Syllabus
Course Program

Mathematical Problems of Power Engineering

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
5

Language of instruction
English, Ukrainian

Lecturers and course developers

Liudmyla Lysenko
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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 Mathematical Problems of Power Engineering is designed to provide students with knowledge and skills related to steady-state analysis of DC and AC power grids, mathematical modeling and computer simulation of power systems, and application of numerical techniques and specialized software packages for calculations of power system steady-state parameters..

Course objectives and goals

The objective is acquiring theoretical knowledge and practical skills in mathematical description and computation of DC and AC power grids' steady-state operation parameters, mastering numerical techniques and state-of-the-art software packages for power systems' steady-state operation analysis.

Goals:
To know:
- mathematical techniques and algorithms of steady-state analysis of DC and AC power systems;
- numerical methods of solving sets of linear and nonlinear equations that describe steady-state operation of DC and AC power grids;
- methods of computer simulation of DC and AC power system steady-state operation;

- special functions of MS Excel applied for power engineering computations.
To be able to:
- build relevant mathematical models of steady-state operation of DC and AC power systems;
- apply relevant computational techniques to calculate steady-state operation parameters and make relevant analysis of the obtained results;
- solve problems of steady-state analysis of power grids with application of MS Excel and Matlab/Scilab packages.

Format of classes

Lectures, workshops, consultations, self-study. Coursework. 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 3. Ability to use basic knowledge of general physics, higher mathematics, theoretical foundations of electrical engineering and electrical materials for solving practical problems in the field of electric power engineering, electrical engineering and electromechanics.
PC 12. Ability to study and analyze scientific and technical information in the field of electric power engineering, electrical engineering and electromechanics.

Learning outcomes

PRT 1. To find the necessary information in the information space.
PRT 12. Know and use methods of fundamental sciences to solve general engineering and professional tasks.
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 150 hours (5 ECTS credits): lectures - 48 hours, practical classes (workshops) – 32 hours, self-study - 70 hours.

Course prerequisites

Knowledge of Higher Mathematics, Physics, Theoretical Foundations of Electrical Engineering is required for 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 objective of the discipline and its link with other professional disciplines. The amount of educational material, types of classes and organization of training.

Content module 1. Steady-state analysis of DC power systems
Topic 1. Application of graph theory to analysis of power system operation.

Presentation of a power system with equivalent diagram. System and operation parameters of a power grid. Elements of graph theory applied for power system operation analysis. Power system presentation with a directed connected graph. Vertex-edge matrix. Cycle matrix. The general topological property of a connected directed graph. Analytical dependence of cycle and vertex-edge matrices. Graph tree and chords. A system of the basic contours. Algorithm of selecting a system of basic contours.

Topic 2. Numerical methods applied to solve a system of linear equations.

Inverse matrix method. Gaussian elimination method. Application of MS Excel and MS Solver to solving a set of linear equations.

Topic 3. Generalized Matrix State Equation

Matrix form of the electric circuit laws. Balancing bus. Composing the generalized matrix state equation for an n-bus DC power grid. Algorithm of calculating DC power system operation parameters via matrix generalized state equation.

Topic 4. Matrix Nodal Equation

Composing the matrix nodal equation for a DC power grid. Nodal admittance matrix and its properties. Reference bus. Algorithm of calculating DC power system operation parameters via matrix nodal equation. Composing a set of nodal equations for an n-bus DC power grid.

Topic 5. Application of Matlab Simulink to solving a system of linear nodal equations

Simulink libraries. Building a Simulink model for a set of linear nodal equations. Setting parameters of the Simulink modal blocks. Simulation and analysis of the obtained results.

Topic 6. Matrix loop equation

Composing the matrix loop equation for a DC power grid. Selection of a system of the basic contours in n-bus DC power grid. Loop impedance matrix and its properties. Algorithm of calculating DC power system steady-state operation parameters via matrix loop equation. Composing a set of loop equations for an n-bus DC power grid.

Topic 7. Application of Matlab Simulink to steady-state analysis of DC power systems

Simulink Simscape Libraries. Building a Simulink model of a DC power system. Setting parameters of the Simulink modal blocks. Simulation of DC power system steady-state operation. Analysis of the obtained results.

Content module 2. Steady-state analysis of AC power systems

Topic 8. Linear matrix nodal equation for AC power grids

Composing the linear matrix nodal equation for an AC power grid. Features of the nodal admittance matrix for an AC power grid. Composing a set of linear nodal equations for an n-bus AC power grid. Composing a matrix of power flow for a homogeneous electric grid. Active and reactive power loss. Power balance. Algorithm of steady-state operation parameter computation for an AC grid. Computation of AC power system steady-state operation parameters via linear nodal equation technique with application of MS Excel.

Topic 9. Noninear equations of nodal current balance for AC power grids

Composing the nonlinear matrix nodal equation for an AC power grid with nonlinear current sources. Composing a set of nonlinear matrix equations of nodal current imbalance. Composing a set of nonlinear equations of nodal current imbalances for an n-bus AC grid. Presentation of the set of nodal current imbalance equations in matrix form. Computation of steady-state operation parameters in the AC grid with nonlinear current sources in MS Excel.

