Syllabus
Course Program

High Voltage 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

mykyta.petrenko@khpi.edu.ua
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 provides an in-depth study into the phenomena of electrical discharges and overvoltages, crucial concepts for electrical engineering and related fields. Initially, students will delve into the theory and types of electrical discharges, examining Townsend, Streamer, and other discharge mechanisms in various mediums such as gases, vacuums, and solid dielectrics. Breakdown phenomena and their underlying principles, both in gases and solid dielectrics, will be meticulously explored.
Further emphasis is placed on the practical implications of these phenomena in real-world applications. Students will learn about the potential hazards of overvoltages, the intricacies of lightning as a major source of surge overvoltages, and the design of protection systems to combat these challenges. Different types of arresters and their applications will be highlighted, including tube spark gaps, long spark gaps, and non-linear surge limiters. The course also covers comprehensive aspects of high-voltage insulation structures, ranging from air transmission lines to powerful transformers and capacitors.
Practical and laboratory sessions are strategically intertwined with theoretical lectures to offer hands-on experience. These sessions emphasize calculations, modeling, analysis, and experimental studies related to the course's core concepts. By the end of the course, students will possess both theoretical knowledge and practical skills, ensuring a robust understanding of electrical discharges, overvoltages, and associated protection measures.

Course objectives and goals

The primary objective of this course is to impart a deep understanding of electrical discharges, overvoltages, and their implications in electrical networks. Students will be equipped with the knowledge

and skills to design and analyze protection systems against potential electrical hazards. Through a combination of theoretical lectures and hands-on laboratory and practical sessions, the course aims to produce competent individuals capable of addressing challenges in modern electrical engineering scenarios.

Format of classes

Lectures, workshops, 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 180 hours (6 ECTS credits): lectures - 48 hours, workshops - 16 hours, laboratory classes - 16 hours, self-study - 100 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. General Characteristics of Electrical Discharges in Gases
An introduction to the fundamentals of electrical discharges in gases. The lecture will provide a general overview, discussing the basic principles, types, and the environments in which these discharges occur.
Topic 2. Processes and Types of Discharges in Gases
A deep dive into various processes that lead to electrical discharges in gases. We'll explore the mechanics behind each type and their typical characteristics and behaviors.
Topic 3. Townsend and Streamer Discharges
This session will focus specifically on the Townsend and Streamer discharges. Students will learn about the genesis, evolution, and properties of these specific discharge phenomena.
Topic 4. Spark Current and Spark Resistance
An examination of the properties of spark current and the associated resistance during electrical discharges. We'll also touch upon how these values are measured and their significance.
Topic 5. General Characteristics of Electrical Discharges in Vacuum
Shifting our focus to vacuum environments, this lecture provides an overview of the unique characteristics of electrical discharges in a vacuum, contrasting them with gaseous environments.
Topic 6. Vacuum Breakdown and Surface Electrode Effects
A deeper look into the phenomenon of vacuum breakdown. The session will also elucidate the effects that surface electrodes have on this process.
Topic 7. Auto-electron Emission and Vacuum Breakdown Criteria
Delving into the mechanisms of auto-electron emissions and how they relate to vacuum breakdown. The criteria determining when and how vacuum breakdown occurs will also be explored.
Topic 8. Electrical Explosion of Metal
An exploration of the circumstances under which metals undergo electrical explosions. The lecture will discuss the causes, processes, and effects of such occurrences.
Topic 9. Classification of Liquid Dielectrics
An introduction to the various types of liquid dielectrics, their categorization, and their typical applications and properties.
Topic 10. Impact of Various Factors on the Breakdown of Liquid Dielectrics
A comprehensive discussion on how different external and internal factors influence the breakdown threshold of liquid dielectrics.
Topic 11. Barrier Effect and Influence of Electrode Geometry
Exploring how barriers affect the process of dielectric breakdown and the significant role played by electrode geometry in influencing discharge behavior.
Topic 12. Types of Solid Dielectric Breakdown
A systematic overview of the different types of breakdown mechanisms observed in solid dielectrics, discussing their causes and characteristics.
Topic 13. Partial Discharges and Charge Accumulation
This lecture focuses on the phenomenon of partial discharges, their causes, and their effects. The topic of charge accumulation in dielectrics and its implications will also be discussed.
Topic 14. Electroluminescence and Aging of Dielectrics
An exploration of the light-emitting properties (electroluminescence) of dielectrics under certain conditions and how aging affects dielectric materials.
Topic 15. General Characteristics of Overvoltages
A broad overview of overvoltages, their types, causes, and effects on electrical equipment.
Topic 16. Lightning as a Source of Surge Overvoltages
Examining the phenomenon of lightning and its role as a significant source of surge overvoltages, including the processes leading to lightning formation and its impact on electrical systems.
Topic 17. Protection Zones of Different Types of Lightning Rods
A comprehensive look at various types of lightning rods, their designs, and the areas they protect against lightning strikes.
Topic 18. Protective Devices and Equipment
An overview of the devices and equipment used to safeguard electrical systems from overvoltages, discussing their design, operation, and application.

