Syllabus
Course Program

High Voltage Pulse Equipment

Specialty
141 – Electric Power, Electrical Engineering and Electromechanics

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

Educational program
Electric Power Industry

Department
Engineering Electrophysics (135)

Level of education
Bachelor's level

Course type
Special (professional)

Semester
6

Language of instruction
English

Lecturers and course developers

Mykyta Petrenko

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Ph. D., Associate Professor at the Engineering Electrophysics Department of NTU "KhPI".

Authored 6 publications in the domain of strong magnetic field calculations, computation of strong magnetic fields, electromagnetic forming and related areas. Lecturer on “Modelling of Electro-Physical and Electric Power Equipment and Processes”, “High Voltage Measurements”, “High Voltage Equipment”, “High Voltage Pulse Equipment”, etc.
More about the lecturer on the department's website

General information

Summary

The course delivers a comprehensive exploration into high-voltage pulse technology, a pivotal area in power electronics and associated applications. Beginning with a foundational understanding, students are introduced to the core principles and components of power electronics in energy entities, emphasizing devices such as high-voltage impulse equipment. Special attention is devoted to various semiconductor devices, analyzing their key functionalities, advantages, and limitations within power circuits, including Bipolar, MOSFET, and IGBT transistors.
The practical implications of these concepts are further illuminated through real-world application scenarios, enabling students to grasp the importance of impulse equipment in energy infrastructure. Detailed studies on impulse transformers, inductive elements, and the nuances of thermal calculations in pulse devices provide depth and breadth to the curriculum.
To ensure a holistic learning experience, laboratory sessions have been seamlessly integrated, emphasizing hands-on activities, simulations, and computational modeling in various areas like electric field dynamics, circuit design, and device performance analysis. As students progress, they will be adept at not only the theoretical facets but also practical applications, ensuring proficiency in high-voltage impulse technology and its role in modern electro-energetics.

Course objectives and goals

The chief aim of this course is to bestow a profound comprehension of high-voltage pulse technology and its significance in power electronics and broader energy systems. Students will gain the tools and insights to design, assess, and optimize devices integral to power electronic circuits, such as Bipolar, MOSFET, and

IGBT transistors. Merging rigorous theoretical lectures with immersive laboratory and simulation sessions, the course seeks to cultivate adept professionals, primed to meet the demands and complexities of contemporary electro-energetic environments.

Format of classes

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

Competencies

GC 3. The ability to apply knowledge in practical situations
GC 7. Skills of using information and communication technologies.
GC 8. The ability to learn and master modern knowledge.
GC 9. Ability to search, process and analyze information from various sources
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 4. Ability to use professional knowledge in the basics of electric power: electrical part of stations and substations, electrical systems and networks, relay protection and automatics of power systems and high voltage equipment 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.
PC 20. Receiving and using professional knowledge and understanding related to the processes of electrophysical highvoltage installations for scientific research and industrial technologies, as well as renewable energy installations.

Learning outcomes

PRT 2. Discuss professional topics
PRT 18. To evaluate the parameters of the electrical, electrical and electromechanical equipment and related complexes and systems work and to develop measures to increase their energy efficiency and reliability.
PRT 19. Solving professional tasks in the design, installation and operation of electric power, electrical engineering, electromechanical complexes and systems.
PRT 40. Know and understand the processes of operation of electrophysical high-voltage installations for scientific research and industrial technologies, as well as renewable energy installations.

Student workload

The total volume of the course is 120 hours (4 ECTS credits): lectures - 48 hours, laboratory classes - 16 hours, self-study - 56 hours.

Course prerequisites

Physics, Theoretical Foundations of Electrical Engineering p.1, Theoretical Foundations of Electrical Engineering p.2

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

Lectures employ modern multimedia tools to enhance the learning experience. Laboratory classes are structured around a mix of student preparatory self-study and collaborative team activities. Experiential learning is also an integral part of the coursework, allowing students to learn from real-world scenarios. Knowledge and skills cultivated during practical sessions are further reinforced as students tackle individual computational tasks.

Program of the course

Topics of the lectures

Topic 1. Introduction to High Voltage Pulse Equipment
Introduction to the purpose, objectives, and requirements for high voltage pulse equipment components.
Topic 2. Analysis Methods of Pulse Processes
Choosing the time constant and trigger threshold. Introduction to power switches.
Topic 3. Bipolar Transistor in Switching Mode
Advantages and disadvantages of bipolar transistor-based switches.
Topic 4. MOSFET Transistor in Switching Mode
Pros and cons of MOSFET-based switches.
Topic 5. IGBT Transistor in Switching Mode
Advantages and disadvantages of IGBT-based switches.
Topic 6. Pulse Gas Discharge Devices
Introduction to the function, design, and application of impulse gas discharge devices.
Topic 7. Applications and Limitations of Semiconductor vs. Non-semiconductor Devices
Understanding where and why certain devices are preferred over others.
Topic 8. Energy Losses during Switching
Understanding the skin effect and how to counteract it.
Topic 9. Inductive Components for Pulse Devices
Properties of inductive components.
Topic 10. Pulse Transformers
Principles and calculation of pulse transformers.
Topic 11. Basics of Thermal Calculations for Pulse Devices
Fundamental concepts related to the thermal management of pulse devices.
Topic 12. Inverters and Their Properties
Introduction to the construction schemes and characteristics of inverters.
Topic 13. Control and Protection Systems for Inverters
An overview of systems that manage and protect inverters.
Topic 14. Pulse Voltage Stabilizers: Choppers
Understanding and calculating choppers.
Topic 15. Boost Converters: Properties and Construction
Deep dive into the characteristics and design of boost converters.
Topic 16. Calculation of Boost Converters
Mathematical principles and practical aspects of designing boost converters.
Topic 17. Pulse Stabilizers with Polarity-Changing Capabilities
Introduction to stabilizers that can modify voltage polarity.
Topic 18. Calculation of Polarity-Changing Pulse Stabilizers
Practical design considerations for polarity-changing pulse stabilizers.
Topic 19. Pulse Converters with Galvanic Isolation
Understanding and designing converters that offer galvanic isolation.
Topic 20. Calculation of Galvanically Isolated Pulse Converters
Deep dive into the mathematical and practical design of galvanically isolated pulse converters.
Topic 21. Modern High Voltage Pulse Devices
A look into the latest advancements and trends in high voltage pulse equipment.
Topic 22. Safety and Precautionary Measures in HVPE
Important safety guidelines and best practices in high voltage environments.
Topic 23. Simulation and Modeling of HVPE Systems
Introduction to simulation tools like FEM and EDA for HVPE design and analysis.
Topic 24. Future Trends and Innovations in HVPE
Forecasting the future of HVPE, including potential technological breakthroughs and novel applications.