Topic 10. Newton's method

Newton's method. Matrix of Jacobi (Jacobian). Newton's method application to solving a set of nonlinear equations of current . Calculation of Jacobian elements for a set of nonlinear equations of nodal current imbalances. The calculative procedure in MS Excel.

Topic 11. Nonlinear equations of nodal power balance for AC grids

Matrix equation of nodal power balance. Composing a set of nonlinear equations of nodal power imbalance for nodal voltages presentation with active and reactive components and phase angle. Composing a set of nonlinear equations of nodal power imbalance for nodal voltage presentation with modulus and phase angle. Calculation of Jacobian elements for nodal voltage presentations with modulus and phase angle.

Topics of the workshops

Topic 1. Presentation of a power system with a directed connected graph. Composing vertex-edge and cycle matrices.
Topic 2. Operation with arrays in MS Excel. Selection of a system of the basic contours in a directed connected graph with application of MS Excel.
Topic 3. Solving a set of linear equations with inverse matrix method and Gaussian elimination method in MS Excel. Solving a set of linear equations with MS Solver.
Topic 4. Composing the generalized matrix state equation and calculating branch currents and nodal voltages for a DC grid under given initial conditions with application of MS Excel.
Topic 5. Composing the matrix nodal equation and calculating nodal voltages and branch currents for a DC grid under given initial conditions with application of MS Excel.
Topic 6. Building a Simulink model of a set of nodal equation and calculating nodal voltages of a DC grid under given initial conditions.
Topic 7. Composing the matrix loop equation and calculating branch currents and nodal voltages for a DC grid under given initial conditions with application of MS Excel.
Topic 8. Building a Simulink model of a DC grid to determine steady-state parameters.
Topic 9. Engineering functions in MS Excel. Operations with complex numbers.
Topic 10. Composing the linear matrix nodal equation and calculating steady-state operation parameters for an AC grid under given initial conditions with application of MS Excel.
Topic 11. Composing the nonlinear matrix nodal equation and calculating steady-state operation parameters for an AC grid under given initial conditions with iterative application of MS Excel Solver.
Topic 12. Composing the nonlinear matrix nodal equation and calculating steady-state operation parameters for an AC grid under given initial conditions with application of Newton' method in MS Excel.

Topics of the laboratory classes

Self-study

Topics
Topic 1. Graph theory. Application of graph theory to electric power system operation analysis.
Topic 2. Application of linear algebra to electric power system operation analysis.
Topic 3. Direct and iterative numerical methods of solving sets of linear equations.
Topic 4. Calculative techniques applied in DC power grid steady-state analysis: state equations, nodal equations, loop equations.
Topic 5. Matlab Simulink and Matlab Simscape libraries. Building Simulink models. Setting block parameters. Setting simulation parameters.
Topic 6. AC power grid steady-state analysis with linear nodal equations.
Topic 7. Numerical techniques of solving sets of nonlinear equations.
Topic 8. AC power grid steady-state analysis with nonlinear equations of nodal current imbalance.
Topic 9. Newton's method and its application for AC power grid steady-state analysis.

Coursework
Topic "Steady-State Analysis of an AC Power System with Nonlinear Current Sources with Application of MS Excel".
Assignment according to the variant.
The term of defense of the coursework is the 16th week.

Course materials and recommended reading

Compulsory.
1. L. Lysenko, O. Danylova, S. Fedorchuk. Practical Methods of Power System Steady-State Analysis. Study Guide for Practical Classes in the discipline “Mathematical Tasks of Power Engineering” for students of specialty 141 “Electric Power Engineering, Electrical Engineering and Electromechanics” of English Educational Program. Kharkiv: FOP Panov A. M. FOP Panov A. M., 2021. – 108 p. [Electronic resource]. Access: http://library.kpi.kharkov.ua/uk/technics/practical-methods-power-system-steady-state-analysis

2. 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
3. R. Bergen and V. Vittal, “Power System Analysis”. WSU Tri-Cities, 2017. [Electronic resource]. Access: https://www.academia.edu/36477274/POWER_SYSTEM_ANALYSIS_SECOND_EDITION

Additional.
1. J. A. Bondy, U. S. R. Murty. Graph Theory with Applications. Fifth Printing, Elsevier Science Publishing Co., Inc., 1982. – 264 p [Electronic resource]. Access: https://www.zib.de/userpage/groetschel/teaching/WS1314/BondyMurtyGTWA.pdf
2. Hudson S. EE 221 Numerical Computing for Engineers. WSU Tri-Cities, 2017. – [Electronic resource]. Access: https://users.tricity.wsu.edu/~hudson/Teaching/EE221
3. Excel Esay. [Electronic resource]. Access: https://www.excel-easy.com/data-analysis/analysis-toolpak.html]

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

Assessment and grading

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

Final score consists of up to:
30 points for two module tests,
32 points for workshop tasks,
18 points for coursework, and
20 points for final tests.

Coursework 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