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

Automation of electrotechnical and mechatronic complexes

Computer control systems of thermochemical and electrochemical processes of hydrogen production

Working program of the educational discipline (Syllabus)

Detail of educational discipline	
Level of higher education	***Second (Master's)***
Branch of knowledge	*14 Electrical engineering*
Specialty	*141 Power engineering, electrical engineering and electromechanics*
Educational program	*Engineering of intelligent electrotechnical and mechatronic complexes*
Discipline status	*Selective*
Form of education	*daytime*
Year of training, semester	*1st year, spring semester*
Scope of the discipline	*5 credits 150 hours*
Semester control/ control measures	*Exam/ calculation and graphic work (CGW), modular control work MCW)*
Schedule	*roz.kpi.ua*
Language of teaching	*English*
Information about course teachers	Lecturer: Ph.D. (Eng), associate professor, Anton V.Toropov, tel. 066-736-54-53, email: toropovtosha@ukr.net Practical Ph.D (Eng), associate professor, Anton V.Toropov, tel. 066-736-54-53, email: toropovtosha@ukr.net
Placement of course	https://classroom.google.com/c/NTk3MDQyNTQxMTAw

Program of educational discipline

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

This discipline is a continuation of students' acquaintance with the automation of technological processes and the synthesis of logical control systems. The basics of building automated hydrogen production systems based on computer control systems are provided. The main requirements for automation system elements, computing devices, control algorithms and processing of digital signals from sensors of technological parameters are described. A description of Ukraine's standards and requirements for automation nodes, requirements for intrinsic safety and explosion safety of electrical equipment, functional safety and requirements for the level of information presentation to operational personnel is also provided.

Program learning outcomes:

Competencies: (C19) Ability to use software for computer modeling, automated design, automated production and automated development or construction of elements of electric power, electrotechnical and electromechanical systems; (C22) Ability to develop means, methods and methods of science and technology aimed at automating existing and creating new automated and automatic technologies and productions.

Abilities: (PR14) To master new versions or new software designed for computer modeling of objects and processes in electric power, electrotechnical and electromechanical systems; (PR17) To create intelligent and adaptive systems of automated regulation and control of the technical condition of electromechanical equipment based on using of 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)

The educational discipline "Computer control systems for thermochemical and electrochemical processes of hydrogen production" is taught based on knowledge and skills acquired by students during the study of credit modules at the first level of education in such disciplines as "Automation of technological processes", "Physics", "Automation and modern technologies", etc.

The knowledge and skills acquired in the process of studying the credit module " Computer control systems of thermochemical and electrochemical processes of hydrogen production" are necessary for every specialist in this specialty who solve engineering tasks in the field of automation of electrochemical and thermal processes, as well as when completing a master's degree theses.

3. Content of the educational discipline

The educational discipline "Computer control systems of thermochemical and electrochemical processes of hydrogen production" consists of 3 sections:

Chapter 1. Technological processes of hydrogen production.

Topic 1.1. Electrochemical process of hydrogen production.

Topic 1.2. Thermochemical process of hydrogen production.

Chapter 2. Controllers for managing hydrogen production processes.

Topic 2.1. Basic classification of controllers.

Topic 2.2. Input/output devices for signal processing.

Chapter 3. Peculiarities of using programmable logic controllers in hydrogen production systems.

Topic 3.1. PID - regulators and their variations.

Topic 3.2. Automation of dangerous elements.

Topic 3.3. Computers and communication interfaces in hydrogen production systems.

Topic 3.4. Protection of measuring channels.

Topic 3.5. Protection of personnel and equipment.

4. Educational materials and resources

Primary literature:

1. Wylie E.B., Streeter V.L. Fluid transients. FEB Press, 2016- 384 p.

2. David Bailey. Practical SCADA for lndustry / David Bailey, Edwin Wright.: IDC Technologies, 2003, - 298 p. IISBNI 07506 58053]

3. PLC Handbook Practical Guide to Programmable Logic Controllers [Online]. Available: https://cdn.automationdirect.com/static/eBooks/PLC%20Handbook.pdf Accessed on: May 19, 2022

4. Hydrogen Energy and Vehicle Sys - tems.1 edition. Edited By Scott E. Grasman., CRC Press, April 2021, - 366p. ISBN 9781138071735

Secondary literature:

5. Scott M. Birkemeier, “Industrial automation of solar-poweredhydrogen generation plant, 2018 [Online]. Access on: https://apps.dtic.mil/sti/trecms/pdf/AD1059755.pdf , May,19,2023

6. Thomas Hübert, Lois Boon-Brett, William Buttner. Sensors for Safety and Process Control in Hydrogen Technologies. - CRC Press,12, 2018 .-416p.

