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

APPROVED:
Chairman of the Subject Commission
Guarantor of the educational program
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«24» «01» 2022

AGREED:
Vice-rector for educational work
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«28» «01» 2022

PROGRAM

ENTRANCE EXAMINATION

to obtain the degree of Doctor of Philosophy

specialty 141 Electric power engineering, electrotechnics and electromechanics

The program is recommended by academic councils of Faculty of Electric Power Engineering and Automatics, Educational and Scientific Institute of Energy Saving and Energy Management

Kyiv – 2022

I. GENERAL INFORMATION

The entrance exam for the degree of Doctor of Philosophy in the specialty 141 "Electric power engineering, electrotechnics and electromechanics" is conducted for those entrants who have a master's degree *.

The educational program " Electric power engineering, electrotechnics and electromechanics " corresponds to the mission and strategy of Igor Sikorsky KPI, according to which the strategic priority of the university is the fundamentalization of training. Features of the educational program are taken into account by selecting the appropriate sections of the entrance exam program. Conducting an entrance examination should reveal the level of preparation of the entrant in the chosen specialty for admission.

Theoretical questions of the entrance exam can be divided into seven sections:

1. Theoretical electrical engineering.
2. Technique of strong electric and magnetic fields.
3. Power plants, networks and systems
4. Electromechanical automation systems and electric drive
5. Electrical machines and devices
6. Unconventional and renewable energy sources
7. Systems of providing consumers with electric energy, electrotechnical complexes, electromechanical systems, automation of electrotechnical and electrotechnological complexes, energy management and energy efficiency.

The task of the entrance test consists of three theoretical questions. The examination ticket includes, respectively: 1 question from the first or second sections, 2 - from the third or fourth, 3 - from the fifth or sixth.

Entrance test in the specialty is conducted in the form of an oral exam.

The duration of the entrant's preparation for the answer is 2 academic hours.

The next section of the program lists only those topics from these sections that relate to the tasks of the entrance examinations.

Information on the rules of admission and requirements for entrants to the educational program " Electric power engineering, electrotechnics and electromechanics " is provided in the section "Admission to postgraduate program" on the website of graduate school and doctoral Igor Sikorsky KPI at the link https://aspirantura.kpi.ua/

* According to appendix 2 of Section XV of the Law on Higher Education higher education at the educational and qualification level of a specialist is equated to higher education with a master's degree

II. TOPICS SUBMITTED FOR THE ENTRANCE EXAMINATION

Section 1 Theoretical electrical engineering

Topic 1.1. Basic concepts of electromagnetic field and electric circuits

General characteristics of the problems of the theory of the electromagnetic field and the theory of electric and magnetic circuits. Basic equations of the electromagnetic field in integral form. Energy, forces and mechanical manifestations of electric and magnetic fields. The main parameters of electric and magnetic fields in integral form. Statement of problems of automated design of electrical devices.

Topic 1.2. Theory of linear electric circuits

Electrical and electronic circuits in energy and information transmission and conversion systems. Classification of circles and their elements. Bipolar and multipolar. Managed sources. Inductively coupled elements. Graphs and topological matrices of electrical circuits, topological equations. Ohm's law for the generalized branch, matrix component equations. Nodal and extended nodal equations, contour equations. Numerical methods for solving the equations of circles at steady states. Accurate and iterative methods. Gaussian method; decomposition of matrices into triangular factors; numerical methods of matrix rotation. Conditions of convergence of iterative methods. Calculation of input and transfer functions in symbolic form. Topological methods of analysis. Signal graphs and their application to the analysis of electrical circuits.

Multiphase circuits. Calculation of symmetric and asymmetric three-phase circuits. Method of symmetrical components.

Multipoles; matrix of multipoles. Basic equations of regular quadrupoles. Characteristic supports and transmission ratio. Substitute schemes of mutual and non-reciprocal quadrupoles. Connection of four-poles. Four-pole feedback. Features of formation of equations of circles with multipolar components. Hybrid equations. Resistor gyrators and converters.

Electrical circuits with inharmonic voltages and currents. Harmonic analysis of periodic functions. Current value and power. Signals and their spectra. Spectral density. Signal conversion by linear systems. Elements of filter theory. Reactive filters. Induction filters. Frequency characteristics and methods of their calculation.

Transients in linear circles. Analysis of dynamic processes in the time domain. The classic method. Features of calculation in the presence of capacitive circuits and inductive sections. Compilation and numerical methods for solving state equations. Discrete circuit models of circuit components and their application for numerical solution of state equations. Analysis of dynamic processes in the frequency domain. Application of Laplace and Fourier transforms to calculate

transients. Approximate and numerical methods of spectral analysis. Relationship between transient and frequency characteristics.

Elements of synthesis of linear circles. Properties of functions and methods of realization of bipolar and quadrupole passive electric circuits. Synthesis of inductive quadrupoles with active and non-reciprocal elements.

Circles with distributed parameters. Basic equations of long lines and their transportations for steady-state sinusoidal oscillations. Transients in circles with distributed parameters.

Topic 1.3. Theory of nonlinear electric circuits

Steady processes in nonlinear circles. Methods for calculating nonlinear electric and magnetic circuits at constant currents and voltages. Features of nonlinear alternating current circuits and methods of their calculation. Analysis of steady-state processes in nonlinear alternating current circuits. Formation and numerical methods for solving algebraic equations of nonlinear resistive electric circuits. Small parameter method.

Transients in nonlinear circles. Basic methods of analysis. Asymptotic methods. Perturbation method. Harmonic balance method and frequency properties of nonlinear circuits. Phase plane. State variable method. Numerical methods for solving nonlinear equations of state. Methods of implicit integration. Discrete models of nonlinear reactive elements and their application for calculation of dynamic processes.

Self-oscillation. Almost harmonic oscillations. Relaxation oscillations. Stability. Energy ratios. Machine method for calculating periodic and self-oscillating modes.

Basic vectors and basic equations of the electromagnetic field. Systems of Maxwell's equations. Electrodynamic potentials. Boundary conditions. Energy. Condition-Pointing Theorem. Gauss's theorem.

Static fields. Basic equations of electric and magnetic static field. Boundary value problems and methods of their solution, Method of conformal transformations and method of separation of variables. Numerical methods for solving boundary value problems: grid method, finite element method. Method of integral equations of potential theory and its numerical realization. Capacity, capacitance and potential coefficients.

