Syllabus
Course Program

Modeling of Electric Power Equipment and Processes

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

Department
Electric Power Stations (130)

Level of education
Master's level

Course type
Special (professional), Mandatory

Semester
1

Language of instruction
English, Ukrainian

Lecturers and course developers

Heorhii Melnykov
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PhD, Associate Professor

Author of more than 50 scientific publications and educational and methodological works. Leading lecturer in the disciplines: "Modeling of electric power and electromechanical devices and systems", "Electric power quality and quality management", "Design of electric power systems and devices", "Modern and perspective equipment of electric power systems".
More about the lecturer on the department's website

Vladyslav Hrytsenko
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Assistant

Field of interests:
Modelling and operation of electric system processes in case of production-consumption balance disturbance. Investigation of processes in grids with different participation of renewable energy sources (RES) in the energy mix to develop a control algorithm for a virtual synchronization generator (VSG) unit coupled with energy storage (BESS, CAES, H2P) in grids with low inertia. Author of 8 scientific publications.
More about the lecturer on the department's website

General information

Summary

The course “Modeling of Electric Power Equipment and Processes" introduces knowledge required to build the comprehensive understanding of the power system structure, analysis main processes in elements of power system and its connections overall. The course consists of the topics which connected to principles of modeling processes in power systems and its elements, tools and software for mathematical modeling of processes in electric networks, electromechanical systems and devices.

Course objectives and goals

— to introduce key concepts to analyze and understand electrical power supply networks, electromechanical systems and devices;
— software and tools for mathematical modeling of processes in electrical networks electromechanical systems and devices;
— methods and tools for creating models, their mathematical description, improvement and research.
To be able to:
— develop and calculate replacement schemes for energy supply systems for various modes of their operation;
— perform simulations of energy supply systems and correctly interpret the results of the simulation;
— apply modern computer programs for mathematical and computer modeling of processes in power supply networks;
— carry out an analysis of the impact of loads in electric networks on the characteristics and indicators of the quality of electricity in power supply systems;
— carry out a study of the behavior of power supply systems in different operating conditions.

Format of classes

Lectures, laboratory classes, consultations, self-study. Final control in the form of an exam.

Competencies

GC1. Ability for abstract thinking, analysis, and synthesis.
GC2. Ability to search, process, and analyze information from various sources.
GC4. Ability to apply knowledge in practical situations.
GC6. Ability to make informed decisions.
PC1. Ability to apply theoretical knowledge, scientific and technical methods, and appropriate software to solve scientific and technical problems and conduct research in the fields of power engineering, electrical engineering, and electromechanics.
PC3. Ability to apply analytical methods, mathematical modeling, and perform physical, mathematical, and computational experiments to solve engineering tasks and conduct scientific research.
PC8. Knowledge and understanding of modern technological processes and systems of technological preparation of production, technical characteristics, design features, purpose, and rules of operation of power engineering, electrical engineering, and electromechanical equipment and devices.
PC11. Ability to use acquired knowledge and skills to conduct scientific research at the appropriate level.
PCs 14. Ability to select methods and perform appropriate calculations for analyzing the operating modes of electrical systems and networks, as well as the modes in circuit elements and processes in systems and networks.

Learning outcomes

LO 1: Reproduce processes in power engineering, electrical engineering, and electromechanical systems during their modeling on a personal computer.
LO 2: Analyze processes in power engineering, electrical engineering, and electromechanical equipment and corresponding complexes and systems.
LO 3: Find options to improve the energy efficiency of power engineering, electrical engineering, and electromechanical equipment and corresponding complexes and systems.
LO 6: Master methods of mathematical and physical modeling of objects and processes in power engineering and electromechanical systems.
LO 7: Master new versions or new software designed for computer modeling of objects and processes in power engineering, electrical engineering, and electromechanical systems.
LO 11: Choose the direction of scientific research and participate in it, taking into account modern problems in the field of power engineering, electrical engineering, and electromechanics.
LO 17: Know the methods of organization, technology, and processes of energy production based on traditional and renewable energy sources, and energy storage for maneuvering and maintaining balance in energy systems.

LOs 18: Know the principles of organizing the processes of transportation and distribution of electricity and power in electrical systems and networks from generation to consumer.
LOs 19: Know the principles of organizing the processes of managing the production and distribution of electricity in power systems and consumer power supply systems.

Student workload

The total volume of the course is 150 hours (5 ECTS credits): lectures - 32 hours, laboratory works - 32, workshops - 16 hours, self-study - 70 hours.

Course prerequisites

The course requires the student to successfully obtain knowledge from previous years of study in courses such as:
Theoretical Foundations of Electrical Engineering
Automatic Control Theory
Fundamentals of Electronics
Electrical Part of Stations and Substations
Electromagnetic Transient Processes
Electromechanical transient processes

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

Topic 1. Introduction
Objectives of the course. The importance of this course for other professional disciplines. Scope of the material, types of classes, and organization of work for mastering the material.
Topic 2. Objectives and types of energy system modeling
Development and current state of global and Ukrainian energy sectors. Problems of modern global energy and ways to overcome them. Modeling of energy supply systems. Types of modeling. The modeling processes.
Topic 3. Tools for modeling electrical circuits
Features of modeling electrical and electronic circuits. Software and computer tools for modeling electrical and electronic circuits, their general characteristics.
Topic 4. Application of Electronics Workbench for modeling energy supply systems
The program Electronics Workbench and its application for modeling energy supply systems. Advantages and disadvantages of the program. Features of modeling individual elements of power supply systems. Selection and configuration of element parameters. Calculation of substitution circuit parameters for modeling power supply systems.
Topic 5. Instruments and their application in Electronics Workbench
Instruments and their features in Electronics Workbench. Use of multimeter, oscilloscope, function generator, and Bode plotter.
Topic 6. Tools used for analyzing electrical circuits
Construction of amplitude-frequency and phase-frequency characteristics of electrical networks. Tools for setting and selecting simulation parameters for electrical networks.
Topic 7. Simulink environment
Overview of the block library. Creating a model. Main capabilities for preparing and editing models. Main blocks in the Simulink library
Topic 8. Composition of the SimPowerSystems block library
Composition and main features. Units of measurement for electrical and non-electrical quantities. Increasing speed and reducing calculation errors. Performing series of computational experiments.

