Syllabus
Course Program

FUNDAMENTALS OF RELAY PROTECTION AND AUTOMATIC OF POWER SYSTEMS

Specialty
141 – Power engineering, electrical engineering and electromechanics

Institute
Institute of Energy, Electronics and Electromechanics

Educational program
Power engineering

Department
Department of Electric Power Engineering Automation and cyber security of energy systems (132)

Level of education
Bachelor's level

Course type
Special (professional)

Semester
6

Language of instruction
English

Lecturers and course developers

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Author and co-author of more than 5 scientific publications.
Courses: Fundamentals of Relay Protection and Automation of Power Systems
More about the lecturer on the department's website

General information

Summary

The educational component "Fundamentals of Relay Protection and Automation of Power Systems" is aimed at forming knowledge of the principles of implementation, features of operation and calculation of parameters of operation of relay protection devices of electric power systems.

Course objectives and goals

Formation of knowledge on the basics of conventional and complex devices for relay protection of elements of electric power systems.

Format of classes

Lectures, practical classes, laboratory classes, independent work, consultations. Calculation work. Final control - exam.

Competencies

General competences:
K01. Ability to abstract thinking, analysis and synthesis.
K02. Ability to apply knowledge in practical situations.
K05. Ability to search, process and analyze information from various sources.

K06. Ability to identify, pose and solve problems.
K07. Ability to work in a team.
K08. Ability to work autonomously.
GK 1. The ability to apply knowledge and understanding in practice in a way that indicates a professional approach to solving problems in the field of electrical engineering
GK 5. Ability to search, process and analyze information from various sources that take into account relevant social, scientific or ethical issues.
GK 7. The ability to make informed decisions on issues of relay protection in the field of electric power.

Special (professional) competences
K11. The ability to solve practical problems using automated design and calculation systems (CAD).
K12. The ability to solve practical problems involving the methods of mathematics, physics and electrical engineering.
K13. The 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 high-voltage equipment.
K16. The ability to solve complex specialized tasks and practical problems related to the problems of production, transmission and distribution of electric energy.
K17. The ability to develop projects of electric power, electrotechnical and electromechanical equipment in compliance with the requirements of legislation, standards and specifications.
K19. Awareness of the need to increase the efficiency of electric power, electrotechnical and electromechanical equipment.
K20. Awareness of the need to constantly expand one's own knowledge of new technologies in electric power, electrical engineering and electromechanics.
K21. The ability to promptly take effective measures in emergency (emergency) situations in electric power and electromechanical systems.
K25. Obtaining and using professional knowledge and understanding related to the processes of transmission, distribution of electricity and electricity supply in compliance with the specified parameters of technological processes and electricity quality.
K31. Obtaining and using professional knowledge and understanding related to modern digital technologies of electricity distribution and consumption processes.
PK 4. The ability to use professional knowledge of the basics of power engineering: the electrical part of stations and substations, electrical systems and networks, relay protection and automation of power systems to solve practical problems in the field of power engineering, electrical engineering and electromechanics.
PK 8. Ability to use modern methods of relay protection calculations in the field of electric power.
PK 12. The ability to study and analyze scientific and technical information in the field of electric power on issues of relay protection.
PKs 17. Obtaining and using professional knowledge and understanding related to the operation of relay protection devices.

Learning outcomes

PR01. Know and understand the principles of operation of electrical systems and networks, power equipment of electrical stations and substations, protective grounding and lightning protection devices and be able to use them to solve practical problems in professional activities.
PR07. To carry out the analysis of processes in electric power, electrotechnical and electromechanical equipment, relevant complexes and systems.
PR08. Choose and apply suitable methods for the analysis and synthesis of electromechanical and electric power systems with given indicators.
PR10. Find the necessary information in scientific and technical literature, databases and other sources of information, evaluate its relevance and reliability.
PR17. Solve complex specialized problems in the design and maintenance of electromechanical systems, electrical equipment of power stations, substations, systems and networks.
PR18. Be able to learn independently, acquire new knowledge and improve skills in working with modern equipment, measuring equipment and application software.
PR19. Apply appropriate empirical and theoretical methods to reduce losses of electrical energy during its production, transportation, distribution and use.
PR20. To solve professional problems in the design, installation and operation of electric power, electrotechnical, electromechanical complexes and systems.

PR24. To know and understand the processes of transmission, distribution of electricity and electricity supply in compliance with the specified parameters of technological processes and the quality of electricity.
PR30. To know and understand the processes associated with modern digital technologies of electricity distribution and consumption processes.

Student workload

The total volume of the course is 150 hours (5 ECTS credits): lectures - 32 hours, practical classes - 16 hours, laboratory classes - 16 hours, self-study - 86 hours.

Course prerequisites

To successfully complete the course, you must have knowledge and practical skills in the following disciplines: "Theoretical basics of electrical engineering. part 1, 2", "Electric machines", "Electrical systems and networks", "Electrical part of stations and substations", "Electromagnetic transient processes".

