National Technical University of Ukraine
"Igor Sikorsky Kyiv Polytechnic Institute"

Department of Automation of
Energy Systems of the FEA

Relay protection and automation of energy systems

Syllabus of the educational component

Details of the academic discipline	
Level of higher education	***First (undergraduate)***
Discipline	*14 "Electrical engineering"*
Specialty	*141 "Electric power engineering, electrical engineering and electromechanics"*
Educational program	*Electromechanical automation systems, electric drive and electric mobility*
Discipline status	*Normative educational components. Cycle of general training.*
Form of education	*Part-time (day) 4 b.n. Day (day) accelerated 3 b.n.*
Year of training, semester	*And 5th year, fall semester (for full-time education),* *III year, autumn semester (for full-time accelerated form of education)*
Scope of the discipline	*120 hours / 4 ECTS credits (36 hours of lectures, 18 hours of laboratory work)*
Semester control/ control measures	*Examination / D KR, MKR, protection of laboratory work*
Class schedule	*http://rozklad.kpi.ua/* *1 lecture (2 hours) once a week;* *1 laboratory work (2 hours) once every 2 weeks.*
Language of teaching	*Ukrainian*
Information about the head of the course / teachers	Lecturer: *Ph.D. Assoc. Oleksandr Dmytrenko, 0672382408* Laboratory practicum: *Ph.D. Assoc. Dmytrenko Oleksandr Oleksiyovych, 0672382408, Zakolodyazhnyi Volodymyr Vasyliovych, 0505959933*
Placement of the course	*Google Classroom* *https://classroom.google.com/c/MTY3NjcxMjI5NjM2?cjc=qlyla6c* *https://classroom.google.com/c/MTQ1NDQ5NTk4NjY3?cjc=orsvrmb*

Program academic discipline

1. Description educational discipline, its purpose, subject of study and learning outcomes

The syllabus of the educational component "Relay protection and automation of power systems" is compiled in accordance with the educational program of bachelors "Electromechanical automation systems, electric drive and electric mobility" from the field of knowledge 14 "Electrical engineering" in the specialty 141 "Electric power, electrical engineering and electromechanics".

The purpose of the academic discipline *is to form and consolidate the following competencies in students: (K07) Ability to work in a team; (K08) Ability to work autonomously; (K14) Ability to solve complex specialized tasks and practical problems related to problems of metrology, electrical measurements, operation of automatic control devices, relay protection and automation; (K21) Ability to promptly take effective measures in emergency (emergency) situations in electric power and electromechanical systems.*

The subject of the educational discipline *is the principles of construction and algorithms of the functioning of systems and individual devices of relay protection (RZ) of electric networks and energy systems, namely: directional and non-directional maximum current, remote protection of power transmission lines, current cut-offs, protection against earth faults of electric networks of various classes voltage, differential protection of power transformers, generators and electric motors, technical and economic justification of engineering solutions; modern methods of analysis and calculation of the parameters of the RZ operation, conducting research and analyzing the obtained results using modern intellectual, informational computer-integrated technologies.*

Program learning outcomes, the formation and improvement of which is aimed at the discipline:
(PR02) Know and understand the theoretical foundations of metrology and electrical measurements, the principles of operation of automatic control devices, relay protection and automation, have the skills to perform appropriate measurements and use the specified devices to solve professional tasks; (PR06) Apply application software, microcontrollers and microprocessor technology to solve practical problems in professional activity; (PR17) Solve complex specialized problems in the design and maintenance of electromechanical systems, electrical equipment of power stations, substations, systems and networks.

2. Pre-requisites and post-requisites of the discipline (place in the structural and logical scheme of training according to the relevant educational program)

To successfully master the discipline, the student must possess: the theoretical basis of the disciplines "Higher Mathematics", "General Physics", "Theoretical Foundations of Electrical Engineering", "Electric Machines", "Electrical Parts of Stations and Substations", "Electrical Networks and Systems". Competences, knowledge and skills acquired in the process of studying the discipline are necessary for studying the discipline "Relay protection and automation of power systems" and further high-quality performance of research on the topic of certification work.