Stationary electric and magnetic fields. Basic field equations. Differential form of the laws of Ohm, Lenz-Joule, Kirchhoff. Similarity of static and stationary fields. Vector magnetic potential. Flow inoculation. Own and mutual inductance. Application of the method of integral equations.

Alternating electromagnetic field in a conductive medium. Waves in conductive media. Surface effect. Penetration of the magnetic field into the ferromagnet array for the rectangular magnetization characteristic. Modeling of variable fields in conducting environments.

Electromagnetic waves and radiation. Wave equation and its solution. Harmonic waves in an ideal dielectric. Reflection of electromagnetic waves.

Waves in space bounded by leading boundaries. Waveguides and resonators. Types of waves. Phase and group speed. D'Alembert's equation. Radiation of quantum generators. Electromagnetic fields in real dielectrics, ferromagnets and anisotropic media. Complex parameters of the environment.

Numerical methods for calculating nonstationary fields. Electromagnetic fields in moving media. Basic equations of magnetic hydrodynamics.

REFERENCES TO SECTION 1

1. Boyko V.S. Teoretychni osnovy elektrotekhniky: V 3-kh t. Pidruchn. dlya stud. elektrotekhn. spetsial′n. vyshchykh zakl. osv. Tom 1 / V.S. Boyko, V.V. Boyko, YU.F. Vydolob [ta in.]; za zah. red. I.M. Chyzhenka, V.S. Boyka.– K.: IVTS «Politekhnika», 2004. – 272 s.
2. Boyko V.S. Teoretychni osnovy elektrotekhniky: V 3-kh t. Pidruchn. dlya stud. elektrotekhn. spetsial′n. vyshchykh zakl. osv. Tom 2 / V.S. Boyko, V.V. Boyko, YU.F. Vydolob [ta in.]; za zah. red. I.M. Chyzhenka, V.S. Boyka. – K.: IVTS «Politekhnika», 2008. – 224 s.
3. Boyko V.S. Teoretychni osnovy elektrotekhniky: V 3-kh t. Pidruchn. dlya stud. elektrotekhn. spetsial′n. vyshchykh zakl. osv. Tom 3 / V.S. Boyko, V.V. Boyko, YU.F. Vydolob [ta in.]; za zah. red. I.M. Chyzhenka, V.S. Boyka. – K.: IVTS «Politekhnika», 2013. – 244 s.
4. Osnovy teoriyi elektromahnitnoho polya. Kurs lektsiy [Elektronnyy resurs] : navch. posib. dlya stud. cpetsial′nosti 141 «Elektroenerhetyka, elektrotekhnika ta elektromekhanika», spetsializatsiyi «Elektromekhanichni systemy avtomatyzatsiyi ta elektropryvod, elektromobil′nist′» / KPI im. Ihorya Sikors′koho, uklad. L. YU. Spinul. – Kyyiv : KPI im. Ihorya Sikors′koho, 2020. – 102 s.

Section 2 Technique of strong electric and magnetic fields

Topic 2.1. Electrophysical foundations of strong electric and magnetic fields

Formation and neutralization of charged particles in the gas. The motion of charged particles in a gas. Condition of discharge independence in gas. Initial voltages of intervals with homogeneous and inhomogeneous electric field. Avalanche breakdown theory of Townsend-Rogovsky. Pashen's law. Streamer breakdown theory. Features of breakdown of long air gaps, leadership process. Characteristics and features of SF6 application. Overlapping solid insulation in the air. Ways to increase the floor voltage of insulating structures. DC corona discharge. Crown losses on the power line. Radio interference from corona discharge. Electrical conductivity of liquids in strong electric fields. Pre-discharge processes in liquids. Ignition discharge. Dynamics of pulse discharge in liquids. Breakdown of liquid dielectrics with impurities. Theory of thermal breakdown of solid dielectrics. Theory of electric breakdown of solid dielectrics. Breakdown of inhomogeneous solid dielectrics. Partial discharges. Aging insulation. Discharge on the contaminated and moistened surface of the insulator.

Topic 2.2. Lightning surges and lightning protection of electrical installations

Characteristics and parameters of lightning discharges. Lightning protection grounding. Methods of calculation and modeling. Induced overvoltages on overhead lines. Overvoltages of direct lightning strike in power lines. Protection against direct lightning strikes. Lightning protection zones. Methods for determining the probability of lightning breakthrough. Wave propagation in a line. Refraction and reflection of waves in power lines. Influence of pulse corona on wave processes in power lines. Lightning protection of substations. Tubular and valve arresters. Nonlinear surge arresters. Number of thunderstorms of overhead power lines, APV. Indicator of lightning resistance of substations. Lightning protection of overhead power lines.

Topic 2.3. Internal overvoltages in electrical systems and their limitations

Internal overvoltages in networks with isolated neutral. The role of arc suppressors. Overvoltages when unloaded lines are switched off. Overvoltages when unloaded transformers are switched off. Resonant overvoltages in power lines. Limitation of internal overvoltages. Statistical characteristics of internal overvoltages. Estimated multiplicity of internal overvoltages.

Topic 2.4. Insulation of high voltage installations and high voltage test installations

Methods of electric field regulation in insulating structures. Insulation of overhead power lines. The main types of internal insulation. Short-term and long-term electrical strength. Isolation of power transformers. Insulation of power cables. Isolation of power capacitors. Insulation of rotating electric machines. High voltage inputs. External insulation tests. Internal insulation tests. Diagnosing internal insulation. Transformer installations for insulation testing. Test high-voltage direct current installations. Pulse voltage generators. Methods of generating switching pulses.

Topic 2.5. Technique of high voltages and high currents

Measurement of high voltage pulses. Voltage dividers. Measurement of high DC and AC voltage. Measurement of large pulse currents. Measurement of capacitance and angle of dielectric losses. High-precision pulse discharges and their application. Charging of macroscopic particles and their motion in an electric field. Electrostatic precipitators and electroseparators. Ecological factors of ultra-high voltage overhead and cable lines.

REFERENCES TO SECTION 2

1. Brzhezyts′kyy V.O., Isakova A.V., Rudakov V.V. ta in. Tekhnika i elektrofizyka vysokykh napruh: Navch. posibnyk / Za red. V.O. Brzhezyts′koho ta V.M. Mykhaylova. – Kharkiv: NTU «KHPI» – Tornado, 2005. 930 s.

