

MINISTRY OF SCIENCE AND HIGHER EDUCATION OF THE RUSSIAN FEDERATION
Federal State Autonomous Educational Institution for Higher Education
«North-Caucasus Federal University»

APPROVED BY

Dean of FPE of NCFU
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COURSE SYLLABUS
«Optimization Methods in Power Systems»

Field of study	<u>13.04.02 Electric Power Engineering and Electrical Engineering</u>
Specialization (Profile)	<u>Training Program of Electrical Engineering</u>
Year of commencement of studies	<u>2026</u>
Mode of study	<u>full-time</u>
Implemented in semester(s)	<u>1</u>

DEVELOPED BY:

Candidate of Technical Sciences, Associate
Professor, E.G. Zelenskii

1. Purpose and objectives of studying the discipline (module)

The "Optimization Methods in Electric Power Engineering" course is designed for students majoring in energy engineering studying modern methods for analyzing and optimizing electrical networks and power systems. The course covers a wide range of approaches to solving optimization problems in the electric power industry, including both classical mathematical methods and innovative heuristic approaches.

Key topics include the principles of constructing digital network models, methods for minimizing energy losses, organizing control and monitoring of power supply modes, and the use of computational tools for implementing practical solutions.

The course is designed to provide students with a broad range of theoretical foundations and practical skills in developing effective strategies for improving the operation of electric power systems using modern software tools.

The goal of this course is to develop the competencies necessary for the successful design and operation of electric power systems. Upon completion of the course, students will be able to:

- understand the principles of formulating and solving optimization problems applicable to electric power networks;
- select appropriate optimization methods for specific engineering situations;
- master modern tools for modeling energy supply processes;
- effectively solve practical problems of improving the energy efficiency and reliability of power systems;
- evaluate the effectiveness of implementing technical and economic measures to reduce energy losses.

Thus, the goal of the course is to train qualified electric power engineers with the necessary knowledge and skills to effectively analyze and manage electric power systems of varying complexity.

2. Place of the discipline (module) in the structure of the educational program

The discipline "Optimization Methods in Electric Power Engineering" belongs to the obligatory part. It is studied in the 1th semester.

3. List of planned learning outcomes for the discipline (module), mapped to the planned outcomes of the educational program

Competency code and formulation	Indicator code and formulation	Planned learning outcomes for the discipline (module) describing the stages of competency and indicator formation
UC-1 Capable of conducting critical analysis of problem situations based on a systems approach and developing an action strategy	ID-2 UC-1. Analyses a problem situation and performs its decomposition into individual tasks;	Able to formalize an engineering problem in the electric power industry (loss reduction, load distribution optimization) as a mathematical optimization model. This includes defining the objective function, identifying control variables, and setting a system of constraints.
	ID-3 UC-1. Develops a strategy for solving the assigned task.	Able to select and justify the most effective numerical method for solving a given optimization problem. The solution strategy includes choosing between deterministic methods (simplex method) and directed or random search methods (genetic algorithms, simulated annealing)

		depending on the nature of the problem.
PC-1 Capable of participating in research and development activities in the field of electrical power engineering	ID-1 PC-1. Performs analysis and processing of scientific and technical information on the research subject from domestic and foreign sources;	Able to conduct a comparative analysis of existing optimization methods and algorithms for solving applied problems in the electric power industry. Can generalize information on the applicability of various approaches (linear, non-linear, heuristic) for specific power system operating conditions.
	ID-2 PC-1. Conducts experiments according to a given methodology; processing and analyses research results;	Able to implement mathematical models and optimization algorithms as program code (in Python). Conducts computational experiments for power flow calculation and network state estimation, as well as analyzes algorithm convergence and solution sensitivity to changes in input parameters.
PC-2 Capable of participating in the design of objects of professional activity	ID-1 PC-2. Performs calculation and analysis of the economic and technical characteristics of the object being designed;	Able to formulate and solve techno-economic optimization problems taking into account capital and operational expenditures. Applies mathematical programming methods to analyze and select equipment parameters or network operating modes that ensure the best economic performance.
	ID-2 PC-2. Evaluates the feasibility of implementing an investment project and selects the most optimal investment alternative.	Able to construct multi-criteria models for comparing investment alternatives in the electric power industry. Applies decision support methods to assess risks and economic efficiency of equipment modernization projects while taking into account technical constraints.

