APPROVED
at a meeting of the
Scientific Council
NJSC «Al-Farabi KazNU».
Minutes No.10 dated
May 23, 2022.

The program of the entrance exam for applicants to the PhD for the group of educational programs D099 – «Energy and electrical engineering»

1. General provisions.

1. The program was drawn up in accordance with the Order of the Minister of Education and Science of the Republic of Kazakhstan dated October 31, 2018 No. 600 "On Approval of the Model Rules for Admission to Education in Educational Organizations Implementing Educational Programs of Higher and Postgraduate Education" (hereinafter referred to as the Model Rules).

2. The entrance exam for doctoral studies consists of writing an essay, passing a test for readiness for doctoral studies (hereinafter referred to as TRDS), an exam in the profile of a group of educational programs and an interview.

Block	Points
1. Essay	10
2. Test for readiness for doctoral studies	30
3. Exam according to the profile of the group of the educational program	40
4. Interview	20
Total admission score	100/75

3. The duration of the entrance exam is 4 hours, during which the applicant writes an essay, passes a test for readiness for doctoral studies, and answers an electronic examination. The interview is conducted on the basis of the university separately.

2. Procedure for the entrance examination.

1. Applicants for doctoral studies in the group of educational programs D099 - «Energy and electrical engineering» write a problematic / thematic essay. The volume of the essay is at least 250-300 words.

2. The electronic examination card consists of 3 questions.

Topics for exam preparation according to the profile of the group of the educational program.

Discipline **«Electrical networks and systems»**

Topic: Basic information about electric power systems and electric networks

subtopics: Electric power systems. Basic concepts and definitions. Basic information about the development of power systems. General characteristics of electrical networks. Classification of electrical networks. Basic information about the development of electric networks of power systems.

Topic: Design and operating conditions of overhead lines of electric networks

subtopics: Basic information. General characteristics of overhead lines and the main elements. Supports of overhead lines. Overhead line wires. Lightning protection cables. Overhead line insulators. Linear fittings. Brief information on the operation of overhead lines.

Topic: Cable power lines.

subtopics: Basic information. Construction of cable lines. Marking of cables. Laying of cable lines. Current lines, busbars, and internal wiring.

Topic: Power transmission line as an element of the electrical network

subtopics: Basic information. Linear parameters of AC overhead and cable lines. A single-chain transposed aerial line with a non-split phase. Power line with steel wires. A single-chain transposed aerial line with a split phase. Two-chain transposed aerial line. Cable lines. Replacement schemes of power transmission lines. Operating characteristics of the line. Vector diagrams of currents and voltages. Determination of the parameters of the steady-state mode of the line. Calculation of the line mode according to the specified parameters at its receiving end. Calculation of the line mode based on the specified parameters at its transmitting end. Power diagrams. The influence of the relations between the parameters of the line substitution scheme on the parameters of its mode. Influence of the ratio of active and inductive resistances. The effect of charging power

Topic: Principles of design of electrical networks.

subtopics: Development of capacity balances in the design process. Selection of the rated voltage of electrical networks. Development of a rational configuration of electrical networks. Selection of cross-sections of power transmission lines. Principles of selection of cross-sections of wires and cables. Selection of cross-sections according to the economic criterion. Selection of cross-sections according to the quality criterion.

Discipline **«Electric power stations and substations»**

Topic: Modern and promising sources of electricity

subtopics: Basic concepts and definitions. General characteristics of electricity sources. Types, purposes, and environmental impacts of hydroelectric power plants, hydroelectric power plants, and thermal power plants. Renewable energy sources, types, purposes, conditions of use. Power system load schedules: Fill in the daily load schedule. Electrical receivers and their categories.

Topic: Electrical diagrams and electrical equipment of power stations

subtopics: Electrical diagrams of power stations; electrical equipment of power plants; own needs and their schemes; switchgears and their schemes; selection of communication transformers and transformers of own needs at power stations. Switching devices: types of designation on the diagram, purpose. Complete switchgear with a voltage above 6-10 kV. Circuit diagrams of switchgears(RC), their scope of application, closed and open RC; design implementation of RC. Layout of the substation ORU. Connection diagrams of HV switchgears: types, scope of application. Complex switchgears and substations: ZRU,KRU, KRUN, KTPB, KRUE. Design of electrical connections between power transformers and switchgears.

Topic: Power equipment of power plants

subtopics: Power plants: purpose, types of features, development trends, environmental impacts. Features of technological schemes. Diagrams of power stations and substations. Gas turbine stations. Diesel generator sets. Synchronous generators, synchronous compensators, power transformers: design features, operating mode, normal mode control.