3. Content of the academic discipline

The discipline is structurally divided into 3 ***sections*** *, namely:*

1. ***General information about relay protection***
   Topic 1.1. *Appointments, requirements for RZ. Types of damage and abnormal modes of electrical systems.*
   Topic 1.2. *The general structure of the RZ.*
   Topic 1.3. *Connection diagrams of current transformers*
   Topic 1.4. *Principles of construction of operational power supply schemes of power plants and substations.*
2. ***Relay protection of power transmission lines***
   Topic 2.1. *Maximum current protection (MHZ)*
   Topic 2.2. *Current cut-off*
   Topic 2.3. *Directed maximum current protection (NMZS)*
   Topic 2.4. *Protect current networks (lines) from shorting to earth*
   Topic 2.5. *Remote protections*
3. ***Relay protection of power transformers and autotransformers, synchronous generators, electric motors***
   Topic 3.1. *Relay protection of power transformers*
   Topic 3.2. *Relay protection of synchronous generators*
   Topic 3.3. *Relay protection of electric motors*

4. Educational materials and resources

Main information resources:

1. *Kidiba V.P. Relay protection of power systems: Textbook. - Lviv: Publishing House of the National University "Lviv Polytechnic", 2013.-533 p.*
2. *Rules for arranging electrical installations: 2017. – Official. view. - K.: Fort: Ministry of Oil and Energy of Ukraine. 2017.*
3. *Relay protection of power systems: Textbook for students majoring in power engineering, electrical engineering and electromechanics / E.I. Sokol, G.A. Senderovych, O.G. Hryb et al. - Kharkiv: FOP Brovin O.V., 2020. - 306 p. I SBN 978-617-7912-25-4*

4. *Relay protection and automation: Training. manual / S.V. Panchenko, V.S. Blindyuk, V.M. Bazhenov and others; under the editorship V.M. Bazhenov – Kharkiv: UkrDUZT, 2020. – Part 1. – 250 pp., fig. 41, tab. 20.*
5. *Relay protection and automation: Training. manual /S.V. Panchenko, V.S. Blindyuk, V.M. Bazhenov and others; by ed. V.M. Bazhenov – Kharkiv: UkrDUZT, 2021. – Part 2. – 276 p., fig. 48, tab. 19.*
6. *Relay protection. Digital devices of relay protection, automation and control of electric power systems [Electronic resource]: study guide / O. S. Yandulskyi, O. O. Dmytrenko; NTUU "KPI". - Kyiv: NTUU "KPI", 2016. - 103 p. http://ela.kpi.ua/handle/123456789/16600*

Additional:

7. *Dmytrenko, O. O. Relay protection of electrical networks: calculation of protection parameters for the current of electrical networks 6–35 kV: a collection of problems and exercises [Electronic resource]: study guide for bachelor's degree holders in the educational programs "Management, protection and automation energy systems", "Non-traditional and renewable energy sources", "Power stations", "Electrical systems and networks", "Electrotechnical devices and electrotechnological complexes", "Electric machines and devices", "Electromechanical systems of automation, electric drive and electric mobility" specialties 141 " Electric power, electrical engineering and electromechanics" / O. O. Dmytrenko; KPI named after Igor Sikorsky. – Electronic text data (1 file: 5.13 MB). – Kyiv: KPI named after Igor Sikorskyi, 2022. – 47 p. – Name from the screen . https://ela.kpi.ua/handle/123456789/48923*
8. *Relay protection of electrical networks: Electromechanical and microelectronic devices of RZA: Laboratory practice [Electronic resource]: study guide for bachelor's degree holders in the educational programs "Management, protection and automation of power systems", "Non-traditional and renewable energy sources", "Power stations" , "Electrical systems and networks", "Electrotechnical devices and electrotechnological complexes", "Electrical machines and devices", "Electromechanical automation systems, electric drive and electromobility" specialty 141 "Electric power, electrical engineering and electromechanics" / KPI named after Igor Sikorskyi; structure. : O. O. Dmytrenko, V. V. Zakolodyazhnyi, V. M. Khlistov. – Electronic text data (1 file: 11.33 MB). – Kyiv: KPI named after Igor Sikorskyi, 2022. – 55 p. – Title from the screen. The fretboard was provided by the Methodical Council of the KPI named after Igor Sikorskyi (protocol No. 6 dated 06/24/2022) at the request of the Academic Council of the Faculty of Electrical Engineering and Automation (protocol 9 dated 05/17/2022). https://ela.kpi.ua/handle/123456789/48926*
9. *Relay protection and automation of power systems: microprocessor devices of RZA: laboratory practice [Electronic network educational edition]: study guide for bachelor's degree holders in the educational programs "Management, protection and automation of power systems", "Non-traditional and renewable energy sources", "Power plants" ", "Electrical systems and networks", "Electrotechnical devices and electrotechnological complexes", "Electrical machines and devices", "Electromechanical systems of automation, electric drive and electric mobility" specialty 141 "Electric power, electrical engineering and electromechanics" / O. O. Dmytrenko, V V. Zakolodyazhnyi; KPI named after Igor Sikorsky. – Electronic text data (1 file: 56.21 MB). – Kyiv: KPI named after Igor Sikorskyi, 2022. – 151 p. – Title from the screen. https://ela.kpi.ua/handle/123456789/48955*
10. *Relay protection and automation of energy systems. Study of two-stage current protection with independent time delay. Homework [Electronic resource]: study guide for bachelor's degree holders in the educational programs "Management, protection and automation of power systems", "Non-traditional and renewable energy sources", "Power stations", "Electrical systems and networks", "Electrotechnical devices and electrotechnological complexes", "Electric machines and devices", "Electromechanical systems of automation, electric drive and electromobility" specialty 141 "Electric power, electrical engineering and electromechanics" / KPI named after Igor Sikorskyi; structure. O. O. Dmytrenko, V. M. Khlistov. – Electronic text data (1 file: 4 MB). – Kyiv: KPI named*

after Igor Sikorskyi, 2022. - 15 p. – Title from the screen. https://ela.kpi.ua/handle/123456789/48943

Educational content

5. Methods of mastering an educational discipline (educational component)

Lecture classes

No s/p	The name of the topic of the lecture and a list of main questions (list of didactic tools, links to information sources)
	Chapter 1. General information about relay protection .
1-2	***Topic 1.1.*** *Appointments, requirements for RZ. Types of damage and abnormal modes of electrical systems.* *Basic questions. The place of relay protection in the overall control system of production and distribution of electric energy. Purpose of relay protection. Basic requirements for RR. Types of damage and abnormal modes of electrical systems.* *Literary sources: [1-6]*
3.	***Topic 1.2.*** *The general structure of the RZ* *Basic questions. General structure of relay protection. Information used in relay protection systems. Information sensors in relay protection systems. Types of RZ devices (main, reserve, by type of selectivity).* *Literary sources: [1-6]*
4-5.	***Topic 1.3.*** *Connection diagrams of current transformers* *Basic questions. Connection schemes of current transformers in three-phase alternating current systems, features of their operation, coefficient of the scheme. Measuring current transformers, their parameters.* *Literary sources: [1-5]*
6.	***Topic 1.4.*** *Principles of construction of operational power supply schemes of power plants and substations* *Basic questions. Sources of operational power supply of elements of the structural scheme of relay protection. Operational power supply from TVP substation.* *Literary sources: [1-6]*
	Chapter 2. Relay protection of power transmission lines
7.	***Topic 2 . 1 .*** *Maximum current protection (MHZ)* *Basic questions. Maximum current protection (MZS). Principle of operation, calculation of operating parameters, construction of a selectivity map. Schemes of implementation, advantages and disadvantages, scope of use. Types of RZA schemes: structural, functional, principle compatible and principle separated schemes.* *Literary sources: [1-5]*
8.	***Topic 2 . 2 .*** *Current cut-off* *Basic questions. Current cut-off, principle of action, calculation of tripping parameters, differences from MFA, purpose. Schemes of implementation, advantages and disadvantages, scope of use. Joint use of cut-off by current and MZS.* *Literary sources: [1-5]*
9-10.	***Topic 2 . 3 .*** *Directed maximum current protection (NMZS)* *Basic questions. Directed maximum current protection (NMZS). Principles of action, ensuring selectivity. Characteristics of power directional relays. Schemes of implementation, advantages and disadvantages, scope of use.* *Literary sources: [1-5]*
11.	***Topic 2 . 4 .*** *Protect current networks (lines) from shorting to earth* *Basic questions. Protect the current of networks (lines) from shorting to the ground in networks with a grounded neutral. Maximum protection against zero sequence current. Schemes of*