4. Scope (credit load) of the academic discipline (module) and forms of control

Total study load: 4 credits / 144 academic hours	In academic hours
Contact work:	36
Lectures / of which practical training	0 / 0
Laboratory works / of which practical training	0 / 0
Practical classes / of which practical training	54 / 0
Independent work	54
Forms of control:	
Exam	1th semester
Pass/Fail (Credit)	—
Graded Pass/Fail (Credit with grade)	—
Course project/paper	—

* The discipline (module) provides for the use of e-learning and distance educational technologies (unless otherwise stipulated by the educational standard).

5. Content of the discipline (module), structured by topics (sections), indicating the number of hours and types of classes

№	Section (topic) of the discipline and brief content	Formed competencies and indicators	Full-time form				Forms of ongoing progress control
			Contact work of students with the teacher / of which in the form of practical training, hours			Independent work, hours	
			Lectures	Practical classes	Laboratory works		
1	Section 1. Introduction to the discipline 1.1 Problem statement and overview of optimization tasks in modern electric power systems.	ID-2 UC-1 ID-3 UC-1 ID-2 PC-1 ID-1 PC-2	–	2	–	6	Interview
2	Section 2. Linear optimization methods 2.1 Linear optimization problems. Brief theoretical background. The problem of rational use of resources at power plants. The graphical method and the Simplex method.	ID-2 UC-1 ID-3 UC-1 ID-1 PC-1 ID-2 PC-1 ID-1 PC-2 ID-2 PC-2	–	6	–	8	Interview
3	Section 3. Nonlinear optimization methods 3.1 Nonlinear optimization problems. Brief theoretical background. Optimal distribution of active power generation among thermal power plants in a power system. Method of uncertain Lagrange multipliers.	ID-2 UC-1 ID-3 UC-1 ID-1 PC-1 ID-2 PC-1 ID-1 PC-2 ID-2 PC-2	–	4	–	6	Interview
4	Section 4. Digital (mathematical) network model 4.1 Digital (mathematical) network model for power flow optimization and energy loss reduction. The simplest digital network model in Python.	ID-2 UC-1 ID-3 UC-1 ID-1 PC-1 ID-2 PC-1 ID-1 PC-2	–	4	–	6	Interview

5	Section 5. Organizational measures to optimize the electrical network 5.1 Ways to reduce energy losses through organizational measures. Topology reconfiguration, transformer tap position optimization, load balancing. Calculation of power flows and losses of electric energy in elements of the network model in Python. An example of searching for closed loops in an electrical network to solve the topology reconfiguration problem. 5.2 The method of coordinate descent and examples of its application in practice. 5.3 The Monte Carlo method and examples of its application in practice 5.4 Simulated annealing method and examples of its practical application 5.5 Genetic algorithms and practical examples of their application 5.6 The ant colony method and examples of its practical application	ID-2 UC-1 ID-3 UC-1 ID-1 PC-1 ID-2 PC-1 ID-1 PC-2 ID-2 PC-2	–	4	–	8	Interview
6	Section 6. Technical measures to optimize the electrical network 6.1 Ways to reduce energy losses using technical measures A digital (mathematical) network model in Python for assessing the effect of replacing cross-sections and transformers. 6.2 Linear programming in solving the problem of drawing up a program for reducing electricity losses, taking into account financial constraints. An example of using linear programming methods to develop an effective program for reducing electricity losses, taking into account financial constraints on the modernization of the power system.	ID-2 UC-1 ID-3 UC-1 ID-1 PC-1 ID-2 PC-1 ID-1 PC-2 ID-2 PC-2	–	8	–	4	Interview

7	Section 7. Optimization in SCADA 7.1 Purpose, general architecture, and problem statement for state estimation Telemetry and telesignals in a digital (mathematical) network model in Python. 7.2 The problem of assessing the state of the EPS as an optimization problem of calculating the optimal flow distribution under given constraints Solving the problem of state estimation using a digital (mathematical) network model in Python. 7.3 The problem of optimizing the placement of PMUs and ways to solve it An example of solving the problem of optimizing the placement of PMUs	ID-2 UC-1 ID-3 UC-1 ID-1 PC-1 ID-2 PC-1 ID-1 PC-2 ID-2 PC-2	–	4	–	10	Interview
8	Section 8. Assessment 8.1 Final Test. Assessment of Theoretical Knowledge and Practical Skills.	ID-2 UC-1 ID-3 UC-1 ID-1 PC-1 ID-2 PC-1 ID-1 PC-2 ID-2 PC-2	–	4	–	6	Interview
	TOTAL		0	36	–	54	

