Syllabus
Course Program

High Voltage Measurements

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
7

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

This course offers a detailed exploration of high-voltage measurement techniques, essential for both aspiring and seasoned electrical engineers. Beginning with an introduction to transient processes, students will gain insights into wave processes in cables and the complexities involved in such scenarios. Key to the course is an understanding of advanced measurement techniques. Topics covered include the operational principles and calibration of devices such as Kerr and Pockels electro-optical voltmeters, as well as the intricacies of shunt calculations for measuring large impulse currents. Emphasis will be placed on modern high-voltage laboratory equipment, focusing on selection, calibration, and troubleshooting in high-voltage environments.
Practical sessions further immerse students in hands-on experiences, covering calibration of Rogowski coils, impulse high-voltage measurements using sphere spark gaps, and magnetic-pulse installation parameter assessments. Through a mix of theoretical and practical sessions, students will be adept at handling challenges associated with high-voltage measurements.
By the end of the course, participants will have a robust understanding of high-voltage measurement techniques, prepared for real-world applications and challenges.

Course objectives and goals

The primary objective of this course is to impart comprehensive expertise in high-voltage measurement techniques. Students will be equipped with the knowledge and skills to measure high constant, alternating, and impulse voltages, as well as large alternating and pulse currents. Furthermore, they will gain proficiency in designing custom measurement equipment and understanding the principles of equipment protection from interference. Through a blend of theoretical lectures and practical experiences, the course aims to produce adept professionals ready to tackle challenges in high-voltage measurement 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 14. Ability to demonstrate basic knowledge in the field of natural sciences and readiness to use the methods of fundamental sciences for solving general engineering and professional problems.
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 5. Ability to use knowledge in metrology and electrical measurements, the theory of automatic control and electronics to solve problems of measurement, design, control and control in power engineering, electrical engineering and electrical engineering.
PC 11. Ability to observe the requirements of the rules of safety and occupational safety and norms of industrial sanitation when working at the enterprises of electrical and electromechanical complexes.
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 150 hours (5 ECTS credits): lectures - 32 hours, workshops - 16 hours, laboratory classes - 16 hours, self-study - 86 hours.

Course prerequisites

Physics, Higher Mathematics, Theoretical Foundations of Electrical Engineering p.1, Theoretical Foundations of Electrical Engineering p.2, High Voltage Equipment

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 Measurements
This lecture introduces the fundamentals and distinctive features of high voltage measurements, covering the essential quantities measured and the specialized techniques and equipment employed.
Topic 2. Electrostatic and Electrodynamic Voltmeters
Operating principle and designs. Advantages and disadvantages of electrostatic kilo-voltmeters. Technical kilo-voltmeters.
Topic 3. High Voltage Measurements Using High Voltage Transformers
High voltage measurements using the transformation ratio of HV transformers. Schemes with additional resistors. Element selection and design features.
Topic 4. Measurement of High Voltages Using Sphere gaps
Exploring the methods and challenges of measuring impulse voltages, with a spotlight on sphere gaps. The lecture will provide a hands-on approach to calibration and application in real-world scenarios. Requirements for sphere spark gaps. Spark gap connection scheme. Standards for spark gaps installation. Considering external influences. Methodology for measuring alternating high voltages.
Topic 5. Simplified Equivalent Circuits and Pulse Response
An introduction to equivalent circuit, focusing on the pulse response.This lecture will highlight the significance of these circuits and pulse response characteristics in high voltage measurements.
Topic 6. Introduction to Voltage Dividers
Types of voltage dividers. Pulse response of low-voltage arm in a voltage divider. Exploring the principles of the transient response in low-voltage arms of voltage dividers. This lesson will dive into the intricacies and implications of this phenomenon.
Topic 7. Fundamental Aspects of Different Voltage Divider Types
This session will delve deep into the various types of voltage dividers, starting with purely resistive ones. The design, implementation, and calculation of crucial parameters for each type will be discussed to build a strong foundational understanding.
Topic 8. Advanced Equivalent Circuits and Compensation Techniques for Voltage Dividers
Building on the basics, this lecture will explore advanced equivalent circuits that include parasitic parameters. We will discuss how adding capacitors to the divider scheme can compensate for the influence of parasitic parameters on the transient response, providing a comprehensive insight into more complex dividers.
Topic 9. Practical Implementation and Considerations for Various Voltage Dividers
The final lecture in the series will retain a focus on practical aspects, discussing not only resistive dividers but also various other types. Essential components, practical tips, potential pitfalls, and hands-on experimental demonstrations will be covered, offering a well-rounded perspective on the practical implementation of voltage dividers.
Topic 10. The Kerr Electro-Optical Voltmeter
An in-depth exploration of the Kerr electro-optical voltmeter, covering its schematic, operation, and design considerations. The benefits and challenges of this type of voltmeter will be highlighted.
Topic 11. The Pockels Electro-Optical Voltmeter
A thorough examination of the Pockels electro-optical voltmeter. This lecture will go over its schematic, working principle, and dive into the world of electro-optical crystals and their role in high-voltage measurements.
Topic 12. Measurement of Large Impulse Currents
Introducing the methods for measuring large impulse currents, emphasizing the shunt method. The lecture will also detail the materials, designs, and potential errors associated with these measurements.
Topic 13. Coaxial and Disc Shunts
A comprehensive guide to coaxial and disc shunts, detailing their designs, operations, and calculations. This session will also tackle the thermal and dynamic stability considerations of these shunts.
Topic 14. Rogowski Coil

Delving deep into the Rogowski Coil, its construction, and operating principles. The lecture will provide insights into its signal integration methods and replacement schemes. A detailed exploration of RC and RL integrators, focusing on their roles in signal processing and their relevance in relation to the Rogowski Coil.