	implementation, advantages and disadvantages, scope of use. Calculation of settings. Protect the current of networks (lines) from shorting to the ground in networks with isolated and compensated neutrals. Basic requirements for protection. Principles of protection against ground fault in networks with small ground fault currents. Zero sequence current transformer. Schemes of implementation, advantages and disadvantages. *Literary sources: [1-5]*
12.	***Topic 2 . 5 .*** *Remote protections* *Basic questions. Remote protections. The principle of action. Calculation of operating parameters, construction of a selectivity map. Schemes of implementation, advantages and disadvantages, scope of use.* *Literary sources: [1-5]*
	Chapter 3. Relay protection of power transformers and autotransformers, synchronous generators, electric motors
13-14.	***Topic 3 . 1 .*** *Relay protection of power transformers* *Basic questions. Types of damage and abnormal modes of operation of power transformers and autotransformers. Features of protection of power transformers. Current cut-off for protection of power transformers. The principle of action. Schemes of implementation, advantages and disadvantages, scope of use. Longitudinal differential protection for protection of power transformers. Differential protection with braking characteristic. The principle of action. Schemes of implementation, advantages and disadvantages, scope of use.* *Literary sources: [1-5]*
15-16.	***Topic 3 . 2 .*** *Relay protection of synchronous generators* *Basic questions. Types of damage and abnormal modes of operation of synchronous generators. Protection against phase-to-phase short-circuits in the stator winding of the generator (principle of operation, execution scheme, features). Protection of the generator from damage to the stator winding to the ground (principle of operation, execution scheme, advantages, disadvantages, area of use).* *Literary sources: [1-5]*
17.	***Topic 3 . 3 .*** *Relay protection of electric motors* *Basic questions. Types of damage and abnormal operation modes of electric motors. Protection against interphase short-circuits in the stator winding of motors up to 5000 kW (principle of operation, scheme of execution, features). Protection against phase-to-phase short-circuits in the stator winding of motors over 5000 kW (principle of operation, execution scheme, features). Protection against short-circuits of the stator winding to the ground, double short-circuits to the ground (principle of operation, scheme of execution, calculation of settings, advantages, disadvantages).* *Literary sources: [1 - 5]*
18.	*MKR*

Practical classes
(missing)

Laboratory classes

No s/p	*The name of the laboratory work*	*Number audio hours*
1	*Study of connection schemes of secondary windings of current transformers and relays* *Literary sources: [8]*	*2*
2	*Study of current, voltage, time and intermediate electromagnetic relays* *Literary sources: [8]*	*2*
3	*Study of induction current relay* *Literary sources: [8]*	*2*

4	*Study of power directional relays* *Literary sources: [8]*	*2*
5	*Research of the microprocessor device of relay protection and automation MRZS-05-01* *Literary sources: [9]*	*2*
6	*Study of the UZA-10V microprocessor relay protection and automation device* *Literary sources: [9]*	*2*
7	*Research of the 7UT513 microprocessor relay protection and automation device* *Literary sources: [9]*	*2*
8	*REF - 615 microprocessor relay protection device* *Literary sources: [9]*	*2*
9	*Research of the microprocessor relay protection device REM - 630* *Literary sources: [9]*	*2*
	IN GENERAL	*18*