7. Hydrogen Science and Engineering: Materials, Processes, Systems, and Technology. Edited By Detlef Stolten and Bernd Emonts– January 2016- 1220p.

Literature, the bibliography of which is provided with a link, can be found on the Internet. Literature whose bibliography does not contain references can be found in the library of KPI named after Igor Sikorsky. Certain sections of the basic literature [1]-[3] are required reading. Sections of the basic

literature, which are mandatory for reading, as well as the connection of these resources with specific topics of the discipline are given below, in the methodology of mastering the educational discipline. All other literary sources are optional, it is recommended to read them.

Educational content

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

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

No.lp	***Content of educational work***
1-2	**Lecture 1.** Production of hydrogen. **Literature: [2,5].** **Lecture 2.** Thermochemical decomposition of water. **Literature: [2,5].**
3-4	**Lecture 3.** The system of automation of the electrolytic hydrogen production process. **Literature: [2,4].** **Lecture 4.** Pyrolysis production of hydrogen. **Literature: [2,5].**
5-6	**Lecture 5.** Controllers for automation systems of the hydrogen production process. **Literature: [1,3].** **Lecture 6.** Selection of controllers for automation systems. Characteristics. **Literature: [1,4].**
7-8	**Lecture 7.** Data collection devices. **Literature: [4,6].** **Lecture 8.** Input/output devices. Connecting discrete inputs. **Literature: [5].** **Modular control work (part No.1).**
9-10	**Lecture 9.** Input/output devices. Connection of discrete outputs. **Literature: [3].** **Lecture 10.** Modifications of PID - regulators of hydrogen production processes. **Literature: [4].**
11-12	**Lecture 11.** Features of real regulators. **Literature: [2,3].** **Lecture 12.** Automation of dangerous objects. Spark safety. **Literature: [2].**
13-14	**Lecture 13.** Automation of dangerous objects. Explosion safety. **Literature: [2,7].** **Lecture 14.** Computers as elements of automation systems. Visualization requirements. **Literature: [2,7].**
15-16	**Lecture 15.** Communication interfaces. **Literature: [2,3].** **Lecture 16.** Galvanic protection. Measuring channels, and reducing interferences. **Literature: [4,5].**
17-18	**Lecture 17.** Reservation. **Literature: [4,5].** **Lecture 18.** Safety systems for work in production. **Literature: [3].**

	Modular control work (part No.2).

Practical lessons:

No l/p	Content of educational work
Practical lesson No.1	Setting of digital filtering of analog signal measurements
Practical lesson No.2	Construction of a mathematical model of technological processes with net delay.
Practical lesson No.3	Building and using custom libraries.
Practical lesson No.4	Synthesis of the electrolysis control algorithm for the programmable logic controller
Practical lesson No.5	Implementation of two-loop control of the electrolysis process.
Practical lesson No.6	Work with target files. Data transformation.
Practical lesson No.7	Emulation of technological processes and performance testing of algorithms.
Practical lesson No.8	Visualization of the technological process of controlling the electrolyte level.
Practical lesson No.9	Synthesis of the water level control system in the tank based on PID - the Codesys regulator.

6. Independent work of the student

Independent work of the student involves:
preparation for classroom lessons - 54 hours;
preparation for the modular control work - 2 hours;
execution of CGW - 10 hours;
preparation for the exam - 30 hours

Policy and control

1. Policy of educational discipline (educational component)

At the time of each lesson, both lecture and practical, the student must have the Zoom application installed on the device from which he works (in the case of distance learning), and the discipline " Computer control systems of thermochemical and electrochemical processes of hydrogen production" must be opened on the "Google Classroom" platform (the access code to the course to students at the first lesson according to the schedule should be given). Syllabus; lecture material; tasks for each practical session; variants of modular control work; tests to be completed after lectures; methodical recommendations for practical lessons and calculation graphic work; variants of exam work are posted on the "Google Classroom" platform and in the "KPI Electronic Campus" system.

