Syllabus
Course Program

High Voltage Equipment

Specialty
G3 –Electrical Engineering

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)

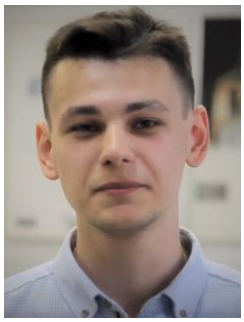
Level of education
Bachelor's level

Course type
Special (professional), Mandatory

Semester
7

Language of instruction
English

Lecturers and course developers



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 renewable energy sources in the energy mix to develop a control algorithm for a virtual synchronization generator unit coupled with energy storage in grids with low inertia. Author of 14 scientific publications.
More about the lecturer on the department's website

General information

Summary

Theoretical fundamentals in power system overvoltages, transient surge propagation, and insulation coordination according to international standards. It systematically investigates the physical conduction and breakdown mechanisms in gaseous, liquid, solid, composite, and vacuum insulating dielectrics subjected to uniform and non-uniform electric fields. The curriculum covers the analytical circuit design, operation, and precision metrology of high-voltage laboratory generation systems, including cascaded transformers, resonant circuits, voltage multipliers, and Marx impulse generators. Through interactive computational simulations and virtual laboratory diagnostics—such as partial discharge analysis, transient recovery voltage modeling, and stress grading—students develop practical competencies in apparatus testing, condition monitoring, and operational electrical safety.

Course objectives and goals

Purpose: To form in students' knowledge about theoretical foundamentals in power system overvoltages, surge propagation, and insulation coordination and to familiarize students with the causes, physical characteristics, and system impacts of transient overvoltages resulting from atmospheric lightning strikes, switching operations, and temporary system faults. Additionally, to systematically impart essential competencies in high-voltage generation circuits, precision measurement techniques,

standardized apparatus testing, and insulation coordination required for the design and safe operation of modern power grid infrastructure.
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Objectives: to explain various overvoltage's and its effects on power systems, the methods of generating and measuring High DC, AC, Impulse voltage and currents, the Industrial Applications of Electrostatic Fields, to understand the breakdown phenomena in different medium under uniform and non-uniform fields

Format of classes

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

Competencies

GC01. The ability for abstract thinking, analysis and synthesis.
GC02. Ability to apply knowledge in practical situations.
GC05. Ability to search, process and analyze information from various sources.
PC02. Ability to solve practical problems involving the methods of mathematics, physics and electrical engineering.
PC03. Ability to solve complex specialized tasks and practical problems related to the operation of electrical systems and networks, the electrical part of stations and substations, and highvoltage equipment
PC10. Awareness of the need to constantly expand one's own knowledge of new technologies in electric power, electrical engineering and electromechanics..

Learning outcomes

LO05. To know the basics of electromagnetic field theory, methods of calculating electric circuits and be able to use them to solve practical problems in professional activities.
LO07 To carry out the analysis of processes in electric power, electrotechnical and electromechanical equipment, relevant complexes and systems..
LO10. Find the necessary information in scientific and technical literature, databases and other sources of information, evaluate its relevance and reliability.
LO18. To be able to learn independently, acquire new knowledge and improve skills in working with modern equipment, measuring equipment and application software.
LO23. To know and understand the operating principles of modern designs of switching devices and distribution installations.

Student workload

The total volume of the course is 90 hours (3 ECTS credits): lectures - 32 hours, the laboratory classes - 16 hours, self-study - 40 hours, consultations - 2 hours.

