Syllabus
Course Program

Optimization Problems of Power Engineering

Specialty
141 – Electric Power Engineering, Electrical Engineering and Electromechanics

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

Educational program
Electrical Power Engineering

Department
Electric Power Stations (130)

Level of education
Master's level

Course type
Profile training, Optional

Semester
2

Language of instruction
English, Ukrainian

Lecturers and course developers

Liudmyla Lysenko

Liudmyla.Lysenko@khpi.edu.ua
Candidate of Technical Sciences, Associate Professor, Associate Professor at the Department of Electric Power Stations

Lecturing experience of 18 years. Author and co-author of over 60 scientific and educational works. The courses delivered: Automatic Control Theory in Problems of Electricity and Energy Efficiency, Mathematical Tasks of Power Engineering, Optimization Problems of Power Engineering, Ecological Aspects of Power Industry.
More about the lecturer on the department's website

General information

Summary

The course of Optimization Problems of Power Engineering gives knowledge and develops practical skills in mathematical modeling and solving of optimization problems related to power generation, operation and control.

Course objectives and goals

The goal of the course is gaining knowledge of concept and techniques of mathematical programming, acquiring good command of building mathematical models of optimization problems, mastering application of linear and nonlinear optimization methods and software packages to solve problems of power plant and power system control including renewable energy integrated power grid operation.

Format of classes

Lectures, workshops, consultations, self-study, individual assignments and calculated task, module tests. The final control is exam.

Competencies

General competences:
GC 1. Ability to think, analyze and synthesize.

GC 3. Ability to use information and communication technologies.
Professional competences:
PC 1. Ability to apply the obtained theoretical knowledge, scientific and technical methods and corresponding software for the decision of scientific and technical problems and carry out scientific researches in the field of power engineering, electrical engineering and electromechanics.
PC 3. Ability to apply analytical methods of analysis, mathematical modeling and perform physical, mathematical and computational experiments for solution of engineering tasks and in conducting research.
PC 4. Ability to apply information and communication technologies and programming skills to solve typical tasks of engineering activities in power engineering, electrical engineering and electromechanics.

Learning outcomes

PLO 2. To analyze processes in electric power, electro-technical and electromechanical equipment and corresponding complexes and systems.
PLO 6. To possess methods of mathematical and physical modeling of objects and processes in electric power and electromechanical systems.
PLO 25. To possess modern methods of mathematical and physical modeling of objects and processes, planning of experiment, processing of its results and efficient use of results in research in the field of power engineering.

Student workload

The total volume of the course is 120 hours (4 ECTS credits):
For full-time students:
lectures - 32 hours, workshops - 16 hours, self-study - 72 hours.
For correspondence students:
lectures - 10 hours, workshops - 8 hours, self-study - 102 hours.

Course prerequisites

For successful completion of the course, knowledge and skills acquired in such disciplines as Higher Mathematics, Physics, Electrical Systems and Networks, Electrical Part of Stations and Substations, Renewable Energy Sources and Power Facilities, Modeling of Electric Power Equipment and Processes are required.

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

Lectures are conducted interactively using multimedia technologies. At workshops, students are given individual assignments to train the ability to distinguish between types of optimization problems, develop the skill of building mathematical models, select and apply relevant mathematical programming methods, and make analysis of obtained solutions. Practical tasks are performed using open-source software or on Microsoft 365 platform. Learning materials are available to students through the OneNote Class Notebook.

Program of the course

Topics of the lectures

Objectives of the discipline
The value of this discipline for other professional disciplines. The amount of educational material, types of classes and organization of training.

Content module 1. Linear Programming (LP) Problems in Power Engineering
Topic 1. Mathematical Formulation of Optimization Problems
Mathematical programming. General mathematical formulation of an optimization problem. Optimization criteria. Mathematical model and its components: objective function, decision variables, constraints. Feasible domain. Multi-criteria optimization problems. Classification of mathematical programming

methods. The basic stages of solving an optimization problem. Typical optimization problems of power engineering.

