Syllabus
Course Program

Modelling of Electro-Physical and Electric Power Equipment and Processes

Specialty
141 – Electric Power, Electrical Engineering and Electromechanics

Educational program
Electric Power Industry

Level of education
Masters's level

Semester
1

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

Department
Engineering Electrophysics (135)

Course type
Optional

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 "Modelling of Electro-Physical and Electric Power Equipment and Processes" serves as an essential guide to students, introducing them to the fundamental tenets of electrical engineering modeling. The learning trajectory commences with a concise overview of the standardized designing workflow, encapsulating stages from problem statement to manufacturing. The core emphasis of this course centers around the "modeling and analysis" phase of this workflow, acquainting students with various CAD and analysis tools, though not in an exhaustive manner.
A foundational grounding is laid with a refresher on Maxwell's equations, the cornerstone of all electrical engineering modeling. Following this, the spotlight shifts to analytical solutions and delves into the specifics of numerical methods such as the finite difference method and finite element method. In the practical dimension of the course, students get hands-on experience with the FEMM (Finite Element Method Magnetics) software. This open-source software facilitates a deep understanding of FEM, giving students a practical edge. Both during scheduled practical classes and individual assignments, students are expected to engage actively in modeling using FEMM.

Course objectives and goals

The primary goal of this course is to empower students with a deep understanding of modeling techniques pertinent to electro-physical and electric power equipment and processes. Through this curriculum, learners will comprehend the standardized designing workflow, reinforce foundational

concepts by revisiting Maxwell's equations and related analytical solutions, solidify their theoretical grounding, ensuring a strong foundation for subsequent topics, master numerical methods with the practical component of the course centered around the FEMM software, develop the skills to apply their theoretical knowledge in tangible scenarios, thereby ensuring their readiness for real-world challenges in the field of electrical engineering modeling.
This course is designed to equip students with both the theoretical understanding and practical skills, nurturing them to become proficient professionals in the realm of electro-physical and electric power equipment modeling.

Format of classes

Lectures, laboratory classes, workshops, 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 1. Ability to use computer-aided design (CAD), manufacturing (CAM) and engineering calculations (CAE) and related application software packages.
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 8. Ability to use modern methods of calculations, modeling and analysis of modes of operation of electric power, electrotechnical and electromechanical equipment and design of electric 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 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 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, Theoretical Foundations of Electrical Engineering p.1, Theoretical Foundations of Electrical Engineering p.2, Modelling of Electro-Physical and Electric Power Equipment and Processes

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 Electro-physical and Electric Power Equipment Design Workflow
An overview of the complete design workflow, providing students with a structured approach from problem identification to the manufacturing phase.
Topic 2. Overview of CAD Tools and Basic Analysis Software
A brief introduction to Computer-Aided Design (CAD) tools, laying the foundation for digital design and analysis essential in modern electrical engineering.
Topic 3. Maxwell's Equations and Analytical Solutions: Fundamentals of Electrical Engineering Modeling
A deep dive into the foundational Maxwell's equations and their significance. The lecture also touches upon analytical solutions, reinforcing their application in electrical modeling.
Topic 4. Introduction to the Finite Difference Method (FDM)
This topic introduces the Finite Difference Method, outlining its principles, applications, and its role in numerical modeling within electrical engineering.
Topic 5. Applications and Limitations of FDM
A detailed look into practical applications of FDM, also highlighting its limitations and scenarios where other methods might be more appropriate.
Topic 6. Introduction to the Finite Element Method (FEM)
An introductory session on the Finite Element Method, focusing on its core principles and its significance in the realm of electrical engineering modeling.
Topic 7. Advanced Concepts and Techniques in FEM
Delving deeper into FEM, this lecture covers advanced techniques, methodologies, and real-world applications, providing a comprehensive understanding of FEM.
Topic 8. Introduction to Modeling in FEMM
A practical introduction to the open-source software FEMM, emphasizing its utility in Finite Element Analysis for electrical engineering applications.
Topic 9. Electrostatics Modeling in FEMM
Covering the fundamentals of electrostatics, this lecture provides hands-on insights into modeling electrostatic phenomena using FEMM.
Topic 10. Magnetostatics Modeling in FEMM
This session focuses on magnetostatics, equipping students with the knowledge and skills to accurately model magnetic phenomena within FEMM.
Topic 11. Current Flow Modeling in FEMM
Delving into the intricacies of current flow, students will be introduced to the techniques and practices of modeling current flow dynamics within the FEMM environment.
Topic 12. Optimization Techniques in Electrical Engineering Modeling
A comprehensive overview of optimization methodologies, teaching students how to refine and enhance their electrical models for better accuracy and efficiency.
Topic 13. Errors, Validations, and Verifications in Numerical Modeling
Addressing the challenges in numerical modeling, this lecture covers error analysis, model validation, and verification techniques, ensuring robust and reliable modeling outcomes.
Topic 14. Interpreting Results and Post-processing in FEMM

Post-modeling stages are crucial. This session delves into result interpretation, visualization, and post-processing techniques within the FEMM software.
Topic 15. Case Studies: Challenges & Solutions in Electrical Engineering Modeling
Description: Real-world scenarios are discussed, presenting challenges faced in the industry and how modeling techniques offer solutions, giving students a practical perspective.
Topic 16. Course Recap and Future Trends in Electro-physical Modeling
Description: A holistic recap of the course content, this lecture also introduces students to emerging trends and future prospects in the field of electro-physical modeling.

