chapter 7. Additional functions of the control units of the SIMATIC S7 series controllers.

Topic 7.1. Digital functions.

Topic 7.2. Logical functions.

Chapter 8. Online mode and program test

Topic 8.1. Connection of a programming device to the PLC station. IP addresses of the programming device.

4. Training materials and resources

Basic

1. Berger, Hans. Automating with SIMATIC S7-1500: configuring, programming and testing with STEP 7 Professional. Publicis Publishing, John Wiley & Sons, 2014, 832 p.

2. Siemens AG. SIMATIC S7-1200 Programmable Controller System Manual / Siemens AG. – Germany: Siemens Industrial Automation, 2021. – 780 p.

3. Berger, Hans. Automating with SIMATIC: controllers, software, programming, data. John Wiley & Sons, 2012.

4. Rabbie, Max (2018). Programmable Logic Controllers: hardware and programming. ISBN: 9781631269325 (accessed at link https://cutt.ly/IChInHV).

Secondary

5. Basile F, Chiacchio P, Gerbasio D. Progress in PLC programming for distributed automation systems control. In2011 9th IEEE International Conference on Industrial Informatics 2011 Jul 26 (pp. 621-627). IEEE.

6. Berger H. Automating with STEP7 in STL and SCL. Publicis Corporate Pub, 2005.

7. SIMATIC S7 Troubleshooting and Diagnostics. Guide.Germany: Siemens Industrial Automation, 2022. – 600 p.

8. SIMATIC S7-1500 Programmable Controller System Manual. Germany: Siemens Industrial Automation, 2022. – 860 p.

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

Educational content

5. Methods of mastering the academic discipline (educational component)

Active learning strategies are applied, which are determined by the following methods and technologies: problem-based learning methods (research method); person-centered technologies based on such forms and methods of teaching as visualization and information and communication technologies, in particular electronic presentations for lectures. Teaching is carried out in the form of lectures and practical classes.

Lectures

№ salary	*Title of the lecture topic and list of main questions (list of didactic tools, references to literature)*
1	**Lecture 1.** *Topic 1.1.* Basic information about programmable logic controllers. Specific feature of using Siemens controllers compared to other controllers. Typical structure of controller panels. **References: [1,3]**
2	**Lecture 2.** *Topic 1.2.* Configuration of inputs and outputs of programmable logic controllers. Device configuration**.** Station settings. Adding a PLC station. Adding a module. Parameterizing modules. Parameterizing processor properties. Addressing modules. Parameterizing signal modules. **References: [1,2]**
3	**Lecture 3.** *Topic 1.2.* Configuration of inputs and outputs of programmable logic controllers. Network settings. Connection of the station to the network. Addresses of nodes in the subnet.

	Communication services and types of communication. Connection settings. Setting up the PROFINET subnet. Configuring the PROFIBUS subnet. **References: [1,4]**
4	**Lecture 4.** *Topic 1.3.* Diagrams for connecting typical automation devices to programmable logic controllers. Typical components for programmable logic controllers. Signal modules. Digital input modules. Digital output modules. Analog input modules. Analog output modules. Process modules. Communication modules. Other modules. System power modules. **References: [1,2]**
5	**Lecture 5.** *Topic 1.3.* Diagrams of connection of typical devices of automation systems to programmable logic controllers. Distributed I/O. PROFINET IO. PROFINET IO components. Addresses with PROFINET IO. PROFINET IO settings. PROFIBUS DP. Компоненти PROFIBUS DP. Addresses from PROFIBUS DP. Setting up the PROFIBUS DP. Pairing modules for PROFIBUS DP. **References: [1,4]**
6	**Lecture 6.** *Topic 2.1.* Data types. Assignment of bit data types. Assignment of a byte of clock memory. CPU registers. **References: [1,3]**
7	**Lecture 7.** *Topic 2.2.* Operand areas: inputs and outputs. Operand area: bit memory. Operand area: data. Operand area: temporary local data. Addressing of operands and tags. Signal path. Absolute addressing. Symbolic addressing. Addressing of a tag area. Addressing a constant. **References: [1,2]**
8	**Lecture 8.** *Topic 2.3.* Typical S7 processor architecture. Status word (flag register). Indirect addressing. Indirect addressing of ARRAY components . Indirect addressing of a tag in an ARRAY DB. Indirect addressing of a data block. Indirect addressing with an ANY pointer. Indirect addressing with PEEK and POKE (SCL). **References: [2,4]**
9	**Lecture 9.** *Topic 2.4.* Parameter Types. TIMER and COUNTER parameter types. Parameter types for IEC timer functions. Parameter types for IEC counter functions. Parameter types BLOCK_FC and BLOCK_FB (STL). Parameter type DB_ANY. Parameter type VOID. Parameter types POINTER, ANY, and VARIANT. **References: [1,2,8]**
10	**Lecture 10.** *Topic 3.1.* Technology of process control by the LD (Ladder Diagram) programming language of controllers. Program elements of relay logic. *Topic 3.2.* Software control with LAD. Jump functions in stair logic. Block call functions in circuit logic. Block completion function in stair logic. EN/ENO mechanism in stair logic. **References: [2,3]**
11	**Lecture 11.** *Topic 4.1.* Technology of process control by the FBD (functional block diagram) programming language of controllers. Programming binary logic operations with FBD. Scanning the signal state "1" and "0". Function I on a functional block diagram. Function OR on a functional flowchart. Function of exceptional OR on a functional block diagram. Combined binary logical operations that deny the result of a logical operation. **References: [2,3]**
12	**Lecture 12.** *Topic 4.2.* Technology of process control by the FBD (functional block diagram) programming language of controllers. Programming standard boxes with FBD. Assignment and negating assignment. Set and reset boxes boxes. Edge evaluation with pulse output in the function block diagram. **References: [2,3]**

