Syllabus
Course Program

Energy Storage Systems and Maneuvering at Power Grid

Specialty
141 – Electrical Power Engineering, Electrical Engineering and Electromechanics

Institute
Institute of Power Engineering, Electronics and Electromechanics

Educational program
Power Engineering

Department
Electric Power Stations (130)

Level of education
Master's level

Course type
Special (professional), Mandatory

Semester
9

Language of instruction
English

Lecturers and course developers

Andrii Ivakhnov

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Assisyant profesor at Electrical Power Stations department

Author and co-author of more than 20 scientific and methodological works. Courses: "Energy Storage Systems and Maneuvering at Power Grid", "Modern Technologies of Electricity Generation", "Accounting and Measurement of Parameters of Energy Resources", "Renewable Energy Systems and Secondary Energy Resources", "Modeling of Processes in the Energy Sector".
More about the lecturer on the department's website

General information

Summary

The discipline is aimed at mastering the theoretical foundations of existing and perspective Energy Storage Systems and Maneuvering at Power Grid, methods of their calculations and modeling.

Course objectives and goals

Knowledge formation about physical processes occurring in Power Grid during changing modes of their operation; formation of the ability to mathematically describe and analyze these processes; formation of skills in the use of computer technology for modeling and detailed research of electric power facilities. Formation of the ability to analyze processes in electrical, electrotechnical and electromechanical equipment and corresponding complexes and systems.

Format of classes

Lectures, laboratory works, practical work, self-work. Individual task - abstract. Final control – exam.

Competencies

PC 3. Ability to use basic knowledge of general physics, higher mathematics, theoretical foundations of electrical engineering and electrical materials to solve practical problems in the field of electric power engineering, electrical engineering and electromechanics.

PC 6. Ability to use knowledge of the basics of electromechanics: the theory of electrical machines, devices and automated electric drive to solve practical problems in the field of electric power engineering, electrical engineering and electromechanics.
PC 8. Ability to use modern methods of calculation, modeling and analysis of operating modes of electrical, electrical and electromechanical equipment and design of electric power and electromechanical systems.
PC 12. Ability to study and analyze scientific and technical information in the field of electric power engineering, electrical engineering and electromechanics.
PC 13. Ability to perform experimental (model) studies of operating modes of electrical, electrical and electromechanical equipment.
PC 16. Obtaining and using professional knowledge and understanding related to the processes of transmission, distribution of electricity and power supply in compliance with the specified parameters of technological processes and electricity quality.

Learning outcomes

PR 01. Find options for improving the energy efficiency and reliability of power, electrotechnical and electromechanical equipment and related complexes and systems.
PR 03. Master new versions or new software designed for computer modeling of objects and processes in electrical, electrical and electromechanical systems.
PR 05. Analyze processes in power engineering, electrotechnical and electromechanical equipment and related complexes and systems.
PR 07. Master methods of mathematical and physical modeling of objects and processes in power engineering, electrotechnical and electromechanical systems.
PR 10. To present research materials at international scientific conferences and seminars devoted to modern problems in the field of electric power engineering, electrical engineering and electromechanics.
PR 14. Adhere to the principles and directions of the strategy for the development of energy security of Ukraine.
PR 16. Adhere to the principles and rules of academic integrity in educational and scientific activities.
PR 20. Identify the main factors and technical problems that may hinder the introduction of modern methods of controlling electrical, electrical and electromechanical systems.

Student workload

The total amount of discipline is 120 hours. (4 ECTS credits): lectures – 32 hours, laboratory works – 16 hours, practical works – 16 hours, self-work – 56 hours.

Course prerequisites

Disciplines of bachelor's level in specialty 141 "Electric power engineering, electrical engineering and electromechanics".

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

Lectures are conducted interactively using multimedia technologies. The practical classes use a project approach to learning, focusing on the use of information technology. Learning materials are available to students through the OneNote Class Notebook.

Program of the course

Topics of the lectures

Topic 1. Entry. Maneuvering at the Power Grid
The concept of balance. Maneuvering Space. Electricity markets. Innovative technologies of Energy Storage Systems.
Topic 2. Maneuvering of Traditional Power Plants (Thermal Power Plants, Hydroelectric Power Plants, Nuclear Power Plants)

Definition of traditional generation. Characteristics of the regulatory capabilities of different types of power plants. Inertia. Maneuverability of Nuclear Power Plants. Maneuverability of Thermal Power Plants. Maneuverability of Hydroelectric Power Plants.