Topic 19. Tube Arresters and Other Types of Arresters
A detailed discussion on tube arresters, their design, and operation. The lecture will also touch upon other arrester types, comparing their functionalities and applications.
Topic 20. Insulation of Aerial Power Transmission Lines
A focus on the insulation systems employed in aerial power transmission lines, detailing their design, materials, and challenges.
Topic 21. Insulation of Power Transformers
Exploring the intricacies of insulating power transformers, from design considerations to materials used and the challenges faced during operation.
Topic 22. Insulation of Power Capacitors
A thorough look at how power capacitors are insulated, discussing the materials used, design considerations, and operational challenges.
Topic 23. High Voltage Power Cables
A deep dive into high voltage power cables, their design, construction, and insulation. The lecture will also discuss the challenges faced during installation and operation.
Topic 24. Test Transformers and Testing Methods
A comprehensive look at the transformers used for testing purposes, their design, and the various methods employed to test the insulation of electrical equipment.

Topics of the workshops

Topic 1. Calculation of Electrical Fields
Practical exercises focused on computing electrical fields in various configurations and environments.
Topic 2. Modeling of Electrical Discharges
Students will engage in simulation exercises to model and understand electrical discharges under different conditions.
Topic 3. Analysis of Breakdown Phenomena
Practical exploration of different breakdown phenomena, focusing on their causes and effects.
Topic 4. Examination of Dielectric Properties
Hands-on exercises aimed at understanding the properties of various dielectrics and their applications.
Topic 5. Analysis of Overvoltage Protection Systems
Practical tasks related to evaluating the efficiency and design of overvoltage protection systems in electrical circuits.
Topic 6. Lightning Protection Design
Students will engage in design exercises, focusing on creating effective lightning protection systems for various structures.
Topic 7. Application of Different Types of Arresters
Hands-on exploration of various arrester types, their designs, and their appropriate applications.
Topic 8. Insulation Testing Plan Compilation
Students will learn to compile a detailed testing plan for evaluating the insulation of different electrical equipment.

Topics of the laboratory classes

Topic 1. Experimental Study of Electrical Discharges
Laboratory exercises aimed at observing and understanding electrical discharges in different mediums.
Topic 2. Measurement of Breakdown Voltages
Practical tasks focused on measuring breakdown voltages in various dielectrics and conditions.
Topic 3. Experiments on Townsend and Streamer Discharges
Hands-on exploration of Townsend and Streamer discharges, examining their unique characteristics.
Topic 4. Measurement of Spark Current and Resistance
Laboratory tasks aimed at accurately measuring spark current and associated resistance values during electrical discharges.
Topic 5. Observing Electrical Discharges in a Vacuum
Hands-on exercises to observe and analyze the unique properties of electrical discharges in vacuum environments.
Topic 6. Study of Vacuum Breakdown Phenomena
Experiments focused on understanding the various factors and conditions leading to vacuum breakdown.

Topic 7. Exploration of Liquid and Solid Dielectric Breakdown
Students will perform experiments to study breakdown phenomena in both liquid and solid dielectrics.
Topic 8. Determining Protection Zones of Rod Lightning Conductors
A practical laboratory task where students will measure and determine the protection zones of various types of rod lightning conductors.

Self-study

The course lays stress on a blend of theoretical comprehension and its real-world application, pushing students to immerse themselves deeply through independent assignments and exploration at their own pace.
Students are required to analyze a real-world scenario where electrical overvoltages affected the system, drawing on the principles learned in the lectures. This task will deepen their understanding of how surges and overvoltages can impact electrical networks, highlighting the significance of preventive measures and protection mechanisms.
Utilize analytical tools to assess the efficiency and protective capacity of various surge protection devices, taking into account their specifications, operation curves, and real-world performance metrics.
At the course's conclusion, students should consolidate their analyses, simulations, and findings into a comprehensive document, ensuring detailed, lucid presentation, while maintaining academic rigor.
To bolster a well-rounded understanding, students are encouraged to delve into supplementary resources. A handpicked list of reading materials, software walkthroughs, and lecture recordings is available, granting deeper insights into areas not extensively delved into during the sessions.

Course materials and recommended reading

1. IEEE. IEEE Guide for Surge Voltages in Electric Power Systems. IEEE Xplore Digital Library, 2019. - 80 p.
2. Rakov, V. A., & Uman, M. A. Lightning: Physics and Effects. Cambridge: Cambridge University Press, 2003. - 687 p.
3. Hauschild, Wolfgang & Lemke, Eberhard. High-Voltage Test and Measuring Techniques. Berlin: Springer, 2019. - 320 p.
4. International Electrotechnical Commission (IEC). IEC 61643-11:2011 - Low-voltage surge protective devices. Geneva: IEC Standards, 2011. - 45 p.
5. IEEE. IEEE C37.011-2005 - IEEE Guide for the Application of Transient Recovery Voltage for AC High-Voltage Circuit Breakers. IEEE Xplore Digital Library, 2005. - 60 p.
6. Kuffel, E., Zaengl, W. S., & Kuffel, J. High voltage engineering fundamentals. Oxford: Newnes, 2000. - 534 p.
7. Gers, Juan M. & Holmes, Edward J. Protection of Electricity Distribution Networks, 3rd Edition. London: Institution of Engineering and Technology, 2011. - 340 p.

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. Practical and Laboratory Assignments.
Engaging and participating in practical and 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 2023	Head of the department Serhii MOSTOVYI
	Date, signature 2023	Guarantor of the educational program Halyna OMELIANENKO