During studying of discipline "Computer control systems of thermochemical and electrochemical processes of hydrogen production", students are obliged to adhere to the general moral principles and rules of ethical behavior specified in the Code of Honor of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute". The deadlines for the completion of each task in the discipline "Computer control of technological processes, experiments, equipment" on the "Google Classroom" platform are specified. The presence of students of higher education at practical classes is mandatory. Lessons missed for valid reasons ought to be made up.

All students, without exception, are obliged to comply with the requirements of the Regulations on the Academic Plagiarism Prevention System at the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute". Types of control and rating system for evaluating learning outcomes (RSE).

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

Current control: MCW (divided into 2 parts, each part of MCW has to be done before the calendar control during the second half of lecture at the end of first- and second-part semester in the presence of the teacher, 20 points), CGW (40 points). Each part of the MCW should be performed in the form of an answer to two theoretical questions from the lecture material of the first and second half of the semester, respectively. At the end of the class, the work on the MCW ends and cannot be rewritten. Each part of the MCW is evaluated in 5 points according to the following criteria:

- "excellent" - a complete answer (at least 90% of the required information), relevant justifications and a personal opinion are provided - 5 points;

- "good" - a sufficiently complete answer (at least 75% of the required information), which is completed in accordance with the requirements for the "skills" level or contains minor inaccuracies - 4 points;

- "satisfactory" - an incomplete answer (at least 60% of the required information), completed in accordance with the requirements for the "stereotype" level and containing some errors - 3 points;

- "unsatisfactory" - unsatisfactory answer - 0 points.

The requirements for writing the CGW are provided in the form of methodological recommendations and are posted on the "Google Classroom" platform and in the "KPI Electronic Campus" system.

CGW is estimated at 40 points according to the following criteria:

- "excellent" - fully completed work (at least 90% of the required information), appropriate justifications and personal opinion provided - 38 - 40 points;

- "good" - the work contains certain inaccuracies (at least 75% of the required information), the provided justifications are not complete enough -34-37 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 "stereotypical" level and contains significant errors - 30-33 points;

- "unsatisfactory" - the algorithm proposed in the work is unworkable or there are gross inaccuracies in the developed electrical circuit - 0 points. The requirements for writing the RGR are provided in the form of methodological recommendations and are posted on the "Google Classroom" platform and in the "KPI Electronic Campus" system.

Calendar control: is held twice a semester as a monitoring of the current state of fulfillment of the syllabus requirements. 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: Exam

Conditions for admission to the semester control: completed and enrolled CGW

RC(max) = 20 + 40 = 60 points

RC(min) = 0 + 30 = 30 points

At the exam, students perform a written test. The exam paper is valued at 39 points. The control task of this paper consists of three theoretical questions from the list provided in the appendix to the syllabus. Each question is evaluated in 13 points (in case of receiving 39 points for each question, 1 point is added to the evaluation) according to the following criteria:

- "excellent" - a complete answer (at least 90% of the required information), appropriate justifications and a personal view are provided - 13 points;

- "good" - a sufficiently complete answer (at least 75% of the required information), completed in accordance with the requirements for the "skills" level or containing minor inaccuracies - 11-12 points;

- "satisfactory" - an incomplete answer (at least 60% of the required information), completed in accordance with the requirements for the "stereotypical" level and containing some errors - 10 points; - "unsatisfactory"

- unsatisfactory answer - 0 points.

The sum of points for MCW, CGW and for the examination work is transferred to the final grade according to the table. The exam paper is valued at 39 points, as well as for full-time education. The evaluation criteria are given above.

For correspondence education

Current control: MCW (conducted directly during the lecture session, in the presence of the teacher, 20 points), CGW (40 points). MCW is performed in the form of answers to four theoretical questions from the lecture material. The structure of CGW and MCW questions, requirements for them and evaluation criteria are similar to those for full-time education are given above.