Topic: Grounding devices and lightning protection

subtopics: Purpose of grounding; grounding devices and earthing devices; grounding circuit; grounding resistance; ground resistance; spreading resistance of the vertical electrode; thermal resistance of grounding conductors; grounding of electrical networks. Grounding devices and lightning protection. Purpose, design, selection conditions. Step voltage. The tension of touch. PUE requirements for the design of the grounding device. Lightning protection of OPM at power plants and substations. Layout of lightning protection devices at the substation. Options for placing lightning rods. Connection to the grounding device. PUE requirements for substation lightning protection.

Discipline **«Electric machines»**

Topic: Transformers

Subtopics: General information about transformers. Electromagnetic processes in the transformer at idle. Electromagnetic processes in the transformer under load. Transformation of three-phase currents. Determination of transformer parameters and losses. Transformer voltage regulation.

Topic: Autotransformers

Subtopics: Electromagnetic processes in autotransformers. Areas of application and features of operation of autotransformers.

Topic: Parallel switching on of transformers

subtopics: Application of parallel switching of transformers. Conditions for switching on transformers for parallel operation. Equalizing currents at unequal transformation coefficients.

Topic: Synchronous and asynchronous machines

subtopics: General information about synchronous and asynchronous machines. Purpose and scope of synchronous and asynchronous machines. Design of asynchronous machines with a closed-loop rotor. Design of asynchronous motors with a phase rotor.

Discipline **«High-voltage electrical devices»**

Topic: General information about electrical devices. Classification of electrical devices.

subtopics: Basic requirements for electrical appliances. Parameters and characteristics of electrical devices that determine their choice and application. Nominal parameters and operating modes. Parameters that characterize the reliability of the devices.

Topic: General regularities for determining electrodynamic forces.

subtopics: Electrodynamic forces in coils and coils of apparatuses. Electrodynamic forces between a current-carrying conductor and a ferromagnetic mass. Electrodynamic forces in conductors of variable cross-section. Electrodynamic stability of electrical devices

Topic: Heating of electric devices.

subtopics: Types of contact connections. Heat transfer from the heated parts of the device by thermal conductivity, convection, and thermal radiation. Switching and mechanical wear of contacts. Rattling (vibration) of contacts and ways to deal with it.

Subject: Electric arc.

subtopics: Electric arc. Electric arc – causes of occurrence, conditions for extinguishing the arc of direct and alternating current. Arc-extinguishing devices and spark-extinguishing circuits. Thermal stability of electrical devices.

Topic: Switching devices.

sub-topics: Circuit breakers. Fuses. Purpose, design and requirements for them. High-voltage electrical devices. Classification. Disconnectors, separators, short-circuit breakers: purpose, requirements, basic parameters, device, selection conditions.

Topic: Current-limiting devices.

subtopics: Surge arresters and surge arresters. Reactors. Purpose, principle of operation, requirements, device, main parameters and characteristics. Shunt reactors. Purpose, design, basic parameters, principle of operation.

Topic: Measuring transformers.

subtopics: Current and voltage transformers. Purpose, types, requirements, device, operating modes. Selection conditions.

Discipline **«High voltage engineering»**

Topic: General characteristics of external insulation

subtopic: Features of external insulation. Regulation of electric fields of external insulation. Dielectrics for insulators.

Topic: Corona discharge on power lines

subtopics: General information. Corona on the wires at constant voltage. Corona on wires at alternating voltage. Split wires. Energy loss per corona at alternating voltage.

Topic: Insulation of overhead power lines and distribution lines

subtopics: General information. Discharge characteristics of linear and hardware insulators. Selection of insulators for lines and RU. Determination of the minimum insulation distances on the supports. Isolation distances in switchgears. Electrical strength of solid dielectrics. Thermal and electrical breakdown.

Topic: General characteristics of internal insulation

sub-topic: Features of internal insulation. Regulation of electric fields in internal insulation.

Topic: Protection from direct lightning strikes

subtopics: General information. Lightning protection zones. Features of lightning protection of high objects.

Topic: Earthing in high-voltage electrical installations

subtopics: General information. Requirements for the grounding of stations and substations. Artificial earthing devices for stations and substations. Pulse characteristics of lightning protection earthing devices. Grounding of lightning protection of substations.

Discipline **«Relay protection and automation»**

Topic: General information about relay protection

subtopics: The purpose of relay protection. Analysis of damage and abnormal operating modes of electrical installations and electrical networks. Methods of switching on the relay and the image of the protection schemes in the drawings. Power sources of RZ devices.

Topic: Relays and other electrical devices used in RZ devices.

subtopics: General principles of relay execution and their main types. Current and voltage transformers, information schemes.