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

The course is focused on the students' independent cognitive activity, on their ability to work with regulatory and legal documents in the field of energy, sources of scientific and technical information.
Reproductive methods of learning are used, relying on the step-by-step formation of mental actions with elements of active learning methods.
The main recommendation boils down to ensuring uniform active work of students on the course during the academic year.
They must study the material of the lectures, prepare for practical classes in the form of an oral or written survey. Most of the tasks for practical classes involve the presence of an individual task.
The student's independent work includes studying lecture material, preparing for practical classes and laboratory work, completing an individual task, studying additional material. To prepare for practical and laboratory classes, information resources, lecture materials and recommended literature should be used first of all.

Program of the course

Topics of the lectures

Topic 1. Purpose and main functions of the RZ.

The main features of the UES (on the example of the system diagram). Appointment of SRPA. Primary and secondary parts of the system. Classification and functions of electrical automation of EES. Parameters and modes of electrical installations used in RPA calculations. Normal (pre-emergency mode). Emergency mode (short-circuit, short circuit, open circuit), abnormal mode (overcurrent, voltage increase, swing, asynchronous mode, frequency reduction), self-starting of electric motors.

Topic 2 Basic requirements for RPA.

Selectivity (absolute and relative). Action speed, protection and circuit breaker activation times (on examples of oscillograms of emergency events). Sensitivity of main and backup protections. Reliability of operation in case of internal short circuits. and without short circuits. failures in activation, redundant activations, false activations. Peculiarities of using element base. An example of calculating damage from improper operation of the RPA.

Topic 3 Current transformers.

Schemes. Problem solving.

Topic 4 Maximum current protection.

Degree of selectivity. An example of selecting settings by time. Selection of tripping current. Conditions of non-operation for disconnection after emergency overloads (disconnection of the external three-phase short-circuit, restoration of power supply by the automatic reactivation or automatic reserve entry, disconnection of the element operating in parallel, automatic inclusion of additional load when the automatic reserve entry is triggered). Conditions for coordination of sensitivity protections.
Normalization of the sensitivity coefficient. Measures to increase the sensitivity of current protection. The maximum current protection with a dependent time exposure. Selectivity diagram. Advantages and disadvantages of protection. An example of matching protections with dependent stepped time delay characteristics.

Topic 5 Multi-stage current protection.

The principle of action. Current cut-off without time delay. Calculation of the tripping current. Reconstruction of protection against transient currents of a three-phase short-circuit, swing currents, magnetizing current surges, starting currents. Practical methods of calculating protection settings. Expansion of the protected current cut-off zone. Non-selective current cut-off in the automatic reactivation and automatic reserve entry. Non-selective current cut-off before and after automatic reactivation, after automatic reserve entry, with alternate automatic reactivation. Non-selective current cut-off with multiple reclosers, in order to reduce the power of the short-circuit.

Topic 6 Protection against short circuits to the ground in the network by an effectively grounded neutral.

General Information. The principle of action. Maximum current protection of zero sequence. Starting protection bodies. Selection of exposure time. Imbalance currents. Protection tripping current. Protection sensitivity. Defense assessment. Zero sequence cutoff. Zero-sequence stepped current protection.

Topic 7 Protection against earth faults in a network with an isolated neutral.

Currents and voltages during single-phase grounding. Basic requirements for protection. Principle of execution of protection. Non-selective signaling for ground faults. Current protection of zero sequence. Measuring bodies. Protection schemes. Trigger current. Protection sensitivity.

Topic 8 Direct current protection.

The need for directional protection in networks with two-way power. Functional scheme and principle of protection. The main characteristics of the power relay. Switching schemes of power direction relays. The first level of protection. The second level of protection. The third degree of protection. The step-by-step principle of choosing a time exposure. An example of selecting settings by time. Peculiarities of the operation of protection in ring networks. Dead zone and zone of cascading action of protection, selection of protection activation currents. Schemes of directional maximum current protection.

Topic 9 Current differential protection.

Longitudinal current differential protections. The principle of action. Unbalance currents in differential protection in stable and transient modes. Selection of protection activation parameters and methods of increasing its sensitivity. The principle of operation of fast saturated transformers. The principle of operation of differential protection with a wired communication channel.

Topic 10 Transverse current differential protection.

Distribution of currents in parallel power lines in normal mode and in the event of a short circuit on one power line. The principle of protection. Defense dead zone. Protection scheme. Directed transverse differential protection. Vector diagrams of currents and voltages on power relays. Zones of cascading action of protection. Schemes of directional transverse differential protection.

Topic 11 Remote protections.

Purpose and principle of action. Characteristics of time resistance of remote protections. Principles of implementation of selective protection of the network with the help of step-by-step remote protection. Selection of remote protection settings. Examples of line protection with and without branches. Relay operation characteristics. General principles of performance of the resistance relay. Starting bodies of remote protections.

Topic 12 Protection blocking devices. Assessment of remote protection.

Interaction of remote protections. Mutual action of protection installed at different points of the electrical network, installed at two ends of one line, on several lines. Two-stage, three-stage, and four-stage protection, protection with the reverse direction of thirds of a degree. Examples of calculations of remote protection of power lines 330kV.

Topic 13 High-frequency protection.