Topic 3. Gas turbine units

General information about GTU. Scheme of operation of gas turbines with fuel combustion at constant pressure. The future of GTU.

Topic 4. Energy Storage Systems, their varieties

Types of Energy Storage Systems. Large-scale storage systems. Fuel cells. Flow-through redox batteries. Supercapacitors. Pumped storage power plants. Pneumatic accumulators. Inductive semiconductor drives. Possibilities of application. Hybrid storage systems.

Topic 5. Mechanical storage - Pumped Storage Power Plants

Schematic diagrams of work. Basic energy parameters. Operating modes at the Power Grid.

Topic 6. Mechanical - drives Pneumatic accumulators

General information. Basic parameters. Drivers of development. Pilot projects. Current results.

Topic 7. Mechanical Drives - Flywheels

General information. Overview of characteristics and specifics. Current trends of development. Current results.

Topic 8. Electromagnetic Drives - Inductive semiconductor drives.

The energy of the inductor. The importance of ISD. Principle of operation. Current results.

Topic 9, 10. Electrochemical Storage - Devices Rechargeable Batteries

General information about chemical batteries. Low-care lead-acid batteries. Learn how to create lithium batteries. Batteries with metal lithium anode. Lithium-ion batteries. Nanotechnology in lithium-ion batteries. Design features of lithium batteries. Characteristics of lithium-ion batteries. Lithium batteries with polymer electrolyte. Disposal of lithium batteries.

Topic 11. Electrochemical Drives - Supercapacitors

Basic information. Basic parameters. Pilot projects. Development drivers. Current results.

Topic 12. Electrochemical Storage - Fuel Cells

Basic information. What is a fuel cell? Operating principle. History of development in Ukraine. Application. Autonomous fuel-cell sources of electric current. Properties of fuel-cell ADS.

Topic 13. Electrochemical Accumulators - Flow Redox Accumulators

Principle of operation. Use in the world. Degradation of redox batteries. Flow battery with organic components

Topics of the workshops

Topic 1. Aspects of maneuvering at the Power Grid
Topic 2. Features of gas turbine installations
Topic 3. Photovoltaic Power Plants, calculation of efficiency with and without accumulation
Topic 4. Comparison of large-scale power storage devices
Topic 5. Calculation of Flywheel indicators
Topic 6. Calculation of PSPP indicators
Topic 7. Investigation of the installation of lead batteries in charge mode to restore its capacity
Topic 8. Investigation of flow-through redox batteries

Topics of the laboratory classes

LR-1. Investigation of the features of the technological cycle of a Thermal Power Plant (TPP).
LR-2. Investigation of the efficiency of using a Photovoltaic Power Plant.
LR-3. The study of the structure of lead and alkaline batteries. Set the battery to charge mode to restore its capacity.
LR-4. Research of lithium batteries.

Self-study

Independent work includes: Work with lecture material; Preparation for practical classes; Performing an individual task. Individual task - abstract. It is performed on a given topic. The student must in-depth understand the topic of the essay: Explore the relevance of the issue; Give the basic principles of operation of the devices specified in the topic; Give examples of the use of existing (if any) devices specified in the topic; Make an independent conclusion about the feasibility of using the devices specified in the topic, indicating the advantages and disadvantages; At the end, draw up, according to the citations used in the work, according to the Higher Attestation Commission a list of sources of information used. The work is presented in the form of an explanatory note on 10-30 pages: Title page; Content; List of symbols and abbreviations; Entry; Bulk; Conclusions; List of sources of information.