Topics of the workshops

Topics of the laboratory classes

Topic 1. Bipolar Transistor Switching Behavior Analysis
Objective: Understand the basic characteristics of a bipolar transistor in a switching regime. Utilize circuit simulation tools to analyze its performance under various conditions.
Topic 2. MOSFET and IGBT Comparative Analysis
Objective: Through simulation, compare and contrast the switching behavior of MOSFET and IGBT transistors. Identify unique characteristics and areas of application for each.
Topic 3. Electric Field Simulation in Controlled Dischargers
Objective: Use Finite Elements Method Magnetics or a similar software to model and analyze the electric fields in controlled dischargers. This exercise aims to provide students with a deeper understanding of the factors influencing discharger performance and design considerations.
Topic 4. Analysis of Skin Effect in High-Frequency Circuits
Objective: Explore the skin effect phenomenon in high-frequency circuits. Utilize both analytical methods and simulations to predict and measure its impact on circuit performance.
Topic 5. Chopper Circuit Analysis
Objective: Delve into the principles behind chopper circuits. Using both analytical methods and software simulations, design and analyze a chopper circuit's performance for specified conditions.
Topic 6. Booster Circuit Analysis
Objective: Understand the operation and application of booster circuits. Implement analytical calculations and computer simulations to evaluate the performance of a designed booster circuit.
Topic 7. Polarity-Changing Pulse Stabilizer Analysis
Objective: Delve into the principles and operations of pulse stabilizers that can change output voltage polarity. Through both manual calculations and software simulations, design and evaluate a stabilizer for specific operational criteria.
Topic 8. Galvanic Isolation Pulse Converter Analysis
Objective: Investigate the operation and design considerations of pulse converters with galvanic isolation. Implement analytical methods and simulations to design and evaluate the performance of a specified converter.

Self-study

Students are encouraged to consistently review and reinforce lecture materials to ensure they understand the foundational theories. This regular revision not only solidifies knowledge but also prepares students to actively participate in class discussions.
Before each labs students should familiarize themselves with the core concepts of the upcoming topic. Investing time in this preliminary study will lead to a more productive hands-on experience during the actual sessions.
Each student will undertake an individual project, diving deep into specific aspects of high-voltage pulse technology. The range of topics can span from innovative applications to challenges faced in real-world scenarios. At the course's end, students should merge their independent research, findings, and insights, presenting a comprehensive view of their understanding of the subject.
The expansive realm of high-voltage pulse technology offers numerous areas worth exploring beyond the standard curriculum. Students are advised to delve into areas such as advances in semiconductor devices for voltage pulse generation, environmental implications of high-voltage pulse technologies, and emerging trends in impulse voltage stabilization. To aid in this journey, additional reading materials, software tutorials, and lecture recordings will be made available, providing deeper insights and broadening horizons.

Course materials and recommended reading

1. Mazda, F. F. High Power and High Voltage Engineering: Fundamentals and Applications. Oxford: Butterworth-Heinemann, 2018. - 425 p.
2. Waldemar, K. Pulsed Power Systems: Principles and Applications. Berlin: Springer, 2006. - 290 p.
IEEE. IEEE Guide on High-Voltage Pulse Applications and Devices. IEEE Xplore Digital Library, 2017. - 95 p.

3. Behrend, H. & Czylwik, A. High Voltage Engineering: Basics, Technology, Applications. Berlin: VDE Verlag GmbH, 2018. - 550 p.
4. IEEE. IEEE Standard for Pulse Power Switching Devices. IEEE Xplore Digital Library, 2010. - 70 p.
5. Kaplan, S. M. High Voltage Protection for Telecommunications. Wiley-IEEE Press, 2011. - 245 p.
6. International Electrotechnical Commission (IEC). IEC 61000-4-5:2014 - Electromagnetic compatibility (EMC) – Testing and measurement techniques - Surge immunity test. Geneva: IEC Standards, 2014. - 80 p.
7. Smith, I. R. & Haddad, A. Advances in High Voltage Insulation and Arc Interruption in SF6 and Vacuum.

Assessment and grading

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

The final score for this course is calculated based on a combination of evaluations from module tests, practical and laboratory task achievements, and the execution of individual assignments.
1. Exam.
Students can earn up to 40 points from the final exam. The exam evaluate the student's comprehension and knowledge retention from the lecture material.
2. Laboratory Assignments.
Engaging and participating in laboratory sessions, including quizzes and tasks, can earn students up to 30 points.
3. Individual Assignments.
For the completion of individual assignments students can receive up to 30 points.

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 Serhii MOSTOVYI
	Date, signature	Guarantor of the educational program Halyna OMELIANENKO