2. Sobchuk V.S. Tekhnika ta elektrofizyka vysokykh napruh: navchal′nyy posibnyk– Vinnytsya, VNTU, 2003. – 85 s.

3. Tekhnika vysokykh napruh: navchal′nyy posibnyk / MON MS Ukrayiny; Maystruk E. V., uklad. – Chernivtsi: Chernivets′kyy natsional′nyy universytet, 2012. – 128 s.

4. Tekhnika vysokykh napruh: Kurs lektsiy [Elektronnyy resurs] : navch. posib. dlya stud. spetsial′nosti 141 «Elektroenerhetyka, elektrotekhnika ta elektromekhanika» / KPI im. Ihorya Sikors′koho ; uklad.: V. B. Abramov, V. O. Brzhezyts′kyy, YA. O. Haran, O. R. Protsenko – Kyyiv : KPI im. Ihorya Sikors′koho, 2021. – 345 s.

5. Elektrotekhnolohichni ustanovky ta systemy. Kurs lektsiy [Elektronnyy resurs] : navchal′nyy posibnyk dlya studentiv spetsial′nosti 141 «Elektroenerhetyka, elektrotekhnika ta elektromekhanika», osvitn′oyi prohramy «Elektrotekhnichni prystroyi ta elektrotekhnolohichni kompleksy» / KPI im. Ihorya Sikors′koho ; uklad.: V. O. Brzhezyts′kyy, YA. O. Haran, M. YU. Laposha, YE. O. Trotsenko. – Kyyiv : KPI im. Ihorya Sikors′koho, 2020. – 136 s. – Nazva z ekrana.

Section 3 Power plants, networks and systems

Topic 3.1. Power plants

Features of the technological mode of power plants of different types.

Features of the main schemes and schemes of own needs of power plants of different type.

Modes of operation of synchronous generators and their excitation systems. Modes of operation of synchronous motors and their excitation systems. Modes of operation of electric motors of own needs of power plants under normal and abnormal conditions.

Modes of operation of synchronous compensators and their excitation systems.

Control, monitoring and signaling systems at power plants and substations. Earthing devices of electrical installations.

Symmetrical and asymmetrical short circuits. Complex types of damage. Drawing up substitution schemes for calculations. Applicable assumptions.

Methods for assessing the reliability of electrical wiring diagrams of electrical installations.

Practical methods for calculating short-circuit currents. Modern theory of stability. The concept of the first and second (direct) methods of Lyapunov. Practical criteria of static stability.

The development of the process in time with large and small perturbations.

Stability of modes of complex systems. Dynamic stability of electrical systems. Transients and stability of electrical networks, which are connected by weak connections.

Methodical and normative instructions on the analysis of transients and stability of electric systems.

Measures to improve the stability and quality of transients of electrical networks. Emergency control to maintain stability.

Transients at short circuit in networks containing long lines, longitudinal compensation installations, linear and nonlinear control elements.

Simplified criteria for dynamic and resulting stability of the simplest electrical network. Static stability of the system with regulated excitation. Transients in load nodes at small and large perturbations. Automatic excitation regulators for synchronous generators.

REFERENCES TO SECTION 3, TOPIC 3.1

1. Proektuvannya elektrychnoyi chastyny elektrychnykh stantsiy ta pidstantsiy: CH. 1 [Elektronnyy resurs] : navchal′nyy posibnyk / NTUU «KPI» ; uklad. YE. I. Bardyk, P. L. Denysyuk, YU. V. Bezberezh″yev. – Kyyiv : NTUU «KPI», 2011.
2. Proektuvannya elektrychnoyi chastyny elektrychnykh stantsiy ta pidstantsiy. CH. 2 [Elektronnyy resurs] : navchal′nyy posibnyk / NTUU «KPI» ; uklad. YE. I. Bardyk, P. L. Denysyuk, YU. V. Bezberezh″yev. – Kyyiv : NTUU «KPI», 2012.
3. Haryazha V. M. Konspekt lektsiy z kursu «Elektrychna chastyna stantsiy ta pidstantsiy» (chastyna 1) (dlya studentiv dennoyi ta zaochnoyi form navchannya spetsial′nosti 141 – Elektroenerhetyka, elektrotekhnika ta elektromekhanika) / V. M. Haryazha, A. O. Karyuk; Kharkiv. nats. un-t mis′k. hosp-va im. O. M. Beketova. – Kharkiv : KHNUMH im. O. M. Beketova, 2018. – 149 s.
4. Kazans′kyy, S. V. Nadiynist′ elektroenerhetychnykh system [Elektronnyy resurs] : navchal′nyy posibnyk / S. V. Kazans′kyy, YU. P. Mateyenko, B. M. Serdyuk ; NTUU «KPI». – Kyyiv : NTUU «KPI», 2011. – 216 s.

Topic 3.2. Electrical systems and networks

Schemes of replacement of elements of electric networks. Calculation schemes of electrical systems. Consolidated and calculated load.

Power and energy losses in lines and transformers and their determination according to load and time schedules of the largest losses.

Calculation of voltage mode in electrical networks of systems. Voltage drop and voltage loss.

The main methods of calculating the modes of operation of complex electrical networks. Nodal potential method. The method of cutting contours. Methods for solving the equations of the steady state electric network. Iterative methods: simple iteration, Seidel method, Newton-Rafson method.

The concept of the power system. Local and system-wide parameters of electrical systems. Classification of modes of electric power systems. Requirements for modes of electric power systems.

Characteristics of idealized power transmission power. Transmission capacity. Static stability of power transmission. Circular diagrams of power transmission.

Dynamic stability of power transmission. Criteria for dynamic stability of power transmission. Cascade accidents and survivability of power systems.

Heterogeneity of electrical networks. Factors that determine the heterogeneity of electrical networks. Manifestations of heterogeneity of electrical networks. Ways to compensate for the heterogeneity of electrical networks.

Long-distance power transmission. Ways, methods and means to increase the capacity and efficiency of long-distance power transmission.

Analytical and graphoanalytical methods of analysis of long-distance power transmission modes of operation. Artificial measures to increase the capacity and range of alternating current transmission.

Long-distance direct current power transmission. Technical and economic indicators of long-distance transmission on alternating and direct currents, their comparison and prospects of application.

Voltage regulation and economic modes of electrical systems. Quality of electric energy and its characteristics. Voltage deviations and fluctuations, causes of their occurrence, limit values, influence on the operation of electric receivers.