Semester control: exam. Conditions for admission to the semester control: completed and enrolled CGW. Students who have fulfilled the conditions for admission to the exam perform the examination work.

The sum of points for MCW, CGW and for the examination work is transferred to the final grade according to the table. The exam paper is valued at 39 points, as well as for full-time education. The evaluation criteria are given above.

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

Number of points	Rating
100-95	Excellent
94-85	Very good
84-75	Good
74-65	Satisfactory
64-60	Enough
Less than 60	Unsatisfactory
The conditions of admission are not fulfilled	Not allowed

9. Additional information on the discipline (educational component)

The list of questions submitted for semester control in the appendix to the syllabus is given.

A student of higher education has the opportunity to take an online course(s) on one or more topics provided by the work program of the educational discipline. The applicant can choose an online course independently or on the recommendation of a teacher, for example, the course "From Wire to PLC, A Bootcamp In Industrial Automation" on the Udemy platform. 1 hour of the course is valued at 0.83 points. The maximum number of hours that can be credited based on the results of non-formal education is 12 hours, accordingly the maximum number of points for such results is 10 points.

Recommendations for the implementation of an individual semester task

The studying of the credit module "Computer control systems for thermochemical and electrochemical processes of hydrogen production" involves students performing calculation and graphic work.

1. Design the automation system, according to the task number, for installing hydrogen production.
2. Select the equipment that allows you to solve the necessary task of automation.
3. Compile and configure a closed-loop control system of electrolyte level using an object file created as a custom external library function block in the Codesys environment. The parameters of the object model are determined according to the variant number.

4. Develop a program for responding to warnings and alarms in accordance with the requirements for high-performance NMI systems.

5. Develop an interface for interacting with the operator in the Codesys multi-level display software environment.

6. Draw conclusions on the work and describe the advantages of the proposed solution.

The content of calculation and graphic work.

1. Introduction.
2. Description of the algorithm of the automated electrolyte level control system.
3. Description of the technological process visualization screen.
4. Description of the equipment that will be used to solve the problem.
5. Conclusions from the work.
6. A file with the program of the automation algorithm (on a flexible medium, on a disk, on a USB Flash drive), which works in emulation mode).

Working program of the educational discipline (syllabus):

Developed by: Associate Professor of the Department of Automation of Electrical and Mechatronic Complexes, Ph.D., Anton V. Toropov

Approved by: Department of Automation of Electrical and Mechatronic Complexes. (Protocol No.18 from 24.06.24).

Agreed by: Methodical Commission of Educational and scientific institute of energy saving and energy management (Protocol No.21 from 25.06.24).

Appendix to the syllabus of the educational component of the course "Computer control systems for thermochemical and electrochemical processes of hydrogen production".

The list of tasks submitted for semester control.

1. Formulate the main provisions and requirements for hydrogen production control systems.

2. Explain the requirements for thermochemical hydrogen production control controllers.

3. Explain the requirements for control controllers for electrochemical hydrogen production.

4. Formulate the main characteristics by which controllers are selected for controlling the hydrogen production process.

5. Provide and explain the principle of operation of the electrolytic hydrogen production system.

6. Provide a scheme for automated control of thermochemical hydrogen production and explain the principle of its operation.

7. Draw diagrams for connecting discrete sensors with typical signals to data collection systems.

8. Draw the diagrams for connecting actuators with typical signals to computer control devices.

9. Draw diagrams for connecting analog sensors with typical signals to data collection systems.

10. Provide an extended list of requirements for a highly effective system operator interface.

11. Give and explain the features of using colors to display information.

12. Provide a structure for distributing information by presentation levels for operators.

13. Give a comparative description of various forms of implementation of PID - regulators.

14. Name the advantages of PID - regulators with extended functionality.

15. Give the classification of objects according to intrinsic safety and explain which devices should be used there.

16. Give the classification of facilities according to explosion safety and explain which devices should be used there.

17. Give a comparative description of the devices in terms of functional safety.

18. Name the requirements for data acquisition systems for chemical hydrogen production processes.

19. What are the main ways to protect against human access to the premises in accordance with security requirements?

20. What are the main ways to protect against human access to the control cabinet?