6. Assessment tools for ongoing progress control and intermediate assessment of students in the discipline (module)

The assessment tools (AT) for ongoing progress control and intermediate assessment of students in the discipline "Optimization Methods in Power Systems" are based on the list of competencies to be acquired, indicating the stages of their formation during the study of the discipline (module). The AT ensures objective monitoring of the achievement of the planned learning outcomes. The AT includes:

- a description of indicators and criteria for assessing competencies at various stages of their formation, and a description of grading scales;
- methodological materials defining the procedures for assessing knowledge, skills, abilities, and/or experience of activities that characterize the stages of competency formation;
- standard control tasks and other materials necessary for assessing knowledge, skills, and the level of mastery of the competencies being formed during the study of the discipline (module).

The assessment tools are an appendix to this discipline (module) program.

7. Methodological guidelines for students on mastering the discipline

When starting work, each student should take into account the following provisions.

The discipline (module) is organized thematically; each topic represents a logically complete section.

Practical classes are conducted to consolidate the acquired information and develop skills in applying it to solve practical problems in the relevant subject area.

Students' independent work is aimed at independently studying additional material, preparing for practical and laboratory classes, as well as completing all types of independent work.

For successful mastery of the discipline, it is necessary to complete all types of independent work using the recommended information sources.

8. Educational, methodological, and informational support of the discipline

8.1. List of basic and additional literature required for mastering the discipline (module)

8.1.1. List of basic literature:

1. Boyd, Stephen, and Lieven Vandenberghe. Convex Optimization. Cambridge University Press, 2004.
2. Bertsekas, Dimitri P. Nonlinear Programming. 2nd ed., Athena Scientific, 1999.
3. Bertsekas, Dimitri P. Dynamic Programming and Optimal Control. Vol. 1–2. 4th ed., Athena Scientific, 2017.
4. Zhu, Jizhong. Optimization of Power System Operation: Second Edition, 2015.
5. Optimization Methods Applied to Power Systems (I). MDPI, 2019.
6. Optimization Methods Applied to Power Systems (II). MDPI, 2022.
7. D. P. KOTHARI, J. S. DHILLON, Power System Optimization. – PHI Learning Pvt. Ltd., 2010. – pp.732

8.1.2. List of additional literature:

1. Fan M., Zhang Z., Wang C. Mathematical Models and Algorithms for Power System Optimization: Modeling Technology for Practical Engineering Problems . – Academic Press, 2019. – 434 p.
2. Computational Methods for Electric Power Systems by By Mariesa L. Crow CRC Press, 2015 pp. 345
3. Python for Data Analysis by Wes McKinney (3rd Edition, 2022) – Pandas and data handling.

8.2. List of educational and methodological support for students' independent work in the discipline (module)

1. Methodological Guidelines for Practical Classes in the Discipline "Optimization

Methods in Power Systems" for Students in the Field of Study 13.04.02 Electric Power Engineering and Electrical Engineering / Compiled by E. G. Zelenskii. – Stavropol: North Caucasus Federal University, 2026.

2. Methodological Recommendations for Organizing Independent Work of Students in Preparation for Classes in the Fields of Study: 13.04.02 Electric Power Engineering and Electrical Engineering / Compiled by E. G. Zelenskii. – Stavropol: North Caucasus Federal University, 2026.

8.3. List of resources of the information and telecommunications network "Internet" necessary for mastering the discipline (module)

1. <http://biblioclub.ru> – Electronic Library System "University Library Online"
2. <http://catalog.ncstu.ru> – Electronic Catalog of the Association of Electronic Libraries of Educational Institutions and Organizations of the North Caucasus Federal District
3. <http://www.iprbookshop.ru> – Electronic Library System
4. <http://window.edu.ru/> – Unified Window of Access to Educational Resources
5. <http://openedu.ru> – National Online Learning Portal "Open Education"

9. List of information technologies used in the educational process for the discipline (module), including the list of software and information reference systems

During lectures, computer equipment and presentation of multimedia materials are used. In seminar and practical classes, students present presentations prepared by them during independent study hours.