Means and methods of voltage regulation in electrical networks of power systems. Calculation of parameters of compensating devices. Voltage avalanche. Selection of the place of installation of longitudinal and transverse compensation compensating devices in the network.

Transformer means of voltage regulation in electric networks of power system. The concept of counter voltage regulation. Voltage regulation schemes with the help of autotransformers. Longitudinal and transverse voltage regulation by means of booster transformer.

Balance of active and reactive power and quality of electricity in systems. Balance and reserve of active power in power systems. Frequency regulation in power systems. Primary frequency control, shortcomings of primary control. Secondary frequency control. Frequency control in emergency modes. The concept of automatic frequency unloading and frequency automatic reconnection systems. Features of frequency control in integrated power systems.

REFERENCES TO SECTION 3, TOPIC 3.2

1. Elektrychni systemy i merezhi. Chastyna 1 [Elektronnyy resurs] : navchal′nyy posibnyk / YU. V. Malohulko, O. B. Burykin, T. L. Katsadze, V. V. Netrebs′kyy ; Vinnyts′kyy natsional′nyy tekhnichnyy universytet ; za red. P. D. Lezhnyuka. – Vinnytsya : VNTU, 2020. – 200 s.

2. Analiz ta syntez system peredachi elektrychnoyi enerhiyi postiynoho strumu [Elektronnyy resurs] : navchal′nyy posibnyk dlya studentiv spetsial′nosti 141

«Elektroenerhetyka, elektrotekhnika ta elektromekhanika», osvitn′oyi prohramy «Elektrychni systemy i merezhi» / KPI im. Ihorya Sikors′koho; uklad. V. V. Kyryk. – Kyyiv : KPI im. Ihorya Sikors′koho, 2021. – 59 s.

3.Elektrychni merezhi ta systemy. Rezhymy roboty rozimknenykh merezh [Elektronnyy resurs] : navchal′nyy posibnyk dlya studentiv usikh form navchannya ta studentiv-inozemtsiv napryamu pidhotovky 6.050701 "Elektrotekhnika ta elektrotekhnolohiyi" / NTUU «KPI» ; uklad. V. V. Kyryk. – Kyyiv : Politekhnika, 2014. – 130 s.

4. Katsadze, T. L. Elektrychni systemy ta merezhi. Chastyna 2. Rozrakhunok ta analiz ustalenykh rezhymiv elektroenerhetychnykh system [Elektronnyy resurs] : materialy lektsiy / Katsadze T. L. – 2016. – 284 s.

5. Suleymanov V. M. Elektrychni merezhi ta systemy: pidruchn. / V. M. Suleymanov, T. L. Katsadze. – Kyyiv: NTUU «KPI», 2008. – 456 s. – ISBN 978-966-622-300-8.

6. Katsadze, T. L. Ekspertni systemy pryynyattya rishen′ v enerhetytsi [Elektronnyy resurs] : navchal′nyy posibnyk / T. L. Katsadze ; NTUU «KPI». – Kyyiv : LOHOS, 2014. – 175 s.

Topic 3.3. Electricity generation and distribution control systems

Topic 3.1 Automatic regulation in power systems

Balance of active power and frequency of alternating current. Types of frequency and active power control. Primary frequency control. Turbine speed regulators.

Static frequency characteristics of the generating part of the power system. Static frequency response of consumption. Combined static frequency response of the generating part of the power system and consumption. Regulating load effect.

Secondary frequency and active power control. Organization of automatic frequency and power control (AFPC) in the power association. System part of AFPC. Operating modes of system AFPC. Methods of frequency and active power control. The method of the station that conducts the mode.

Voltage and reactive power regulation in power systems. Means of voltage regulation in power systems. Flexible AC transmission systems (FACTS systems). Stability criteria and quality indicators of regulation. The principle of automatic control. Typical regulators and their characteristics. Asynchronous mode in power systems. Signs of asynchronous mode. Ways to eliminate asynchronous mode.

Topic 3.2 Relay protection of electrical systems

Maximum current and non-directional protections. Primary measuring transducers in protection and automation systems. Relay protection of electrical systems, requirements and principles of operation. Functional and logical elements of automatic devices. Information sensors in relay protection and automation systems. Redundancy of relay protection and switches. Measuring bodies and logical part of relay protection systems.

Protection of electric motors. Protection of transformers of power plants and substations. Protection of synchronous generators. Generator-transformer unit protection. Relay protection of busbars of stations and substations. Automatic frequency unloading (AFU), purpose and principle of operation. Automatic restart (AR), purpose and principle of operation. Automatic backup power on (ABP), purpose and principle of operation.

REFERENCES TO SECTION 3, TOPIC 3.3

1. Yandul′s′kyy, O. S. Matematychne modelyuvannya system ta protsesiv. Matematychne zabezpechennya mikroprotsesornykh prystroyiv releynoho zakhystu i avtomatyky elektroenerhetychnykh system [Elektronnyy resurs] : navchal′nyy posibnyk / O. S. Yandul′s′kyy, O. O. Dmytrenko; pid zah. red. O. S. Yandul′s′koho ; NTUU «KPI». – Kyyiv : NTUU «KPI», 2016. – 60 s.
2. Yandul′s′kyy, O. S. Releynyy zakhyst. Tsyfrovi prystroyi releynoho zakhystu, avtomatyky ta upravlinnya elektroenerhetychnykh system [Elektronnyy resurs] : navchal′nyy posibnyk / O. S. Yandul′s′kyy, O. O. Dmytrenko ; NTUU «KPI». – Kyyiv : NTUU «KPI», 2016. – 103 s.
3.Yandul′s′kyy O.S., Stelyuk A.O., Lukash M.P. Avtomatychne rehulyuvannya chastoty ta peretokiv aktyvnoyi potuzhnosti v enerhosystemakh / Pid zahal′noyu redaktsiyeyu d.t.n. O.S. Yandul′s′koho. – K.: NTUU «KPI», 2010. – 88 s.
4. Obchyslyuval′ni metody ta alhorytmizatsiya: komp'yuternyy praktykum [Elektronnyy resurs] : navchal′nyy posibnyk dlya studentiv spetsial′nosti 141 «Elektroenerhetyka, elektrotekhnika ta elektromekhanika», spetsializatsiyi «Upravlinnya, zakhyst ta avtomatyzatsiya enerhosystem» / KPI im. Ihorya Sikors′koho ; uklad.: O. V. Khomenko, H. O. Trunina, O. O. Dmytrenko. – Kyyiv : KPI im. Ihorya Sikors′koho, 2019. – 89 s.
5. Releynyy zakhyst i avtomatyka: Navch. posibnyk / S. V. Panchenko, V. S. Blyndyuk, V. M. Bazhenov ta in.; za red. V. M. Bazhenova. – Kharkiv: UkrDUZT, 2020. – CH. 1. – 250 s.
6. Releynyy zakhyst i avtomatyka: Navch. posibnyk / S. V. Panchenko, V. S. Blyndyuk, V. M. Bazhenov ta in.; za red. V. M. Bazhenova. – Kharkiv: UkrDUZT, 2021. – CH. 2. – 276 s.