13	**Lecture 13.** *Topic 5.1.* Technology of process control by the SCL (Structured Control Language) programming language of controller. Scanning the signal state "1" and "0". Combined binary logical operations in SCL. Programming memory functions using SCL. Assigning a binary tag value. Setting and resetting in SCL. Edge evaluation in SCL. **References: [2,5,8]**
14	**Lecture 14.** *Topic 6.1.* Process control technology in the programming language of STL (Statement list) and S7-GRAPH sequential control. STL operator structure. STL operator input. 64-bit tag addressing. STL networks in LAD and FBD blocks. *Topic 6.2.* Programming memory functions using STL. Value assignment of a binary tag. Setting and resetting in the SCL. Processing a binary logical operation, step operation. **References: [2, 8]**
15	**Lecture 15.** *Topic 6.3.* Process control technology in the programming language of STL (Statement list) and S7-GRAPH sequential control. Sequential controls. Steps and transitions. Jumps in sequential control. Branching of a sequencer. **References: [2,5,8]**
16	**Lecture 16.** *Topic 7.1.* Additional functions of the control units of the SIMATIC S7 series controllers. Digital functions. Transfer functions. MOVE unit for LAD and FBD. Comparison functions. Range comparison. Mathematical functions. Trigonometric functions SIN, COS, TAN. Arc functions ASIN, ACOS, ATAN. Conversion functions. Conversion of data types using ROUND, CEIL, FLOOR and TRUNC. Conversion of data types of hexadecimal numbers. Scaling and normalization. *Topic 7.2.* Logical functions. Coding functions DECO and ENCO. SEL, MUX and DEMUX selection functions. Minimum MIN selection, maximum MAX selection. **References: [2,3,5,8]**
17	**Lecture 17.** *Topic 8.1.* Online mode and program test. Connection of a programming device to the PLC station. IP addresses of the programming device. Connecting the programmer to the PLC station. Assigning an IP address of the CPU. Switching on online mode. Transferring project data. Uploading project data for the first time. Working with a memory card. **References: [2,7]**
18	**Lecture 18.** Credit assessment

Practical classes:

Practical classes in the discipline are conducted by the lecturer according to the curriculum. **The main goal of** practical classes is to consolidate theoretical provisions and acquire the ability to apply them in practice by performing certain appropriately formulated tasks.

No. s/p	Name of the topic submitted to the practical lesson
Practical lesson No. 1	Programming of press operation control by used of Siemens controllers
Practical lesson No. 2	Using the Function Unit (FC) to Control Conveyor Operation
Practical lesson No. 3	Programming of press operation control using timers (time delay) and controllers in the TIA Portal environment
Practical lesson No. 4	Programming the control of the press using timers and controllers in the TIA Portal environment
Practical lesson No. 5	Modular control work

Practical lesson No. 6	Introduction to the high-level programming language SCL with S7-SCL and SIMATIC S7-300
Practical lesson No. 7	Implementation Tank Level Control in a TIA Portal Environment
Practical lesson No. 8	Using Block Elements of Mathematical Functions to Perform Mathematical Operations in STEP 7
Practical lesson No. 9	Programming of Siemens PLCs in the Simatic Manager environment in ST language

6. Independent work of a student

Independent work of a student involves:
preparation for classroom classes – 56 hours;
preparation for modular control work – 4 hours;
preparation for the test assessment – 6 hours.