Topic 9. Measurement and control devices in the SimPowerSystems block library
Measurement and control devices. Current and voltage meters. Multimeters. Three-phase meters. Impedance meter.
Topic 10. Electrical elements in the SimPowerSystems block library
Sources of electrical signals. Series and parallel RLC electrical circuits. Dynamic loads. Electrical switches. Electrical network lines. Application of harmonic filters.
Topic 11 Modeling power system devices. Part I
Models of various transformers and their features. Models of various electrical machines and their applications.
Topic 12. Modeling power system devices. Part II
Modeling elements of power electronics and devices based on them.
Topic 13. Tools for power system calculations and analysis
Calculation of circuits using the vector method. Model discretization. Calculation of the steady-state operation of the electrical network. Initialization of three-phase circuits including electrical machines. Harmonic analysis. Determination of circuit impedance. Tools for calculating magnetization characteristics.
Topic 14 Nonlinear modeling
Creating blocks for modeling. Principles of their creation. Libraries of nonlinear models. Main commands for model control. Functions for model initialization and determination of the mathematical model of the linear part of the electrical circuit.
Topic 15. FACTS devices from the SimPowerSystems
Block library and their purpose in power systems. Modeling wind and solar power plants using SimPowerSystems.
Topic 16. Case study and practical application of the SimPowerSystems
Studying the characteristics and behavior of power supply systems using SimPowerSystems tools.

Topics of the workshops

Practical Class 1. Tools for modeling electrical circuits
Software and computer tools for modeling electrical and electronic circuits, their general characteristics
Practical Class 2. Application of Electronics Workbench for modeling energy supply systems
Calculation of substitution circuit parameters for modeling power supply systems.
Practical Class 3. Creating a mathematical description of the model
Practical Class 4. Calculation of resonance frequencies for a power supply network with capacitor devices.
Practical Class 5. Calculation of substitution circuit parameters for electrical loads.

Topics of the laboratory classes

Lab Work 1. Introduction to Electronics Workbench. Modeling electrical circuits
Lab Work 2-3. Application of Electronics Workbench for modeling energy supply systems
Modeling a transformer substation with connected load and compensating device.
Lab Work 4. Construction of amplitude-frequency and phase-frequency characteristics of electrical networks
Construction of frequency characteristics of a transformer substation with different.
Lab Work 5. Measurement and control devices.
Measurement and control devices in the SimPowerSystems block library. Current and voltage meters. Multimeters. Three-phase meters. Impedance meter.
Lab Work 6-7. Electrical elements in the SimPowerSystems block library
Sources of electrical signals. Series and parallel RLC electrical circuits. Dynamic loads. Electrical switches and others. Electrical network lines. Application of harmonic filters.
Lab Work 8-9. Modeling power system devices. Part I
Models of various transformers and their features. Models of various electrical machines and their applications.
Lab Work 10-11. Modeling power system devices. Part II
Modeling elements of power electronics and devices based on them.
Lab Work 12-13. Tools for power system calculations and analysis
Graphical user interface. Calculation of circuits using the vector method. Model discretization. Harmonic analysis.

Lab Work 14. Nonlinear modeling
Creating blocks for modeling. Principles of their creation. Libraries of nonlinear models.
Lab Work 15-16. FACTS devices from the SimPowerSystems
Block library and their purpose in power systems.

Self-study

The report covering self-study topics have to be submitted by the end of the assessment week.

Course materials and recommended reading

Mandatory:
1.Paul C. Krause, Oleg Wasynczuk, Scott D. Sudhoff, Steven D. Pekarek, "Analysis of Electric Machinery and Drive Systems", 3rd Edition, Wiley-IEEE Press, 2013.
2.Modelling and Analysis of Electric Power Systems by Goran Andersson. (ETH Zurich, 2008, 183 pages)
3.Power Systems Analysis, second edition, by Artur R. Bergen and Vijay Vittal. (Prentice Hall Inc., 2000, ISBN 0-13-691990-1, 619 pages)
4.M. P. Kazmierkowski, "Renewable Energy Devices and Systems with Simulations in MATLAB and ANSYS,"(IEEE Industrial Electronics Magazine, vol. 12, no. 2, pp. 80-83, June 2018) doi: 10.1109/MIE.2018.2827859
5.Zhang XP., Rehtanz C., Pal B. Flexible AC Transmission Systems: Modelling and Control. Power Systems. Springer, Berlin, Heidelberg, 2012, 552 pages) https://doi.org/10.1007/978-3-642-28241-6_5

Optional:
1.Kundur, P.: Power system stability and control. McGraw Hill, New York (1994)
2.Power System Dynamics and Stability by Peter W. Sauer and M. A.Pai. (Prentice Hall, 1998, ISBN 0-13-678830-0, 357 pages

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,
30 points for workshops tasks,
20 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