Section 4 Electromechanical automation systems and electric drive

Classification of automation devices, their main features. Automatic control systems (ACS), functional diagram of ACS and its elements. Stabilization systems, software control, tracking. Open ACS: Compensation and Software Management. Combined control. General information about the elements of ACS. Feedback in ACS. Feedback and gain.

Conditions of equilibrium of ACS. Static characteristics at serial and parallel connection of links. Characteristics of links with feedback. Static error and gain. Contradictions between the requirements of statics and dynamics. Static error in combined control. Forms of writing static equations.

Compilation of equations of dynamics of links. Methods of compiling equations. The principle of detection. Vyshnegradsky's small deviation hypothesis. Linearization methods. Forms for writing dynamics equations. Operator form, etc. Typical links of CAP. Equations and time characteristics of links.

Transfer functions, frequency characteristics of links. Assignment of transfer functions and frequency characteristics. Transfer functions and amplitude-phase frequency response at serial and parallel connection of links, for links with feedback. Logarithmic frequency characteristics, their features and purpose, construction of logarithmic characteristics. Amplitude-phase frequency response and logarithmic characteristics of typical units.

Equations, transfer functions and amplitude-phase frequency response of control systems. The equation of open CAP, its transfer functions and amplitude-phase frequency response. Equation of single-loop closed stabilization system. Obtaining the equation of a closed ACS by Cramer's theorem. Equation of software (tracking) CAP. Obtaining the equation of statics CAP. Transfer functions and amplitude-phase frequency response SAR on the task and perturbation. Transformation of complex block diagrams of closed CAP. Schemes with simple and cross feedback.

The concept of stability of linear systems. Lyapunov's theorems. Analysis of stability by the type of roots of the characteristic equation. The limit of stability in the plane of the roots. Criteria of stability. Algebraic criteria of Raus-Hurwitz, Vyshnegradsky. Frequency criteria: Mikhailov, D-partition, Mikhailov-Nyquist. Stability analysis using amplitude and phase frequency characteristics. Analysis using logarithmic characteristics. Finding critical values of parameters and determining the margin of safety using various criteria.

Investigation of stability of systems with transport delay. Structurally unstable CAP. Examples. Consecutive and parallel corrective links. Examples of adjustment of structurally unstable CAP.

CAP quality indicators. Features of quality analysis in linear systems. Quality analysis by type of roots of the characteristic equation. The degree of attenuation of transients. Synthesis problems. Methods of synthesis of serial and parallel correcting devices. Use of logarithmic characteristics.

General information about invariance. The invariance of the SAC with respect to the perturbing effect. Implementation of invariance requirements.

The main types of nonlinearities. Methods and research of nonlinear systems. Method of phase trajectories. The concept of the phase plane. Special points. Phase trajectories of stable and unstable systems. Research methodology. Lyapunov stability. The concept of boundary cycles. Harmonic linearization method. Relay CAP. Using the method of phase trajectories for the analysis of relay systems.

Discrete systems, their classification. Differential equations, transformations, transfer functions of pulse systems. Frequency characteristics of discrete systems. Methods for studying the stability of pulse systems (Hurwitz,

Mikhailov, Nyquist test, etc.) Synthesis of discrete correcting devices by the method of logarithmic pseudo-frequency characteristics.

Extreme SAC. Features and limits of application. The concept of utility function and optimal management.

General information about the electric drive. Purpose, features, tasks. Types of electric drives. Functional diagram of the electric drive.

Mechanical part of the electric drive. Kinematic and calculation schemes. Static loads. Accounting for losses. Equation of motion.

DC electric motors. Electromechanical characteristics. Natural characteristic. Types of artificial characteristics. Braking modes. Dynamic properties. Characteristics of DC motors with serial, mixed or combined excitation.

Asynchronous electric motors. Obtaining mechanical characteristics. Slip. Natural mechanical characteristics. Types of artificial characteristics. Braking modes. Construction of artificial characteristics. Dynamic properties.

Synchronous electric motors. Principle of action. Angular characteristic. Braking modes. Dynamic properties. Advantages and disadvantages.

Electromechanical system. Equations and block diagram. Dynamic properties.

Optimal transients: in terms of speed, power consumption with limited torque, acceleration or jerk. Practice of step control and disturbing influence. Smooth start. Reverse. Features of transients for AC motors.

Thermal transients. Nominal modes of electric motors. Methods of equivalent current, torque, power. Engine power selection.

Electric drive coordinate adjustment. Types of control and main functions of EP. Frequency converter-asynchronous motor system. Precision. Adjustment range. Electric drive with subordinate coordinate control. Adjustment of the moment, current, speed.

REFERENCES TO SECTION 4

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Section 5 Electrical machines and apparatus

Topic 5.1. DC machines

Design and principle of operation of a direct current machine (DC). Switching processes in the DC machines. Ways to improve switching: additional poles, brush offset, etc. Compensation winding. Expressions for electromotive force (EMF) and electromagnetic moment of the DC machines. The phenomenon of the anchor reaction and its effect on the magnetic flux of excitation. Traction DC machines. Performance characteristics of the traffic police with sequential excitation.

Topic 5.2. Transformers

Structure and principle of operation of the transformer. Classification of transformers. Transformation coefficient. Design of windings and magnetic circuit of three-phase transformers. Higher harmonics in the curve of magnetizing current, magnetic flux and phase EMF of three-phase transformers with different ways of connecting primary and secondary windings. Modes of non-working (idling) and short circuit of transformers. Short-circuit voltage and idling current. Losses in idling and short circuit modes. Experimental determination of parameters of the substitution scheme. Operation of transformers under load. Fundamentals of mathematical equations. Transformer replacement schemes. Vector and energy charts. Determination of transformer efficiency.