Purpose and types of high-frequency protection. The principle of directional protection with HF blocking. The principle of implementation and operation of the high-frequency part of the protection. Channel of high frequency currents. Elements of the high-frequency channel. Blocker. High frequency transmitter receiver.

Topic 14 Principle of operation of differential-phase high-frequency protection.

Directional RF protection. The principle of action. Schemes. Algorithms.

Topic 15 Bus protection of stations and substations and redundancy of relay protection and circuit breakers.

Purpose of tire protection. Current protection tires. Directional tire guards. Remote protection of tires. General issues of implementation of differential current protection. Scheme, current distributions, unbalance currents, control of the serviceability of current networks, settings. Incomplete differential tire protection.

Topic 16 Necessity and methods of reservation. Principles of implementation of redundancy devices in case of circuit breaker failure (RDBF).

The scheme of starting the RDBF with additional current control. Scheme of starting the RDBF using the "On" position relay.

Topics of the workshops

Topic 1 Damage parameters.
Topic 2 Reading relay protection schemes. Combined and expanded schemes. Examples.
Topic 3 Current transformers. Malfunctions Problem solving.
Topic 4. Solving individual problems. Calculations of short-circuit currents.
Topic 5 Solving individual problems. Calculations of protection settings for elements of the power supply system.
Topic 6 Solving individual problems. Setting the protection settings of the elements of the power supply system.
Topic 7. Gas protection. Float, cup and jet relays. Operating current diagram.
Topic 8. Solution of individual problems with CDPA

Topics of the laboratory classes

Topic 1. Study of the characteristics of the RT-40 electromagnetic current relay.
Topic 2. Study of the characteristics of the RT-82 electromagnetic current relay.
Topic 3. Study of the characteristics of the electromagnetic time relay.
Topic 4. Study of elements of maximum current protection with independent time delay.
Topic 5. Research of protection elements with limited time-dependent exposure.
Topic 6. Checking the correct connection of current transformers.
Topic 7. Study of current differential relays.
Topic 8. Research of differential protection of a two-winding transformer.

Self-study

The course involves performing calculation work that contributes to the familiarization of students at the stage of preparation of bachelors of the educational program "Electroenergetics" with the skills of calculating parameters of damage and parameters of protection devices of elements of the power supply system.

Course materials and recommended reading

Basic literature:
1. Kidiba V. P. Relay protection of electric power systems: Textbook. – Lviv: Publishing House of the National University "Lviv Polytechnic", 2013. – 533 p.
2. Rules for arranging electrical installations. Kharkiv: "Fort" Publishing House, 2017. 760 p.
3. Bukovich N.V. Calculation of short-circuit currents of electric power systems / Ed. Denysenko G.I. – Lviv, Higher school View near Lviv. University, 1988 - 248 p.
4. L Shelepeten T.M. Protective automation of electrical networks.: Training. manual for students of specialties 7.090602 and 8.090602 "Electrical systems and networks" of all forms of education. - Lviv, 2002, 157 p.
5. Relay protection and automation in power supply systems/ P.P. Govorov, G.A. Senderovych, V.F. Sokolov et al. Education manual. - K.: IZMN, 1996. 288 p.
6. Yandulsky O. S., Dmytrenko O. O. Relay protection. Digital devices of relay protection, automation and control of power systems: teaching. manual Kyiv: NTUU "KPI", 2016. 102 p.
7. Relay protection and cyber security of energy systems. / E.I. Sokol, O.G. Hryb, V.M. Bazhenov, V.P. Starenky, O.Yu. Zakovorotnyi, M.M. Odegov et al. (Textbook / Under the general editorship of the correspondent member of the National Academy of Sciences of Ukraine, Doctor of Technical Sciences, Professor E.I. Sokol) - Kharkiv: FOP Panov A.M. 2019. – 390 p.
Additional literature:
1. Kidyba V.P., Shelepeten T.M. Protection of transformers and autotransformers. Lviv: Ed. national Lviv Polytechnic University, 2004. 180 p.
2. Bazhenov V. M., Odegov M. M. Modern technologies and methods of building relay protection and automation systems in electric power engineering. URL: web.kpi.kharkov.ua/avkib/uk/metodichnezabezpechennya/
3. Hewitson Leslie, Brown Mark, Balakrishnan Ramesh. Practical Power Systems Protection. Oxford; Burlington, MA: Newnes, 2005. 289 p.
4. Kidyba V.P., Shelepeten T.M. Protection of power transmission lines. Lviv: Ed. National Lviv Polytechnic University, 2004. 185 p.

5. Bazhenov V.M. Basics of relay protection and automation of power systems. Tests for performing control work. Electronic edition: https://studfiles.net/preview/1955843. Kharkiv: NTU "KhPI", 2018.

Assessment and grading

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

100% of the final grade consists of the assessment results in the form of:
Modular control work 1 (30%);
Modular control work 2 (30%);
Calculation work (20%);
Exam (20%).

Grading scale

Total points	National	ECT
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	28.06.2023	Head of the department Dmytro Gapon
	28.06.2023	Guarantor of the educational program Halyna OMELYANENKO