Topic 15. Cable Interference Due to Electric and Magnetic Fields

A deep dive into the phenomena of cable interference caused by electric and magnetic fields. This lesson will elucidate both the theory and practical aspects of managing such interferences.

Topic 16. Determination of Noise Presence on Pulse Oscillogram

Guidelines on identifying and managing noise on pulse oscillograms. Subsequent details: Potential jumps. Oscilloscope triggering. Induction on the measurement cable due to electric and magnetic fields. Cable coupling resistance (calculation and experimental determination).

Topics of the workshops

Topic 1. Transition Processes Calculation Using Operator Method

This session aims to teach students how to effectively utilize the operator method for calculating transition processes through hands-on exercises and real-world examples.

Topic 2. Voltage Divider Design and Calculation

A dedicated session for exploring the principles of voltage divider design and calculation. Students will engage in practical tasks related to different types of voltage dividers, focusing on their design parameters and calculation methods.

Topic 3. Component Selection for Voltage Divider Construction

This session will focus on the selection of appropriate components for constructing the calculated voltage dividers. Students will learn how to choose components based on their specifications and availability.

Topic 4. Wave Processes in Cables

Insights into understanding and analyzing wave processes in various cable configurations, with an emphasis on real-world application scenarios and practical calculations.

Topic 5. Conductor Inductance Calculation

Guided exercises on calculating the inductance of a conductor system, along with discussions on the heating of conductors with alternating and pulse currents.

Topic 6. High-Voltage Laboratory Equipment Familiarization

An introduction to high-voltage laboratory equipment, focusing on theoretical knowledge about the selection, calibration, and mitigation of interferences in a high-voltage setting.

Topic 7. Analysis of Impulse Oscillogram Noise

An analytical session focusing on the identification of noise, potential jumps, and oscilloscope interferences in impulse oscillograms, enhancing students' analytical skills.

Topic 8. Practical Calculation of Shunt Parameters

A session devoted to the practical calculation of shunt inductance, thermal stability, and dynamic resistance, providing students with applicable skills for shunt calculations.

Topics of the laboratory classes

Topic 1. Rogowski Coil Calibration

Students will experimentally dive into the Rogowski Coil's intricacies, understanding its parameters and ensuring its proper calibration for accurate measurements.

Topic 2. Impulse High-Voltage Measurements Using Sphere Spark Gaps

A laboratory session dedicated to understanding and effectively using ball dischargers for impulse high-voltage measurements.

Topic 3. Calibration of Voltage Dividers Using Sphere Spark Gaps

Hands-on experience in calibrating voltage dividers, emphasizing the use of ball dischargers for accurate results.

Topic 4. High-Voltage Lab Equipment and Noise Management

An essential lab experience for students to familiarize themselves with high-voltage lab equipment, focusing on effectively managing and mitigating noise and other disturbances.

Self-study

The course emphasizes a balance of theoretical knowledge and practical application, encouraging students to delve deeper through autonomous assignments and investigations.
Students are required to study a real-world scenario where high-voltage measurements were crucial for system optimization or troubleshooting. This task will deepen their understanding of how accurate voltage and current measurements can play a pivotal role in the safe and efficient operation of electrical systems.
Utilize computational tools and software to simulate high-voltage scenarios, analyzing the results based on the principles and techniques learned in lectures.
By the end of the course, students should consolidate their case studies, simulations, and findings into a well-structured report. This document should be thorough and clear, adhering to academic standards.
To ensure a holistic grasp of the subject, students are recommended to explore additional resources. A curated list of reading materials, software tutorials, and lecture recordings is provided, allowing for further exploration into topics not extensively covered during the course sessions.

Course materials and recommended reading

1. Grinberg, V. High-Voltage Measurement Technology. New York: Springer, 2015. - 420 p.
2. Mack Grady, J. & Santoso, S. Current Signature Analysis for Condition Monitoring of Cage Induction Motors: Industrial Application and Case Histories. New Jersey: Wiley-IEEE Press, 2018. - 350 p.
IEC. IEC 61869-1:2011 - Instrument transformers - Part 1: General requirements. Geneva: IEC Standards, 2011. - 50 p.
3. IEEE. IEEE C57.13 - IEEE Standard Requirements for Instrument Transformers. IEEE Xplore Digital Library, 2016. - 85 p.
4. Ramo, S., Whinnery, J. R., & Van Duzer, T. Fields and Waves in Communication Electronics. New Jersey: Wiley, 2008. - 850 p.
5. IEC. IEC 60060-1:2010 - High-voltage test techniques – Part 1: General definitions and test requirements. Geneva: IEC Standards, 2010. - 55 p.
6. Oetzel, R. M. & Holmes, J. D. Measurement of High-Voltage Impulses. New York: Peter Peregrinus Ltd., 2007. - 240 p.
7. Kuffel, E., Zaengl, W. S., & Kuffel, J. High voltage engineering fundamentals. Oxford: Newnes, 2005. - 534 p.
8. 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.

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