Topic 5.3. General questions of the theory of alternating current machines

Design of alternating current machines. Insulation of windings. Conditions for obtaining a rotating magnetic field in AC machines. Magnetic field of alternating current machines and its calculation. Inductance and mutual inductance of windings. Magnetic fluxes of mutual induction and scattering of windings. Electromotive forces of the coil, coil, phase of the AC winding. Winding coefficients. Ways to reduce higher harmonics in EMF. Bevel grooves. Magnetomotive forces of AC windings of machines. Higher harmonics of MRS.

Topic 5.4. Asynchronous machines

Equation of electrical circuits of stator and rotor windings. Bringing the rotor winding to the stator winding. Asynchronous machine replacement scheme. Operating modes of asynchronous machine: motor, generator, electromagnetic brake. Vector and energy charts. Methods of speed control of induction motors.

Autonomous asynchronous generator. Conditions of self-excitation. Asymmetric modes of operation of asynchronous machines. Influence of power voltage asymmetry and winding parameters on mechanical characteristics of induction motors.

Topic 5.5. Synchronous machines

Synchronous machine in idle mode. Requirements for the distribution of the magnetic field in the air gap. The phenomenon of the anchor reaction in a synchronous machine and the factors that affect it. Parallel operation of a synchronous generator with the network. Conditions and methods of switching on a synchronous generator for parallel operation, V - similar characteristics, regulation of active and reactive power of synchronous machine. Angular characteristics of a synchronous machine. Static and dynamic stability of the synchronous machine. Synchronous motor and synchronous compensator. Ways to start. Vector charts. Working and V - similar characteristics. Transient, asynchronous and asymmetric modes of operation of a synchronous machine. Inductive impedances of a synchronous machine in transient and asymmetric modes of operation.

Topic 5.6. Electrical appliances

Electrodynamic forces in electrical devices. Thermal processes in electrical appliances. Electrical contacts: definition and classification, their resistance, materials, contact heating, electrodynamic forces in contacts. Designs of low-voltage and high-voltage switching contacts. Electric arc and methods of its extinguishing. The selection of switching devices: general conditions for the selection of electrical devices. Protective devices: fuses and their choice, protective switching device, surge arresters and limiters, current-limiting reactors.

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Haydenko, M. A. Kovalenko ; KPI im. Ihorya Sikors′koho. – Kyyiv : KPI im. Ihorya Sikors′koho, 2017. – 200 s.

Section 6 Unconventional and renewable energy sources

Topic 6.1. Wind energy

The main parameters of wind flow and means of their description in time and space. Types of wind turbines and wind turbines. Their advantages and disadvantages. The main provisions of aeromechanical calculation of wind turbines. Features of electrical circuits of DC wind turbines and their use. Features of electrical circuits of AC wind turbines and their use. Typical modes of operation of wind turbines (start, nominal mode, stop) and algorithms for their implementation. Methods and technical means of stabilizing the speed of wind turbines.

Topic 6.2. Solar energy

The main parameters that characterize the flow of solar energy. Electrodynamic approaches to the description of the interaction of solar radiation with the atmosphere and structural elements of solar collectors and photovoltaics. Basic designs of solar collectors and photovoltaics. Models of electromotive force generation in photoelectric converters. Models of heat generation during the interaction of solar radiation with the elements of solar collectors and photovoltaics. Models of the thermal state of solar collectors and photovoltaics. Structures and schemes of active and passive systems of solar heat supply of buildings and constructions. Features of solar energy systems using concentrated solar radiation.

Topic 6.3. Conversion and accumulation of energy from renewable sources

The principle of operation of chemical current sources. Schemes of use of electric accumulators in power supply systems. The main types of electrochemical batteries of electric energy. Schemes of use of heat accumulators in heat supply systems. Principles of calculation of thermal and electric energy accumulators.

Topic 6.4. Integrated use of renewable energy sources

Energy technology units. Methods of optimization of parameters of combined heat supply systems. requirements for combined energy supply systems. Principles of construction of combined power supply systems.

Topic 6.5. Use of geothermal resources

Basic parameters of geothermal energy. Methods of modeling geothermal reservoirs and wells. Variants of geothermal energy use schemes for power supply needs. Typical schemes of geothermal resources extraction.

Topic 6.6. Use of other types of renewable energy sources

The principle of operation of power plants that use energy for small years. The principle of operation of wave power plants. The principle of operation of bioenergy plants. The principle of operation of power plants that use temperature and concentration gradients in seawater. The principle of operation of magnetohydrodynamic generators. The principle of operation of heat emission generators. The principle of operation of thermoelectric generators and thermal refrigerators. The principle of operation of compressor and absorption heat pumping units.

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2. Netradytsiyni ta vidnovlyuvani dzherela enerhiyi: pidruchn. / S. O. Kudrya. – K. : NTUU «KPI», 2012. – 492 s.
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4. Atlas enerhetychnoho potentsialu vidnovlyuvanykh dzherel enerhiyi Ukrayiny / S. O. Kudrya, V. F. Ryeztsov, T. V. Surzhyk ta inshi. − Kyyiv: Instytut vidnovlyuvanoyi enerhetyky NAN Ukrayiny, 2012. – 60 s. Vydano v 2013 r..

Section 7 Electric energy supply systems, electrotechnical complexes, electromechanical systems, automation of electrical and electrotechnological complexes, energy management and energy efficiency

Topic 7.1. Characteristics of energy complexes and systems

7.1.1 Energy management and its elements. The main types of fuel and energy resources, their classification.

7.1.2 Electricity. Nuclear energy. Heat supply.

7.1.3 Economic aspects of energy. Energy as a natural monopoly. Methods of formation of prices and tariffs for fuel and energy. Taxes and investments in energy. Influence of price and tax factors on fuel and energy consumption. Methods of economic regulation in energy.

Topic 7.2. System research in power engineering

7.2.1. Power engineering as an object of systems research. Basic concepts of systems research. Hierarchy of large energy systems.

7.2.2 Properties of energy systems. Reliability of energy systems and complexes.

7.2.3 Mathematical apparatus of systems research in energy. Probabilistic

methods and their scope in energy. Theory of optimal control. Statistical modeling. Mathematical economics.

