Syllabus
Course Program

Automatic Control Theory in Problems of Electricity and Energy Efficiency

Specialty
141 – Electric Power Engineering, Electrical Engineering and Electromechanics

Institute
Institute of Education and Science in Power Engineering, Electronics and Electromechanics

Educational program
Electrical Power Engineering. Electric Power Stations,
Electrical Power Engineering. Energy Management and Energy-Efficient Technologies

Department
Electric Power Stations (130)

Level of education
Bachelor's level

Course type
Special (professional), Optional

Semester
3

Language of instruction
English, Ukrainian

Lecturers and course developers

Liudmyla Lysenko
Liudmyla.Lysenko@khpi.edu.ua
Candidate of Technical Sciences, Associate Professor, Associate Professor at the Department of Electric Power Stations

Lecturing experience of 18 years. Author and co-author of over 60 scientific and educational works. The courses delivered: Automatic Control Theory in Problems of Electricity and Energy Efficiency, Mathematical Tasks of Power Engineering, Optimization Problems of Power Engineering, Ecological Aspects of Power Industry.
More about the lecturer on the department's website

General information

Summary

The course of Automatic Control Theory in Problems of Electricity and Energy Efficiency is designed to provide students with knowledge and skills in mathematical description and operation analysis of automatic control systems applied in electric and power engineering. The course covers topics such as the elemental structure and block diagrams of automatic control systems, mathematical description of control systems, time- and frequency-domain specifications and analysis, stability analysis with various stability criteria, and control system simulation with Matlab/Scilab packages.

Course objectives and goals

Objective is acquiring theoretical knowledge of the basic control principles and control algorithms implemented in automated control system, mathematical description of linear continuous-time control system, stability analysis techniques, tine-domain performance analysis, frequency domain analysis, types of controllers and their application.

Goals:
To know:
- methods of mathematical description of controlled objects;
- time-domain and frequency-domain specifications of standard dynamic elements, first- and second-order systems;
- block diagram reduction;
- stability criteria;
- techniques of steady-state error calculation.
- methods of control quality improvement.
– basics of simulation in Matlab / Scilab.
To be able to:
– analyze linear time-invariant multiloop control systems' stability and quality;
– build computer models of control systems and simulate their operation.

Format of classes

Lectures, laboratory works, workshops, consultations, calculated task, self-study. Final control – exam.

Competencies

GC 7. Skills of using information and communication technologies.
GC 9. Ability to search, process and analyze information from various sources
PC 1. Ability to use computer-aided design (CAD), manufacturing (CAM) and engineering calculations (CAE) and related application software packages.
PC 5. Ability to use knowledge in metrology and electrical measurements, the theory of automatic control and electronics to solve problems of measurement, design, control and control in power engineering, electrical engineering and electrical engineering

Learning outcomes

PRT 1. To find the necessary information in the information space.
PRT 17. To define the principles of construction and functioning of elements of control, control and automation systems of electric power, electrical and electromechanical complexes
PRT 30. To improve the skills of working with modern equipment and software when performing calculations of operating modes of electrical, electrical and electromechanical equipment, corresponding complexes and systems

Student workload

The total volume of the course is 120 hours (4 ECTS credits): lectures - 32 hours, laboratory classes - 16 hours, self-study - 72 hours including calculated task (10 hours).

Course prerequisites

Knowledge of Higher Mathematics, Physics, Introduction to Specialty, Fundamentals of Information Technology in Electric Power Industry, Theoretical Foundations of Electrical Engineering (p.1) is required to take this course.

Features of the course, teaching and learning methods, and technologies

Lectures are conducted interactively using multimedia technologies. At workshops and laboratory classes, the skills of student work formatting, the ability to use the university educational platform and resources are practiced. Practical tasks are performed using open-source software or on the Microsoft 365 platform. Learning materials are available to students through the OneNote Class Notebook.

Program of the course

Topics of the lectures

Objectives of the discipline

The value of this discipline for other professional disciplines. The amount of educational material, types of classes and organization of training.

Content module 1. Mathematical Description of Automatic Control Systems

Topic 1. Classification of Control Systems

Control system architecture. Control system presentation through block diagrams. SISO, MISO, and MIMO control systems. The basic control principles.

Topic 2. Linear and Nonlinear Control Systems.

Gain as indicator of linear and nonlinear control systems. Principle of superposition. Linearization. The main control laws.

Topic 3. Differential equation and transfer function of a SISO/MISO LTI control system

Mathematical description of dynamic elements. Presentation of o.d.e. of an LTI control system. Usage of differentiation operator notation. Laplace transform presentation. Transfer functions of components of an electrical system.

Topic 4. Time and frequency response of SISO LTI control systems

Parameters of the control system. Time response. Standard signals. Frequency response.

Topic 5. Typical dynamic elements

O.d.e. and transfer functions of zero- and first-order typical dynamic elements (TDE). Proportional TDEs. Integrating TDEs. (Ideal) differentiating TDEs. Time and frequency response of zero- and first-order TDEs.

Topic 6. A first-order control system (TDE)

O.d.e. and transfer function of a first-order control system (TDE). Time and frequency response of a first-order control system (TDE).

Topic 7. Transfer function of a SISO/MISO LTI multiloop control system

Block diagram reduction rules. Example of transfer function calculation for a SISO LTI multiloop control system. Algorithm and example of transfer function calculation for a MISO LTI multiloop control system.

Topic 8. Mathematical description of a MIMO LTI control system

Elements of the complete mathematical description of a MIMO LTI control system. Numerical example of complete mathematical description of a MIMO LTI control system.