Topic 2. Linear Programming Problems (LPP)

General mathematical formulation of an LPP. Assumptions in LPP. General, standard, and canonical form of a single-index LPP. Special cases in LP: infeasible solution, unbounded solution, multiple optimal solution. Examples of different types of single-index LPPs and their mathematical description.
LP methods. Graphical method of solving LPP. Algorithm of the graphical solution: maximization and minimization cases. Simplex method in LP. Condition for the simplex method application. Algorithm of the simplex procedure: maximization and minimization cases.

Topic 3. Single-index LPP in Power Engineering

The economic dispatch and power unit commitment problem under fuel supply contract. Formulation of the mathematical model of the problem: identification of the decision variables, determination of the objective function, specification of the constraints.

Topic 4. Dual Problem of Linear Programming

Sensitivity analysis of an LPP solution. Concept of shadow prices. Duality in LP. Formulation of the dual problem versus LPP type. Weak and strong duality theorems. Primal-dual solution. Economic interpretation of the dual solution. Sensitivity analysis with MS Excel Solver.

Topic 5. Two-Index Problems of Linear Programming in Power Engineering

Transportation Problem (TP): typical TP formulation, building of the transportation matrix. Balanced and unbalanced TPs. Methods of solving TPs. Formulation of TP in power engineering. Determination of the optimal power transmission scheme under special conditions in a power system: power deficiency, power abundance, power transmission constraint, power transfer through a node.
Boolean two-index LPPs: peculiarities of their mathematical formulation.
Assignment Problem (AP): peculiarities of the structure and mathematical model of the AP. The Hungarian method.
Travelling Salesman Problem (TSP): mathematical formulation. Methods of solving the TSP.

Content module 2. Non-Linear Programming (NLP) Problems in Power Engineering

Topic 6. Methods of Solving Non-Linear Programming Problems

Graphical illustration of an NLP problem. Gradient-based techniques of solving NLP problems. Method of Lagrange multipliers and its application.

Topic 7. Optimal Reactive Power Compensation in Electricity Supply Grid

Necessity for reactive power (VAR) compensation. Mathematical formulation and conditions of optimal VAR compensation in a star-type and series-type electric grids. Optimization problems of available VAR compensation capacity allocation and VAR compensators installation among the nodes in a distribution grid of various types.

Topic 8. Economic dispatch of power units at a thermal power plant (TPP)

Typical operational characteristics of a thermal power plant and its main facilities. Incremental rates. Mathematical formulation and conditions for economic dispatch of power units at a TPP. Lagrange multiplier value interpretation in the TPP economic dispatch problem.

Topic 9. Economic Dispatch of a Thermal Power System with Grid Loss Considered

Economic dispatch of TPP operation under power unit output bounds. Condition of optimal thermal power system operation with the grid loss taken into account. Optimization of reactive power generation in a thermal power system. Complex optimization of thermal power system operation and algorithm of solving the problem.

Topic 10. Optimization of a hydropower plants operation

Operational characteristics of hydroplant units. Mathematical formulation of a short-term optimization problem for a hydroelectric system. Condition of optimal loading of cascade hydroelectric plants.

Topic 11. Economic Dispatch of a Hydrothermal Power System with Renewable Sources

Mathematical formulation of an economic dispatch problem for a hydrothermal power system. Efficiency of water resource utilization. Efficient short-term scheduling of limited water resource. Effect of weather-dependent renewable plant (a wind farm or a solar field) availability on the hydrothermal system operation. Complex optimization of hydrothermal power system operation and algorithm of solving the problem.

Topics of the workshops

Topic 1. Building mathematical models and graphical solution of 2-dimensional LPPs. Application of MS Excel Solver to solving one-index LPPs.
Topic 2. Determination of optimal two-day schedule for coal delivery to three TPPs under coal supply contract and their power units commitment in MS Excel Solver. Peculiarities of MS Excel Solver parameters setting for this problem. Sensitivity analysis with MS Excel Solver.
Topic 3. Application of MS Excel Solver to solving two-index LPPs. Determination of the economic power transmission configuration in a given power system with and without power transfer.
Topic 4. Solving assignment problem and travelling salesman problem with MS Excel Solver. Peculiarities of MS Excel Solver parameters setting for TSP.
Topic 5. Determination of optimal VAR compensation capacity allocation and VAR compensators installation in a given power supply grid.
Topic 6. Determination of economic commitment of thermal power units with MS Excel Solver.
Topic 7. 24-hour scheduling of a given thermal power system operation to meet a given active and reactive load profiles with MS Excel Solver.
Topic 8. Daily scheduling of a given TPP+HPP power system operation to meet a given active load profile with MS Excel Solver.