Course materials and recommended reading

Main sources

1. Advanced Power Generation Systems - 1st Edition [Electronic resource]. URL: https://www.elsevier.com/books/advanced-power-generation-systems/dincer/978-0-12-383860-5 (accessed: 27.08.2021).
2. Electrochemical Energy Conversion and Storage Systems for Future Susta [Electronic resource]. URL: https://www.routledge.com/Electrochemical-Energy-Conversion-and-Storage-Systems-for-Future-Sustainability/Samantara-Ratha/p/book/9781771888851?utm_source=cjaffiliates&utm_medium=affiliates&cjevent=3fee33a2072511ec801f7db80a180514 (accessed: 27.08.2021).
3. Energy Storage for Power System Planning and Operation | Wiley [Electronic resource] // Wiley.com. URL: https://www.wiley.com/en-al/Energy+Storage+for+Power+System+Planning+and+Operation-p-9781119189084 (accessed: 27.08.2021).
4. Fundamentals of Thermal and Nuclear Power Generation - 1st Edition [Electronic resource]. URL: https://www.elsevier.com/books/fundamentals-of-thermal-and-nuclear-power-generation/koizumi/978-0-12-820733-8 (accessed: 27.08.2021).
5. Handbook of Energy Storage - Demand, Technologies, Integration | Michael Sterner | Springer [Electronic resource]. URL: https://www.springer.com/gp/book/9783662555033 (accessed: 27.08.2021).
6. Mechanical Energy Storage for Renewable and Sustainable Energy Resources | SpringerLink [Electronic resource]. URL: https://link.springer.com/book/10.1007/978-3-030-33788-9 (accessed: 27.08.2021).
7. Mechanical Energy Storage Technologies - 1st Edition [Electronic resource]. URL: https://www.elsevier.com/books/mechanical-energy-storage-technologies/arabkoohsar/978-0-12-820023-0 (accessed: 27.08.2021).
8. Novel Electrochemical Energy Storage Devices: Materials, Architectures, and Future Trends | Wiley [Electronic resource] // Wiley.com. URL: https://www.wiley.com/en-ae/Novel+Electrochemical+Energy+Storage+Devices%3A+Materials%2C+Architectures%2C+and+Future+Trends-p-9783527821068 (accessed: 27.08.2021).
9. Sallam A.A., Malik O.P. Power Grids with Renewable Energy: Storage, integration and digitalization. IET Digital Library, 2020.
10. Renewable energy conversion systems - 1st Edition [Electronic resource]. URL: https://www.elsevier.com/books/renewable-energy-conversion-systems/kamran/978-0-12-823538-6 (accessed: 27.08.2021).
11. Renewable-Energy-Driven Future - 1st Edition [Electronic resource]. URL: https://www.elsevier.com/books/renewable-energy-driven-future/ren/978-0-12-820539-6 (accessed: 27.08.2021).
12. Smart Energy Grid Engineering - 1st Edition [Electronic resource]. URL: https://www.elsevier.com/books/smart-energy-grid-engineering/gabbar/978-0-12-805343-0 (accessed: 27.08.2021).
13. Thermal, Mechanical, and Hybrid Chemical Energy Storage Systems - 1st Edition [Electronic resource]. URL: https://www.elsevier.com/books/thermal-mechanical-and-hybrid-chemical-energy-storage-systems/brun/978-0-12-819892-6 (accessed: 27.08.2021).

Addition sources

1. Fedorchuk S.O. et al. Modeling of distributed energy systems based on renewable energy sources // Energy Management: State and Development Prospects - PEMS'17. 2017.
2. Ivakhnov A.V., Lazurenko O.P., Fedorchuk S.O. Modelling of energy storage systems as highly-maneuvering power by using it in various nodes of power grid. FOP Panov A. M., 2018. № 195.

3. Ivakhnov A.V., Lazurenko A.P. Increasing reserves of balancing capacities of the energy system through the use of electric batteries. National Technical University "Kharkiv Polytechnic Institute," 2017. Vol. Part 2.
4. Lazurenko A.P., Krugol N.M., Ivakhnov A.V. Increasing the reserves of balancing capacities of the energy system of Ukraine through the use of electric batteries. National Technical University "Kharkiv Polytechnic Institute," 2017.
5. Ivakhnov A.V., Fedorchuk S.O., Lazurenko O.P. Systems of electricity storage, analysis of possibilities and their combination for application in the power system // Power storage systems, opportunities analysis and their combinations for use in the power system. National Technical University "Kharkiv Polytechnic Institute," 2018. № №10(1286).
6. Fedorchuk S. et al. Optimization of Storage Systems According to the Criterion of Minimizing the Cost of Electricity for Balancing Renewable Energy Sources // 2020 IEEE KhPI Week on Advanced Technology (KhPIWeek). 2020. P. 519–525.

Assessment and grading

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

Description of the final score structure, course requirements, and necessary steps to earn points, especially paying attention to self-study and individual assignments.

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 LASURENKO
	Date, signature	Guarantor of the educational program Halina OMELIANENKO