Student's independent work

No. z/p	*Type of independent work*	*Number of hours of SRS*
1	*Preparation for classroom classes* *Literary sources: [1-6 , 7 , 10]*	*26*
2	*Execution of DKR* *Literary sources: [10]*	*5*
3	*Preparation for MKR* *Literary sources: [7]*	*5*
4	*Preparation for the exam*	*30*
	In general	*66*

Control work

- *The purpose of the test is to consolidate and verify theoretical knowledge from the educational component, students to acquire practical skills of independent analysis of the type and consequences of a short circuit and calculation of current protection settings.*
- *The modular control work (MCW) is performed after studying Chapters 1-3. Each student receives an individual task, according to which 4 (four) problems must be solved.*

6. Policy and control Policy of educational discipline (educational component)

The system of requirements that the teacher sets before the student:

- *rules for attending classes: in accordance with Order 1-273 dated 14.09.2020, it is prohibited to evaluate the presence or absence of the winner at the classroom class, including the awarding of incentive or penalty points. According to the RSO of this discipline, points are awarded for passing laboratory work, performing homework and modular control work;*
- *rules of conduct in classes: the student has the opportunity to receive points for the appropriate types of educational activity provided for by the RSO of the discipline. The use of means of communication to search for information on the teacher's Google Drive, on the Internet, in a distance course on the Sikorsky platform is carried out on the condition that the teacher instructs;*
- *rules for the protection of individual tasks: the protection of homework control work in the discipline is carried out individually in accordance with the calendar plan for the implementation of the DKR;*

- *rules for assigning incentive and penalty points: incentive and penalty points are not included in the main scale of RSO, and their sum does not exceed 10% of the starting scale. Incentive points are awarded for participation in faculty and institute Olympiads and scientific conferences. Penalty points are charged for late execution of DKR.*
- *policy of deadlines and rescheduling: untimely execution of the DCR involves the accrual of penalty points. If the student did not pass or did not appear for the MKR, his result is evaluated at 0 points. Recompilation of MKR results is not provided for;*
- *policy on academic integrity: the Code of Honor of the National Technical University of Ukraine "Kyiv Polytechnic Institute" https://kpi.ua/files/honorcode.pdf establishes general moral principles, rules of ethical behavior of individuals and provides a policy of academic integrity for persons working and studying at the university, which they should be guided by in their activities, including when studying and preparing control measures for this discipline.*
- *when using digital means of communication with the teacher (mobile communication, e-mail, correspondence on forums and social networks, etc.), it is necessary to observe generally accepted ethical norms, in particular, to be polite and limit communication to the working hours of the teacher.*

7. Types of control and rating system for evaluating learning outcomes (RSO)

Current control *: MKR, DKR, submission of laboratory work .*
Calendar control *: is carried out once a semester as a monitoring of the current state of fulfillment of the syllabus requirements.*
Semester control *: exam*
Conditions for admission to the semester control *: a minimum positive grade for the DKR, all laboratory work completed and defended, a semester rating of more than 30 points.*
Table of correspondence of rating points to grades on the university scale:

Number of points	*Rating*
100-95	*Perfectly*
94-85	*Very good*
84-75	*Good*
74-65	*Satisfactorily*
64-60	*Enough*
Less than 60	*Unsatisfactorily*

The overall rating of the student after the end of the semester consists of points, received for:

- *performance and protection of laboratory work;*
- *performance of home control work (DKR);*
- *execution of modular control work (MCR).*
- *exam answers.*

Performance and protection of laboratory work	*DKR*	*MKR*	*Rs*	*Rec*	*R*
27	*8*	*25*	*60*	*40*	*100*

Performance and protection of laboratory work

For admission to the current laboratory work, each student must have a Protocol drawn up in accordance with the standards for the design of technical documentation, which must contain all the necessary points, in accordance with the Teaching Manuals for the laboratory practice [8, 9]. Laboratory work is performed in teams, calculation and analysis of the obtained results are carried out individually.