Topics of the laboratory classes

Self-study

Topic 1. Classification of optimization problems. Branches of mathematical programming. Mathematical programming methods.
Topic 2. Linear programming problems. Conversion of LP textual formulation to a mathematical model. Presentation of mathematical models in MS Excel
Topic 3. LP methods: graphical algorithm, simplex technique.
Topic 4. Duality in LP. Primary-dual solution. Sensitivity analysis.
Topic 5. Two-index LPPs. Peculiarities of their mathematical models. Presentation of a two-index LPP in MS Excel.
Topic 6. Nonlinear programming methods.
Topic 7. Optimal reactive power compensation in distribution grids.
Topic 8. Methods of power system operation optimization. Operational characteristics of thermal power plant facilities. Power unit commitment.
Topic 9. Active power optimization. Reactive power optimization. Optimal economic operation of an all-thermal power system.
Topic 10. Operational characteristics of hydropower plants. Short-term and long-term control of a power system operation with not-coupled and cascade hydropower plants.
Topic 11. Short-term and long-term control of a hydrothermal power system operation

Calculated task
Topic "24-hour scheduling of a given hydrothermal power system operation to meet a given load profile with MS Excel Solver".
Assignment according to the variant.
The term of the calculated task defense is the test week.

Course materials and recommended reading

Compulsory.
1. Lysenko L., Makhotilo K., Chekashyna H. Optimization Problems of Power System Economic Dispatch. Study Guide for Practical Classes in the discipline “Optimization Problems of Power Engineering” for students of specialty 141 “Electric Power Engineering, Electrical Engineering and Electromechanics” of English Educational Program. ФОП Панов А.М., 2021, 130 с. - Access: https://repository.kpi.kharkov.ua/items/208920c3-b011-41f9-a818-628590dde4e6
2. Singiresu S. Rao. Engineering Optimization. Theory and Practice. Fourth Edition. [Electronic resource]. Wiley, 2009, -813 p. – Access: https://www.academia.edu/34774596/Engineering_optimistion_by_rao

3. Allen J. Wood, Bruce F. Wollenberg, Gerald B. Sheble. Power Generation, Operation, and Control. 3rd Edition. [Electronic resource]. IEEE, WILEY, 2014. – 632 p. – Access: https://www.techbooksyard.com/power-generation-operation-and-control-3rd-edition-by-allen-j-wood-and-bruce-f-wollenberg-and-gerald-b-sheble/
4. Jezhong Zhu. Optimization of Power System Operation. [Electronic resource]. IEEE Press Series on Power Engineering, WILEY, 2009. – 603 p. – Access: https://www.academia.edu/22979662/_IEEE_Press_Series_on_Power_Engineering_Jizhong_Zhu_Optimization_of_Power_System_Operation_Wiley_IEEE_Press_2015_

Additional.
1. Andreas Antoniou, Wu-Sheng Lu. Practical Optimization: Algorithms and Engineering Application. Springer Science+Business Media, LLC, 2007. –669 p. – Access: https://www.academia.edu/42865322/Antoniou_Practical_Optimization_Algorithms_and_Engineering_Applications_Springer_2007_
2. M. E. El-Hawary, G. S. Christensen. Optimal economic operation of electric power systems. – New York : Academic Press, 1979. – 278 p. Access: https://www.engineeringbookspdf.com/optimal-economic-operation-of-electric-power-systems-by-m-e-el-hawary-and-g-s-christensen_11301
5. Excel Easy [Electronic resource]. Access code: https://www.excel-easy.com/data-analysis/solver.html

Assessment and grading

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

The final score consists of up to:
30 points for two module tests (15 points each),
32 points for workshop assignments (4 points each),
18 points for the calculated task,
20 points for the exam.

Defense of the calculated task 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