Topic: Maximum current protection and current cut-offs

subtopics: Maximum current protection. The principle of operation and selectivity of MTZ. Selection of the actuation current. Select the time delay. MTZ schemes. Coordination of protections by sensitivity. MTZ rating. Current cut-off. Purpose and principle of operation of the maintenance. Instantaneous maintenance on lines with one-way power supply. Instantaneous maintenance on two-way power lines. THEN with a time delay. THAT with start-up (blocking) on voltage

Topic: Differential, remote and high-frequency line protection

subtopics: Purpose and types of differential line protection. Longitudinal differential line protection. The principle of protection. Determination of the protection response parameter. Performing longitudinal differential line protection and evaluating it. Transverse differential line protection. The principle of protection. Current transverse differential protection. Directional transverse differential protection. Assessment and scope of protection. Remote line protection. Purpose and principle of operation of remote protection. Implementation and operation of remote protection. Evaluation of remote protection. High-frequency protection. Purpose and types of high-frequency protection. The principle of operation of directional protection with RF blocking. Principles of implementation and operation of the high-frequency part of the protection. Evaluation and application areas of high-frequency protection

Topic: Protection of power transformers

Subtopics: The main types of damage and abnormal modes of operation of transformers. Protection of transformers from phase-to-phase short circuits in the windings and at their terminals. Types of protection. Unbalance currents in the differential protection of transformers. Calculation of differential protection of transformers. Protection of transformers from external short circuits. Transformer overload protection. Gas protection of transformers. Purpose and principle of operation of gas protection. Improving the design of the gas relay. Shop transformer protection scheme

Topic: Automatic re-activation and automatic backup activation

sub-topics: Purpose and basic requirements for APV devices. Classification and characteristics of APV devices. Acceleration of the action of the relay protection at APV. The principle of operation and the scheme of the APV line. The principle of operation and schemes of APV tires. The principle of operation and schemes of APV engines. Selection of single APV setpoints for one-way power lines. The purpose of the AVR devices and the main requirements for them. The principle of operation and the circuit of the AVR on the sectional switch. The principle of operation and the scheme of the AVR line. The principle of operation and the circuit of the AVR transformers. Features of performing AVR in the presence of synchronous load High-speed AVR.

Discipline **«Renewable energy sources»**

Topic: Traditional and non-traditional energy sources.

subtopics: General information about natural energy sources and energy resources. Traditional energy resources, their assessment and distribution by region. Structure of global energy consumption. Dynamics of energy consumption growth in the world and in Kazakhstan. The role of renewable energy sources in meeting the energy needs of humanity.

Topic: Solar energy and methods of its transformation.

subtopics: Spectral characteristics of solar radiation. Influence of geographical coordinates, orientation of the radiation receiver in space, time of day and time of year. Conversion of solar energy into electrical energy. Physical bases of conversion of solar radiation energy into electrical energy. Schemes, operating principle and characteristics of solar power plants with a thermodynamic cycle.

Topic: The use of wind energy.

subtopics: Wind energy and methods of its transformation. Features of the circulation of the Earth's atmosphere. Factors that affect wind speed and direction. General characteristics of wind power plants (wind turbines).

Topic: Use of biomass.

subtopics: Sources of biomass. Classification of the main processes for producing biofuels. Biofuels for energy and household consumption. Installations for the production of heat, pyrolysis, hydrogenation, and biogas. Methods of processing household waste.

Topic: Geothermal energy.

subtopics: The structure of the earth and the change in temperature in the earth's crust. Classification of geothermal areas. The energy reserve in the Earth's crust and methods of its use. Using the energy of small rivers. Basic principles of using the energy of "falling" water. Ideal and real power of hydraulic turbines. Active and reactive turbines. Types and classification of small hydroelectric power plants.

Topic: Use of ocean thermal energy.

sub-topics: Energy potential of the world ocean and ways of its development. Thermodynamic bases of ocean thermal energy use. Ideal and real heat exchanger, its calculation. The working body of the steam turbine plant. The use of wave energy. Wave motion. Energy and power of the wave. Advantages and disadvantages of wave energy. Features of real waves. Devices for converting wave energy.

Discipline **«Electromagnetic compatibility»**

Topic: Sources of influence

subtopic: General information about electric and magnetic fields. High-voltage AC lines. High-voltage DC lines. Thunderstorms. High-frequency channels of transmission systems on high-voltage AC power lines

Topic: Electromagnetic influence on adjacent lines

subtopics: Electrical influence. Magnetic influence. Galvanic effect.

Topic: Measures to reduce dangerous and interfering influences

subtopics: Passive methods of protecting communication lines from dangerous and interfering influences. Active methods of protecting communication lines from dangerous and interfering influences.

Topic: Influence of overhead power transmission lines and substation switchgears on environmental ecology

subtopics: Calculation of the electric field strength generated by high-voltage AC lines. Calculation of the electric field strength of a three-phase high-voltage line.

3. List of literature

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