Information reference systems:

Information reference and information legal systems used in the study of the discipline:

1	ConsultantPlus – http://www.consultant.ru/
2	https://minenergo.gov.ru/ – Official website of the Ministry of Energy of Russia

Software:

1	Alt Workstation 10
2	Alt Workstation K
3	Alt Server
4	Office suite – R7-Office

10. Description of the material and technical base necessary for the implementation of the educational process in the discipline (module)

Practical classes	Classroom for conducting training sessions, equipped with multimedia equipment and technical teaching aids.
Independent work	A room for independent work of students, equipped with computer equipment with the ability to connect to the Internet and access to the university's electronic information and educational environment.

11. Features of mastering the discipline (module) by persons with disabilities

Students with disabilities are provided with special textbooks, teaching aids and didactic materials, special technical means of learning for collective and individual use, services of an assistant who provides students with the necessary technical assistance, as well as sign language interpreting and typhlo-sign language interpreting services.

Mastering the discipline (module) by students with disabilities may be organized together with other students, as well as in separate groups.

Mastering of the discipline (module) by students with disabilities is carried out taking into account the characteristics of psychophysical development, individual capabilities and health status.

In order to ensure accessibility of higher education under the educational program for persons with disabilities when mastering the discipline (module), the following is provided:

1) For persons with visual disabilities:

- presence of an assistant who provides the student with the necessary technical assistance taking into account individual characteristics (helps to take a seat, move around, read and complete the task, including writing under dictation);
- written assignments, as well as instructions on the procedure for their completion, are formatted in enlarged font;
- special textbooks, teaching aids and didactic materials (with large print or audio files);
- individual uniform lighting of at least 300 lux;
- if necessary, a magnifying device is provided to the student for completing the task

2) For persons with hearing disabilities:

- presence of an assistant who provides the student with the necessary technical assistance taking into account individual characteristics (helps to take a seat, move around, read and complete the task, including writing under dictation);
- provision of collective sound amplification equipment; if necessary, the student is provided with individual sound amplification equipment;
- provision of appropriate sound means of information reproduction.

3) For persons with musculoskeletal disorders (including those with severe motor impairments of the upper limbs or absence of upper limbs):

- written assignments are performed on a computer with specialized software or dictated to an assistant;
- at the student's request, assignments may be completed orally.

12. Features of implementing the discipline using distance educational technologies and e-learning

According to Part 1 of Article 16 of Federal Law No. 273-FZ of December 29, 2012 "On Education in the Russian Federation," e-learning is understood as the organization of educational activities using information contained in databases and used in the implementation of educational programs, information technologies and technical means that ensure its processing, as well as information and telecommunications networks that ensure the transmission of said information through communication lines and the interaction of students and teaching staff. Distance educational technologies are understood as educational technologies implemented primarily using information and telecommunications networks with indirect (remote) interaction between students and teaching staff.

The discipline may be implemented using distance educational technologies and e-learning in whole or in part. The components of the educational and methodological set of the discipline (syllabus, assessment and methodological materials, forms of certification) implemented using distance educational technologies and e-learning contain an indication of their use.

When organizing educational activities using distance educational technologies and e-learning, asynchronous and synchronous methods of interaction between participants in educational relations via the information and telecommunications network "Internet" may be provided.

When using distance educational technologies and e-learning, the schedule for the discipline indicates: methods of interaction between participants in educational relations via the information and telecommunications network "Internet" (VCS – video conferencing, ET – electronic testing); links to the electronic information and educational environment of NCFU, to educational platforms and resources of other organizations to which open access is provided via the information and telecommunications network "Internet"; for synchronous learning – the time of online classes and the instructors; for asynchronous learning – the authors of online courses.

When organizing intermediate assessment using distance educational technologies and e-learning, the Methodological Recommendations on the use of technical means ensuring the objectivity of results during intermediate and state final assessment in higher education programs – bachelor's programs, specialist's programs and master's programs using distance educational

technologies (Letter of the Ministry of Science and Higher Education of the Russian Federation dated December 7, 2020 No. MN-19/1573-AN "On sending methodological recommendations") are applied.

The implementation of the discipline using e-learning and distance educational technologies is carried out using the electronic information and educational environment of NCFU, to which students have access via the information and telecommunications network "Internet", or using resources of other organizations, including platforms that provide services for video conferencing, online meetings and distance learning (MTS-Link), as well as using the capabilities of social networks to facilitate communication between students and instructors.

The educational and methodological support of the discipline implemented using e-learning and distance educational technologies includes the syllabus, educational and methodological manuals or a lecture course, methodological guidelines for performing various types of learning activities provided for by the discipline, and other educational and methodological materials posted in the electronic information and educational environment of NCFU, all presented in electronic form.