7.2.4 The main directions of development of power systems within the Smart Grid concept. Principles of construction and application of smart-systems for measuring, accounting and managing the use of electricity.

Topic 7.3. Fuel and energy balance

7.3.1 The concept of a single energy balance. Fuel and energy balance and separate balances of fuel and energy resources by type. Graphic diagrams to study the structure of fuel and energy balances.

7.3.2 Structure and trends of energy consumption. Methodical approaches to forecasting energy consumption. Indicators of energy intensity of energy consumption objects and their analysis.

Topic 7.4. Economic and mathematical modeling of energy systems and complexes

7.4.1 Technical and economic calculations of energy systems and complexes. The structure of capital investments and operating costs of the fuel and energy complex and its technological systems. Prices and final costs for fuel and energy resources. Losses from energy shortages and environmental pollution. Consideration of reliability in the optimization of energy systems, assessment of technical risks of innovative developments.

7.4.2 Multilevel system of models for optimizing the development of the fuel and energy complex. Choosing a rational number of levels of hierarchy in the system of models. Stages of indicative planning and forecasting. Types of economic and mathematical models for optimizing the structure of the fuel and energy complex.

7.4.3 Modeling of optimal development of fuel and energy complex taking into account reliability. The task of optimal redundancy of the structure of the fuel and energy complex and its technological systems, taking into account the interchangeability of energy. Nodal standards of reliability of power supply. Survival of energy systems and complexes.

Topic 7.5. Purpose and characteristicsof electrical complexes

7.5.1 Efficiency of electricity use and its conversion into other types of energy in the implementation of technological processes.

7.5.2 Features of construction and operation of electromechanical, electrothermal, electric welding, electrochemical, electrospark, electrostatic, magnetostatic and magnetodynamic installations.

7.5.3 General characteristics of automated process control systems.

Topic 7.6. Elements of electrotechnical complexes

7.6.1 Electromechanical converters. Reactors for AC and DC circuits.

7.6.2 Uncontrolled AC rectifiers. Controlled thyristor rectifiers of single- and three-phase current. Current and voltage inverters. Resonant inverters.

Thyristor and transistor AC frequency converters. Semiconductor AC converters. Voltage and current stabilizers. Pulse width converters. Pulse-phase control systems. Magnetic thyristor voltage converter. Active filters. Filter-compensating devices. Electromechanical devices of automated electric drives. Sensors and coordinators of the electric drive. Batteries and energy storage devices for power supply (electrochemical, electrical, electromechanical): construction, principle of operation and main indicators.

7.6.3 Switching elements and their characteristics. Disconnectors and high voltage switches. Switching current source switches. Semiconductor and superconducting current switches. Integrated modules and microprocessors.

Topic 7.7. Electromechanical systems

7.7.1 General functional diagram of the electromechanical system. Characteristics of typical loads of adjustable electric drives. Calculation schemes and mathematical models of the mechanical part of electric drives. Equation of motion. Modes of operation of electric drives. Modes of operation of mechatronic pulse systems.

7.7.2 Structural diagrams, regulating properties, dynamics indicators of dynamics and statics of typical structures of electromechanical systems on the basis of electric drives of direct and alternating current according to the scheme "controlled converter-motor". "Controlled converter-motor" systems in DC and AC electric drives and features of torque (current) and speed control in systems: "controlled converter - DC motor", "generator-motor", frequency converter - asynchronous (synchronous) motor, "Thyristor voltage regulator - induction motor".

7.7.3 Block diagram and mathematical model of the mechatronic system of the technological complex. Electro-hydraulic control systems with adaptive functions. Design properties, characteristics and modes of operation of the electrohydraulic drive of the mechatronic system. Systems such as "executive body - working environment" in mechatronic systems with intelligent control. Statistical modeling of electromechanical systems and complexes.

7.7.4 Systems of subordinate control of coordinates of electromechanical systems, manipulators and executive bodies of complexes.

7.7.5 Tracking electric drive and electric hydraulic drive. Sliding mode of the following electric drive with the relay regulator. Mechatronic control of the electric hydraulic drive.

7.7.6 Dynamic modes of operation of electric drives and electric hydraulic drives. Dynamics of electromechanical systems with rigid and elastic kinematic connection.

7.7.7 Established modes of operation of electric drive and electric hydraulic drive.

7.7.8 Methods of analysis of dynamic properties of electromechanical systems. Transmitting and transient functions of electromechanical systems and their elements.

7.7.9 Equation of motion of electric hydraulic elements based on the

equations of Navier-Stokes, Bernoulli and the methods of D'Alembert and Lagrange.

7.7.10 Determination of loads in the nodes of kinematic systems of manipulators by the method of super-elements. Construction of external load plots and determination of reliability using strength theories.

7.7.11 Stability of linear and nonlinear systems. Algebraic criteria, frequency criteria, Lyapunov function, Popov criterion. Numerical methods for identifying nonlinear systems.

7.7.12 Methods of synthesis of linear, nonlinear and discrete automatic control systems with given quality indicators of dynamics and statics. Adaptive and robust automatic control systems, application of the principles of adaptive and robust control in electromechanical systems.

7.7.13 Microprocessor control of electromechanical systems. Microcontrollers. Programmable logic controllers. Signal processors.

Topic 7.8. Electromechanical and robotic systems and complexes

7.8.1Electromechanical converters in terms of functional electromechanics, energy and information subsystem of electromechanical converters.

7.8.2 Devices for conversion, diagnosis, protection of electromechanical transducers, their main functions and components.

Topic 7.9. Electrotechnological complexes

7.9.1 Classification of electrical installations as consumers of electricity.

7.9.2 Electrical installations of contact heating. Arc steelmaking ore thermal and plasma installations for heat treatment and melting of materials. Electric welding installations. Induction installations heating, deformation, surface hardening, zone melting, mixing, metered pouring and granulation of metals. Installations dielectric heating. Electropulse spark treatment plants environments. Electrobeam processing plants for highly reactive metals. Electrochemical installations. Magnetopulse and electrohydraulic installations. Electric and magnetic separators. Electric gas filters.

7.9.3 Modern systems and means of energy and resource saving in electrical installations.

Topic 7.10. Electrophysical installations

7.10.1 Electrophysical installations for creation of a magnetic field from given spatial-frequency structure and settings for it radiation. Magnetization and demagnetization installations. Devices and equipment for measurements, researches of electric, magnetic and thermal properties of materials. Hall effect sensors. Measurement of electrical resistance, conductivity, and based sensors effects that occur at the interface.