Topics of the workshops

Topic 1. Practical Exploration of the Design Workflow
Engage in hands-on exercises that familiarize students with the various stages of the design workflow, emphasizing the seamless transition from one stage to the next.
Topic 2. Hands-on: Sketching and Designing with Basic CAD Tools
Dive into the practical aspects of CAD tools, enabling students to sketch and design basic electrical components and systems digitally.
Topic 3. Maxwell's Equations and Analytical Solutions: Practical Applications
Work on real-world problems to apply Maxwell's equations and derive analytical solutions, reinforcing theoretical knowledge through practice.
Topic 4. Practical Problem-solving Using FDM
Engage in exercises that expose students to the application of the Finite Difference Method, solving practical electrical engineering problems.
Topic 5. Advanced Scenarios and Challenges in FDM
Delve into more complex problems, exploring the intricacies of FDM while also identifying its challenges and limitations.
Topic 6. Introduction to Modeling with FEM: Practical Session
A hands-on session where students initiate their journey into Finite Element Modeling, working on basic problems to understand FEM's core principles.
Topic 7. Electrostatics, Magnetostatics, and Current Flow: Practical Exercises
A comprehensive workshop, diving into the practical modeling of electrostatics, magnetostatics, and current flow, emphasizing their significance and techniques in FEMM.
Topic 8. Advanced Electrical System Modeling Using FEM Techniques
Tackle advanced modeling challenges, enhancing proficiency in FEM techniques while also emphasizing the real-world application of these skills.

Topics of the laboratory classes

Topic 1. Exploring the Design Workflow in FEMM
Familiarize with the FEMM environment by walking through the entire design workflow, offering a first-hand experience in utilizing the software for electro-physical modeling.
Topic 2. Practical Designing with FEMM's CAD Features
Dive deep into FEMM's CAD capabilities, guiding students in designing simple electrical components, ensuring a grasp of the software's fundamental features.
Topic 3. Modeling Using Maxwell's Equations and Analytical Solutions in FEMM
Harnessing the power of FEMM to apply Maxwell's equations and generate analytical solutions, this lab provides a practical extension to the theoretical understanding of electrical modeling.
Topic 4. FDM in Action: Practical Modeling in FEMM
Engage in a series of exercises applying the Finite Difference Method within FEMM, bolstering understanding through tangible modeling experiences.
Topic 5. Advanced Exploration of FDM Techniques in FEMM
Pushing the boundaries of FDM within FEMM, students will tackle complex problems, exploring advanced techniques and strategies.
Topic 6. Delving Deeper into FEM Modeling in FEMM
A more intricate look at Finite Element Modeling within FEMM, allowing students to delve into deeper applications and understand the nuances of FEM techniques.
Topic 7. Practical Application of Electrostatics, Magnetostatics, and Current Flow in FEMM

A comprehensive laboratory session dedicated to modeling electrostatics, magnetostatics, and current flow, ensuring students are adept at handling these crucial aspects within FEMM.

Topic 8. Real-world Problem-solving and Case Study Analysis in FEMM

Capping off with a real-world perspective, students will engage in case study analyses, addressing genuine industry challenges using the FEMM software.

Self-study

Students are advised to regularly revisit lecture materials to grasp the intricate details of electro-physical and electric power equipment modeling. Such periodic reviews not only fortify foundational understanding but also equip students to actively engage in, and contribute to, class interactions.

Ahead of each laboratory session, it's beneficial for students to acquaint themselves with the primary principles of the upcoming topic. Such proactive preparation ensures that students can optimally leverage the laboratory's hands-on learning environment.

An integral component of this course is the individual project, where students will immerse themselves in specialized facets of electro-physical modeling. Topics can vary from novel modeling methodologies to the challenges inherent in real-life engineering scenarios. Concluding the course, students will be expected to consolidate their research, discoveries, and insights, delivering a holistic perspective on their deepened understanding of the subject matter.

The vast domain of electro-physical and electric power equipment modeling extends beyond the confines of this course's syllabus. Learners are thus motivated to explore topics such as advances in computational modeling techniques, the environmental impacts of electrical equipment, and nascent trends in electro-physical process optimization. To facilitate this expanded study, supplementary reading resources, software walkthroughs, and lecture captures will be accessible, offering richer insights and expanding academic vistas.

Course materials and recommended reading

1. Silvester, Peter Peet, and Ronald L. Ferrari. Finite elements for electrical engineers. Cambridge university press, 1996.
2. Taflove, Allen, Susan C. Hagness, and Melinda Piket-May. "Computational electromagnetics: the finite-difference time-domain method." The Electrical Engineering Handbook 3.629-670 (2005): 15.
3. Smith, Gordon D. Numerical solution of partial differential equations: finite difference methods. Oxford university press, 1985.
4. Meeker, D. C. "Finite element method magnetics, version 4.2." User's Manual, University of Virginia, USA (2015).
5. Jin, Jian-Ming. The finite element method in electromagnetics. John Wiley & Sons, 2015.
6. Zienkiewicz, Olek C., Robert L. Taylor, and Jian Z. Zhu. The finite element method: its basis and fundamentals. Elsevier, 2005.

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 2023	Head of the department Serhii MOSTOVYI
	Date, signature 2023	Guarantor of the educational program Halyna OMELIANENKO