Topic 9. Second-order control systems (TDEs)

O.d.e. and transfer functions of second-order control systems (TDEs). Types of second-order control systems (TDEs) vs damping factor value. Time and frequency response of second-order TDEs.

Content module 2. Control System Stability and Quality

Topic 10. Stability of control system

Control system stability. Conditions of control system stability. Lyapunov stability theorems. Unit step response as the stability indicator. Algebraic stability criteria. Hurwitz stability criterion.

Topic 11. The marginal value of the open-loop gain

Action of open-loop gain of a closed-loop control system on its stability. Determination of the marginal value of the open-loop gain. Correction of an unstable control system with P-controller. Algorithm of multi-loop control system stability determination with Hurwitz criterion.

Topic 12. Frequency criteria of stability

Mikhailov stability criterion. Argument Principle. Mikhailov plot. Mathematical formulation of Mikhailov stability criterion.

Topic 13. Frequency stability criteria based on open-loop transfer function

Nyquist stability criterion. Nyquist plot for a control system with integrating links. Bode plot based stability criterion.

Topic 14. Control quality

Determination of the margin open-loop gain with Bode plot. Stability margins. Time-domain specifications.

Topic 15. Steady-state error

Type-zero (type 0) and type-one (type 1)control systems. I-TDE action on steady-state error. Types of steady-state errors. Coefficient of staticism. Techniques of steady-state error calculation for MISO LTI control systems.

Topic 16. Controllers

P-controllers. I-controllers. PI-controllers. PID controllers. Determination of P-PI- and PID controller parameters.

Topics of the workshops

Topics of the laboratory classes

Topic 1. SIMULINK modeling of 0- and 1st-order typical dynamic elements behavior
Topic 2. Influence of 1st - and 2nd -order control systems (TDEs) parameters on their time and frequency characteristics
Topic 3. Study of a separately excited DC motor operation in different modes
Topic 4. Improvement of a separately excited DC motor operation with a P- and PI-controllers.

Self-study

Topics
Topic 1. Types of control systems. Application of control systems in power plants.
Topic 2. Techniques of mathematical description of control systems and its elements.
Topic 3. Composing ordinary differential equations, obtaining transfer functions, and building block diagrams of electrical circuits and elements of a power system: electric generators, motors, and transformers.
Topic 4. Time and frequency characteristics of typical dynamic elements.
Topic 5. Stability of control systems. Algebraic and frequency stability criteria.
Topic 6. Control quality. Time domain specifications and their improvement.
Topic 7. Techniques of steady-state error reduction.
Topic 8. Controllers and their application for control quality improvement.

Calculated task
Topic " Mathematical description of a separately excited DC motor and determination of P-, PI-, and PID-controller parameters for its operation improvement".
Assignment is according to the variant.
The term of defense of the calculated task is the test week before the exam session.

Course materials and recommended reading

Compulsory.
1. The Control Handbook. Second Edition. Control System Fundamentals. Edited by William S. Levine. [Electronic resource]. Access: https://www.academia.edu/97657169/The_Control_Handbook_Second_Edition_Control_System_Fundamentals?uc-g-sw=43854571
2. Derek Atherton. Control Engineering. An introduction with the use of Matlab [Electronic resource].- 155 p. Access: https://kosalmath.wordpress.com/wp-content/uploads/2010/08/control-engineering-matlab.pdf
3. Steven T. Karris. Introduction to Simulink with Engineering Applications. Orchard Publications, 572 p. [Electronic resource]. Access: https://neuron.eng.wayne.edu/auth/ece4340/Simulink_Introduction.pdf]
4. László Keviczky, Ruth Bars, Jenő Hetthéssym Csilla Bányász. Control Engineering: MATLAB Exercises [Electronic resource]. Springer Nature Singapore Pte Ltd., 2019 - 275 p.

Additional.
1. Dawn Tilbury, Bill Messner. Rick Hill, JD Taylor. Control Tutorials for Matlab and Simulink (On-line resource). Access: https://ctms.engin.umich.edu/CTMS/
2. Control Systems Tutorial (On-line resource). Access: https://www.tutorialspoint.com/control_systems/index.htm
3. Scilab for very beginners [Electronic resource]. Scilab Enterprises, 2011. - 577 p. – Access: https://www.scilab.org/sites/default/files/Scilab_beginners_0.pdf

Resources on the Internet
1. http://scilab.org
2. http://mathworks.com

Assessment and grading

Criteria for assessment of student performance, and the final score structure

Final score consists of up to:
40 points for two module tests (20 points each),
20 points for laboratory classes (5 points each) and workshops tasks,
20 points for calculated task, and
20 points for final tests.

Calculated task defense is mandatory.

Grading scale

Total points	National	ECTS
90–100	Excellent	A
82–89	Good	B
75–81	Good	C
64–74	Satisfactory	D
60–63	Satisfactory	E
35–59	Unsatisfactory (requires additional learning)	FX
1–34	Unsatisfactory (requires repetition of the course)	F

Norms of academic integrity and course policy

The student must adhere to the Code of Ethics of Academic Relations and Integrity of NTU "KhPI": to demonstrate discipline, good manners, kindness, honesty, and responsibility. Conflict situations should be openly discussed in academic groups with a lecturer, and if it is impossible to resolve the conflict, they should be brought to the attention of the Institute's management.
Regulatory and legal documents related to the implementation of the principles of academic integrity at NTU "KhPI" are available on the website: http://blogs.kpi.kharkov.ua/v2/nv/akademichna-dobrochesnist/

Approval

Approved by	Date, signature	Head of the department Oleksandr LAZURENKO
	Date, signature	Guarantor of the educational program Oleksandr LAZURENKO