Topic 7.11. Power supply systems of technological and technical complexes

7. 11.1 Structure and general characteristics of systems power supply. Theoretical substantiation of the calculation load. Practical methods for determining the design load. Requirements for reliability of power supply. Defining the parameters of the elements power supply systems (power

transformers, mains voltage to and over 1000 V). Methods for calculating electricity losses in elements power supply systems, their scope. Organizational and technical measures to reduce electricity losses. The essence of the problem of compensation reactive power. Reactive power compensation in systems power supply of industrial enterprises. Electrical quality indicators energy and their rationing. Electromagnetic compatibility of electrical and electrical installations in the nodes of the load of electrical networks.

Topic 7.12. Autonomous power consumption systems for stationary and moving objects

7.12.1 Characteristics of energy sources, types and main parameters of primary converters of electric energy for autonomous power supply systems of stationary and mobile objects. Types of electric generatorandin and structures of systems of automatic control of electric generating installations with the heat power, wind and water engine. Electrochemical generators on fuel cells.

7.12.2 Hybridization of onboard power supplies for electric traction of moving objects and automatic control strategies. Autonomous power supply systems with renewable energy sources.

Topic 7.13. Automation of electrotechnological and electrotechnical complexes

7.13.1 Electromechanical automation systems in rolling production. Automation of forging and pressing machines. Electromechanical mining and automation equipment automation systems drilling rigs, Control systems for metal-cutting installations. Electromechanical automation systems for paper and cardboard production. Electromechanical route control systems electric vehicles, cranes and elevators. Pump automation, compressor and fan equipment. Automation of mixers, centrifuge and separator.

7.13.2 Diagnostic systems (technical diagnostic systems), control and protection.

7.13.3 Digital and analog electrical automation systems and electrotechnological complexes. Typical analog and digital control systems. Conversion of analog and digital signals. Analog and digital filtering. Analog and digital PID controllers. Programmable logic controllers.

Topic 7.14. Energy saving in energy systems and complexes

7.14.1 The main directions of energy saving policy. Criteria for selecting energy-saving technologies. Basic directions and reserves of energy saving. Efficiency of energy saving measures. Energy saving management.

7.14.2 Measures to realize the technical potential of energy saving. Energy efficient equipment and technologies, materials and structures. Unconventional and renewable energy sources. System of technical and organizational measures for energy saving.

7.14.3 Structural factors of energy saving. Structural re-equipment of production complexes. Optimization of energy use.

Topic 7.15. Energy management

7.15.1 Directions and tasks of energy management. Scientific-methodical and metrological support.

7.15.2 Energy audit. Stages Enterprise survey Choosing the optimal energy source. Energy systemmanagement at an industrial enterprise. Requirements for the energy auditor. Assessment and monitoring of energy consumption.

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III. RATING SYSTEM FOR EVALUATION OF THE ADMISSION TEST

1. The initial rating of the entrant for the exam is calculated based on a 100-point scale. When determining the overall rating of the entrant, the initial rating for the exam is converted into a 200-point scale according to the relevant table (paragraph 4).

2. At the exam, entrants prepare for an oral answer to the task of the exam ticket.

Each task of the complex professional entrance test contains three theoretical questions. The first two questions are common in the field of information technology. The last question is focused on special training of the entrant.

Each of the first two questions is evaluated with 30 points according to the following criteria:

- "excellent", complete answer, not less than 90% of the required information - 27-30 points;
- "good", a fairly complete answer, not less than 75% of the required information (minor inaccuracies are allowed) - 23-26 points;
- "satisfactory", incomplete answer, not less than 60% of the required information (the answer contains certain shortcomings) - 18-22 points;
- "unsatisfactory", the answer does not meet the conditions for "satisfactory" - 0 points.

The third question is evaluated with 40 points according to the following criteria:

- "excellent", complete answer, not less than 90% of the required information - 36-40 points;
- "good", a fairly complete answer, at least 75% of the required information (minor inaccuracies are allowed) - 30-35 points;
- "satisfactory", incomplete answer, not less than 60% of the required information (the answer contains certain shortcomings) - 24-29 points;
- "unsatisfactory", the answer does not meet the conditions for "satisfactory" - 0 points.

3. The sum of points for answers to the exam is transferred to the examination score according to the table:

Points	**Rating**
100… 95	Perfectly
94… 85	Very good
84… 75	Good
74… 65	Satisfactorily
64… 60	Enough
Less than 60	Unsatisfactorily

4. The sum of points for answers to the exam is transferred to a 200-point scale according to the table:

The table of correspondence of estimations of a rating system of estimation (RSE 60…100) to points of a 200-point scale (100…200)

Rate RSE	Points 100...200	Rate RSE	Points 100...200	Rate RSE	Points 100...200	Rate RSE	Points 100...200
60	100.0	70	125.0	80	150.0	90	175.0
61	102.5	71	127.5	81	152.5	91	177.5
62	105.0	72	130.0	82	155.0	92	180.0
6л	107.5	71	132.5	83	157.5	93	182.5
64	110.0	74	135.0	84	160.0	94	185.0
65	112.5	75	137.5	85	162.5	95	187.5
66	115.0	76	140.0	N6	165.0	46	190,0
67	117.5	77	142,5	S7	167.5	97	192.5
68	120,0	78	145,0	88	170.0	98	195.0
69	122,5	79	147,5	89	172.5	99	197.5
						100	200.0

IV. EXAMPLE OF EXAMINATION TICKET

Form № H-5.05

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

(full name of the higher educational institution)

Educational degree *doctor of philosophy*

Specialty *141 Electric power engineering, electrotechnics and electromechanics*

(name)

Academic discipline *Entrance examination*

PAPER ____ ____

1. Question 1

2. Question 2

3. Question 3

Approved
Guarantor of the educational program _____ Oleksandr YANDULSKY

The program is recommended by:

Academic Council of the Faculty of Electric Power Engineering and Automatics

Chairman of the Academic Council _____ Olexandr YANDULSKY

protocol # 6 from "24" "01" 2022

Academic Council of the Educational and Scientific Institute of Energy Saving and Energy Management

Chairman of the Academic Council _____ Sergiy DENYSYUK

protocol # 6 from "24" "01" 2022