Course prerequisites

Electrical Part Of Power Stations And Substations Pt1-3

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 to High Voltage Engineering and Voltage Classifications
Course Objectives. The classification of high voltages, transmission voltage levels, operational system stresses, and the physical origins of high-voltage phenomena in electrical power grids
Topic 2. Electrostatic Fields and Electric Stress Calculations
Focuses on electric field stress distributions, Laplace and Poisson equations for multi-dielectric media, field utilization factors, and geometric field optimization in high-voltage apparatus
Topic 3. Computational Field Analysis and Stress Grading
Examines numerical field computation techniques—including the Finite Element Method (FEM), Charge Simulation Method (CSM), and Finite Difference Method (FDM)—alongside geometric, capacitive, and resistive stress grading methods
Topic 4. Dielectric Conduction, Polarization, and Dissipation
N Analyzes static and complex permittivity, electronic, ionic, dipolar, and interfacial polarization mechanisms, dielectric relaxation, and the derivation of the dielectric loss factor
Topic 5. Gaseous Ionization and Townsend Spark Breakdown
Details electron collision physics, Townsend primary and secondary ionization coefficients, current growth equations, and Townsend breakdown criteria in uniform fields
Topic 6. Streamer Breakdown Mechanism, Paschen's Law, and Electronegative Gases
Explores Raether-Meek streamer theory in non-uniform fields, the physical derivation and application of Paschen's Law, and electron attachment physics in electronegative gases like SF6 and eco-friendly gas mixtures
Topic 7. Corona Discharges, Non-Uniform Fields, and Vacuum Breakdown
Studies Trichel pulse dynamics, visual corona inception, Peek's formula for corona power loss, partial discharge in solid inclusions, and particle-exchange breakdown mechanisms in vacuum insulation
Topic 8. Conduction and Breakdown in Liquid Dielectrics
Examines electrical conduction and breakdown in pure and commercial liquid dielectrics, suspended particle and cavity mechanisms, liquid reconditioning, and oil quality maintenance
Topic 9. Breakdown Mechanisms in Solid and Composite Insulation
Investigates intrinsic, electromechanical, and thermal breakdown in solid dielectrics, interface failure in composite insulation, and degradation processes such as electrical treeing and tracking
Topic 10. High Voltage Power Transformers and Insulation Schemes
Covers major and minor winding insulation design, short-circuit mechanical forces, surge voltage distribution across windings, cooling classifications, and condition monitoring methods like Dissolved Gas Analysis (DGA)
Topic 11. Overhead Line Insulators and Pollution Performance
Evaluates porcelain, toughened glass, and composite polymer insulators, string voltage distribution and efficiency calculations, grading rings, and artificial pollution flashover mechanisms under wet and contaminated conditions
Topic 12. Underground and Subsea Power Cable Systems
Analyzes paper-insulated lead-covered (PILC), self-contained fluid-filled (SCFF), and XLPE power cables, stress cone termination design, capacitive/resistive grading, and cable thermal rating calculations
Topic 13. High Voltage Switchgear, Air/Gas Interruption, and TRV
Explores Air Insulated (AIS) and Gas Insulated Substations (GIS), circuit breaker arc extinction physics, Cassie-Mayr arc models, arcing media (SF6, vacuum, air, oil), and Transient Recovery Voltage (TRV) dynamics
Topic 14. System Overvoltages, Transient Surge Propagation, and Protection
Studies lightning strikes, switching surges, and temporary overvoltages, modeling traveling wave reflection and refraction using Bewley lattice diagrams, and evaluates surge arrester protection schemes
Topic 15. High Voltage and High Current Laboratory Generation Circuits
Details circuit analysis and operation of cascaded test transformers, series resonant AC circuits, rectifiers, Cockcroft-Walton voltage multipliers, Marx impulse generators, and impulse current circuits
Topic 16. High Voltage Measurement Systems, Testing Standards, and Laboratory Safety

Focuses on sphere gaps, electrostatic voltmeters, resistive/capacitive potential dividers, Rogowski coils, digital transient recorders, standardized withstand testing (IEC 60060-1 / IEC 60071-1), non-destructive testing, and high-voltage operational safety protocols

Topics of the workshops

This field is filled in the same way if the curriculum includes workshops.

Topics of the laboratory classes

Topic 1. Numerical Electrostatic Field Computation and Stress Grading Modeling
Topic 2. Virtual Simulation of High-Voltage Direct Current Generation
Topic 3. Circuit Modeling and Parametric Analysis of Multistage Marx Impulse Voltage Generators
Topic 4. Virtual Impulse Current Waveform Generation and Surge Arrester Testing
Topic 5. Simulation of Dielectric Breakdown and Critical Flashover
Topic 6. Computational Modeling of Power System Transients and the Ferranti Effect
Topic 7. Partial Discharge Detection and Insulation Diagnostics
Topic 8. Virtual Transient Recovery Voltage and Circuit Breaker Interruption Dynamics

Self-study

Information on self-study and individual assignments (reports, course projects, etc.), if it is necessary according to the plan. Also, methods of control and assessment of self-study.

Course materials and recommended reading

Mandatory:
1. Kuffel E., Zaengl W. S., Kuffel J. High Voltage Engineering Fundamentals. 2nd ed. Oxford : Newnes / Elsevier, 2000.
2. Naidu M. S., Kamaraju V. High Voltage Engineering. 6th ed. New Delhi : Tata McGraw-Hill, 2020.
3. Wadhwa C. L. High Voltage Engineering. 2nd ed. New Delhi : New Age International Publishers, 2007.
4. Al-Arainy A. A., Qureshi M. I., Malik N. H. Fundamentals of High Voltage Engineering. Riyadh : King Saud University Press, 2005.

Optional:
1. High Voltage Technology / ed. by L. L. Alston. Oxford : Oxford University Press, 1968.
2. Kind D., Feser K. High-Voltage Test Techniques. 2nd ed. Oxford : Newnes, 2001.
3. High Voltage Engineering: Theory and Practice / M. Abdel-Salam, H. Anis, A. El-Morshedy, R. Radwan. 2nd ed. Boca Raton : CRC Press, 2000.
4. Ray S. An Introduction to High Voltage Engineering. 2nd ed. New Delhi : PHI Learning, 2013.
5. Greenwood A. Electrical Transients in Power Systems. 2nd ed. New York : John Wiley & Sons, 1991.
6. Malik N. H., Al-Arainy A. A., Qureshi M. I. Electrical Insulation in Power Systems. New York : Marcel Dekker, 1997.
7. Schwab A. J. High-Voltage Measurement Techniques. Cambridge : MIT Press, 1972.

International Standards:
1. IEC 60060-1:2010. High-voltage test techniques — Part 1: General definitions and test requirements. Geneva : International Electrotechnical Commission, 2010.
2. IEC 60071-1:2019. Insulation co-ordination — Part 1: Definitions, principles and rules. Geneva : International Electrotechnical Commission, 2019.
3. IEC 60270:2000. High-voltage test techniques — Partial discharge measurements. Geneva : International Electrotechnical Commission, 2000.

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