Test work

The purpose of the test work is to consolidate the theoretical knowledge of the educational component and to acquire practical skills for students to independently solve decision-making problems.

Modular control work (MCW) is performed after studying Sections 1-3 and completing practical classes 1-5. Tests are carried out in the Google Classroom environment. Each student receives an individual task.

Policy and control

7. Policy of the academic discipline (educational component)

The policy of the discipline "Control Technologies of Electrical Complexes and Mechatronic Systems" is based on the corporate policy of Igor Sikorsky Kyiv Polytechnic Institute.

KPI named after Igor Sikorsky is a free and autonomous center of education, which is designed to give adequate answers to the challenges of our time, to nurture and protect the spiritual freedom of a person, which makes him able to act according to his own conscience; its civil freedom, which is the basis for the formation of a socially responsible personality, and academic freedom and integrity, which are the main driving factors of scientific progress. The internal atmosphere of the University is built on the principles of openness, transparency, hospitality, respect for the individual.

The study of the discipline "Technologies of Control of Electrical Complexes and Mechatronic Systems" requires: preparation for practical classes of recommended basic and additional literature.

Preparation and participation in practical classes includes: familiarization with the program of the academic discipline and plans of practical classes; study of theoretical material; performing tasks proposed for independent study.

The system of requirements that the lecturer sets for the student:

- Rules for attending classes: it is forbidden to assess the presence or absence of an applicant in a classroom lesson, including awarding incentive or penalty points. In accordance with the rating system of evaluation (RSE) of this discipline, points are awarded for the corresponding types of educational activity in lectures and practical classes;
- rules of behavior in classes: the student has the opportunity to receive points for the relevant types of educational activity in lectures and practical classes, provided for by the RSE of discipline. The use of communication tools to search for information on the lecturer's Google drive, on the Internet, in a distance course on the Sikorsky platform is carried out subject to the instruction of the lecturer;
- deadline and retake policy: if a student did not pass or did not appear at the MCW (without a valid reason), his result is estimated at 0 points. Retaking the results of the ICW is not provided;

• academic integrity policy: 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 persons and provides for a policy of academic integrity for persons working and studying at the university, who should be guided in their activities, including the study and preparation of control evaluation the discipline "Intelligent Systems of Acceptance decisions";

• in case of use the digital devices of communication with the lecturer (mobile communication, e-mail, correspondence on forums and social networks, etc.), it is necessary to adhere to generally accepted ethical standards, in particular, to be polite and limit communication to the lecturer's working hours.

• the applicant for higher education must comply with educational and academic ethics and the schedule of the educational process; be balanced, attentive.

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

Current control: MCW (modular control work) is carried out before the second calendar control at the lecture class in the presence of the lecturer (28 points), 9 practical classes (8 points per practical lesson = 9 x 8 = 72). MCW is performed in the form of an answer to a theoretical question from the lecture material and one practical work. At the end of the lesson, the work on the MCW ends and is not subject to rewriting. MCW is evaluated at 28 points according to the following criteria:

− "excellent" – a complete answer to the theoretical question (at least 90% of the required information), appropriate justifications and personal views are provided, and the problem is solved correctly – 28-23 points;

− "good" – a sufficiently complete answer to the theoretical question (at least 75% of the required information), which is made in accordance with the requirements for the level of "skills" or contains minor inaccuracies, the course of solving the problem is correct, but contains minor inaccuracies, mostly in the calculation – 22-17 points;

− "satisfactory" – an incomplete answer to a theoretical question (at least 60% of the required information), performed in accordance with the requirements for the "stereotyped" level and contains some errors, significant errors in solving problems are traced – 16-11 points;

− "unsatisfactory" – unsatisfactory answer and incorrectly solved problem – 0 points.

Tasks within the framework of the practical lesson are evaluated at 8 points according to the following criteria:

− "excellent" – fully completed work (at least 90% of the necessary information), appropriate justifications and personal opinion provided – 8 points;

− "good" – the work contains certain inaccuracies (at least 75% of the necessary information), the provided justifications are not complete enough – 7-6 points;

− "satisfactory" – the work contains significant inaccuracies (at least 60% of the required information), the work is performed in accordance with the requirements for the "stereotyped" level and contains significant errors – 5-5 points;

− "unsatisfactory" – the problem was solved incorrectly – 0 points.

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

Semester control: test. A prerequisite for admission to the credit assessment is the writing of a modular test work and a starting rating of at least 30 points.