The weighted score is 3.0.
*The maximum number of points for all laboratory classes is 3.0 points * 9 = 27.0 points.*
Evaluation criteria

- the laboratory work is not completed or the protocol is not presented - it is returned for practice or revision - 0 points.

- *performance of laboratory work, independent performance of calculations, preparation of a research protocol, the answer to the defense question was given with significant errors - 1.8 points;*
- *performance of laboratory work, independent performance of calculations, preparation of the research protocol, the answer to the defense question was given with non -significant errors - 1.9 - 2.4 points;*
- *performance of laboratory work, independent performance of calculations, preparation of the research protocol, the answer to the defense question has inaccuracies - 2.5 - 2.9 points;*
- *performance of laboratory work, independent performance of calculations, preparation of research protocol, complete answer to questions on the topic of laboratory work - 3 points.*

WARNING! *Defense of all laboratory work is a condition for admission to the exam. Students who, at the time of the consultation before the exam, have not defended the laboratory work, are not allowed to take the main exam and are preparing for a retake.*

WARNING! *In order to be allowed to retake the exam, it is necessary to pass all laboratory work debts within the deadline set by the teacher.*

Individual semester task (SEC)

According to the curriculum, each student completes homework.
The maximum number of points for DKR performance is 8.0.

Evaluation criteria

- *complete, accurate and timely execution, complete answer to the question on the topic of DKR - 8.0 points;*
- *there are some insignificant errors - 5...7.8 points;*
- *the work is incomplete, there are some significant errors - 3.0...4.8 points;*
- *work done incorrectly - 0 points;*
- *4 weeks from the moment of issuing the task are allocated for the execution of the DKR; submission of the DKR after the set deadline implies the accrual of a penalty point of -0.2 for each week beyond the set deadline.*
-

Modular control work

The modular test consists of four practical tasks.
Weighted score of problems Nos. 1, 4 – 8.
Weighted score of problem No. 2 – 4.
Weighted score of problem No. 3 – 6.
The maximum score for MKR is 25.

Evaluation criteria

- *correct problem solving and - 100% of the number of points for the problem;*
- *partial solution of the problem, the presence of minor errors - 60-95% of the number of points for the problem;*
- *partial solution of the problem, the presence of significant errors - 10-55% of the number of points for the problem;*
- *no answer - 0 points.*

Calendar control is based on the current rating. A condition for a positive assessment is the value of the student's current rating of at least 50% of the maximum possible at the time of assessment.

The form of semester control is an exam

The examination paper consists of two theoretical questions
*Rating Rs ≥ 0.6*R, i.e. 60 points – is counted automatically.*
*Rating Rs within (0.4 - 0.59)*R, i.e. 40 - 59 points - students pass the exam.*
The maximum rating of the exam Rz = 40 points.

Evaluation criteria for each of the two theoretical examination questions

Rating of the task Rz = 20 points - the student gave comprehensive answers to the questions, gave clear definitions of all concepts and values, the answers were logical and consistent.
Rating of the task Rz = 16.5 – 19.5 points – the student gave comprehensive answers to the questions, gives clear definitions of all concepts and values, the answers are logical and consistent, but contain minor inaccuracies.
Rating of the task Rz = 12.5 – 16 points – when answering questions, the student makes individual mistakes, knows the definition of the main concepts and values of the discipline, and generally understands the physical essence of the processes in the objects he studied.
Rating of the task Rz = 8 – 12 points – the student partially answers the exam question, shows knowledge, but does not sufficiently understand the essence of the processes. The answers are inconsistent and unclear.
The rating of the task is R with ≤7.5 points - the student makes significant mistakes in the answer, shows a lack of understanding of the physical essence of the processes. The answers are incorrect, and in some cases do not correspond to the essence of the question.

Working program of the academic discipline (syllabus)
compiled by an associate professor of the Department of Power System Automation, Ph.D. Dmytrenko O.O.

Approved by the Department of Automation of Energy Systems of the FEA (protocol No. 8 dated 05/26/2024)
Agreed by the Methodical Commission of the faculty (protocol No. 10 dated 06/20/2024)