RC(max) = 28 + 72 = 100 points

RC(min) = 30 points.

Test assessment. Students who have fulfilled all the conditions for admission to the test and have a rating score of 60 or more points receive a grade corresponding to the rating scored without additional tests. The sum of rating points received by the student during the semester is converted to the final grade according to the table.

If the sum of points is less than 60, but the practical ones are completed and passed, the MCW, the student performs the test work. The test work is estimated at 100 points. The control task of this work consists of two theoretical questions from the list provided in the appendix to the syllabus and the problem. Each question is evaluated at 50 points according to the following criteria:

− "excellent" – complete answer (at least 95% of the required information), provided appropriate justifications and personal view – 47-50 points;

− "good" – a sufficiently complete answer (at least 75% of the required information) that has been completed according to the requirements for the level of "skills" or contains minor inaccuracies – 37-46 points;

− "satisfactory" – an incomplete answer (at least 60% of the required information) made in accordance with requirements for the "stereotyped" level and contains some errors – 30-36 points;

− "unsatisfactory" – unsatisfactory answer – >30 points.

Incentive points are set for:

Completing an individual semester assignment	depending on the complexity, but not more than 10 points
Report at relevant student conferences on the subject of the discipline and participation in competitions of works	up to 5 points
Preparation of an abstract work on the topic of the lesson missed by the student, or on the topic proposed by the lecturer (up to 10 sheets)	depending on the student's disclosure of the chosen topic, the validity of the conclusions, but not more than 3 points

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

Rating Points, RD	*University Scale Score*
$95 \le RD \le 100$	Perfectly
$85 \le RD \le 94$	Very good
$75 \le RD \le 84$	Well
$65 \le RD \le 74$	Satisfactory
$60 \le RD \le 64$	Enough
$RD < 60$	Disappointing
Failure to meet the conditions for admission to semester control	Not allowed

2. Additional information on the discipline (educational component)

As a semester control, according to the curriculum, students take a test evaluation. The list of questions submitted for semester control is given in the appendix to the syllabus.

A higher education applicant has the opportunity to take an online course(s) on one or more topics provided for by the work program of the academic discipline. The applicant can choose an online course independently or on the recommendation of a lecturer. 1 hour of the course is estimated at 0.83 points. The maximum number of hours that can be counted based on the results of non-formal education is 12 hours, respectively, the maximum number of points for such results is 10 points.

Work program of the academic discipline (syllabus):

Compiled by: Associate Professor of the Department of Automation of Electrical and Mechatronic Complexes, Ph.D., Leonid Kulakovskyi

Approved by the Department of Automation of Electrical and Mechatronic Complexes. Protocol No. 15 of 04.06.25

Agreed: Methodological Commission of the IEE (Minutes No. 30 of 25.06.25)

Appendix to the syllabus of the educational component of the course

"Control Technologies of Electrical Complexes and Mechatronic Systems"

List of tasks submitted for semester control

1. Describe the basic principles of operation of programmable logic controllers (PLCs).
2. Compare Siemens controllers with other manufacturers (Mitsubishi, Allen-Bradley, Omron, etc.).
3. Describe the typical structure of controller panels and their constituent components.
4. Describe the main functions of PLCs in automation systems.
5. Describe the process of setting up a PLC station, adding modules and parameterizing modules.
6. Show the main aspects of the network configuration for PLCs: PROFINET, PROFIBUS.
7. Describe the typical components of automation systems connected to PLCs.
8. Formulate the principle of operation the distributed I/O in PROFINET IO and PROFIBUS DP.
9. Specify the specifics of addressing and configuration of PROFINET IO and PROFIBUS DP networks.
10. Formulate the classification of data types in the SIMATIC S7 PLC and their purpose.
11. Describe bit data types and CPU registers.
12. Characterize the areas of operands: inputs, outputs, data, temporary local variables.
13. Describe the principles of direct and indirect addressing of data in PLCs.
14. Explain the principles of indirect addressing in the context of using the data blocks.
15. Describe the main program elements of relay logic in the LAD language.
16. Characterize the features of programming logical operations in FBD.
17. Describe the mechanisms for denying the assignment and use of standard FBD function blocks.
18. Describe the possibilities of programming logical operations using SCL.
19. Describe the structure of the STL operator and the principles of addressing 64-bit tags.
20. Describe the basics of serial control in S7-GRAPH and its key elements.
21. Describe the main numerical and logical functions in SIMATIC S7.
22. Describe the mathematical and trigonometric functions used in PLCs.
23. Explain the project upload process and PLC online operation.