**APPROVED**
**at a meeting of the Academic Council of**
**NJSC «KazNU named after al-Farabi»**
**Protocol № 11 from 23. 05. 2025 y.**

# The program of the entrance exam for applicants to the PhD for the group of educational programs

## D099 – «Power Engineering and Electrical Engineering»

### I. 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, an exam in the profile of a group of educational programs and an interview.

| Блок | Баллы |
|---|---|
| 1. Interview | 30 |
| 2. Essay | 20 |
| 3. Exam according to the profile of the group of the educational program | 50 |
| Total admission score | 100/75 |

3.The duration of the entrance exam is 3 hours 10 minutes, during which the applicant writes an essay and answers the electronic examination ticket. The interview is conducted at the university premises before the entrance exam.

### II. Procedure for the entrance examination

1. Applicants to the doctoral program group D099 – «Power Engineering and Electrical Engineering» write a problematic / thematic essay. The volume of the essay is at least 250 words.

The purpose of the essay is to determine the level of analytical and creative abilities, expressed in the ability to build one’s own argumentation based on theoretical knowledge, social and personal experience.

Types of essays:

- motivational essay revealing the motivation for research activities;
- scientific-analytical essay justifying the relevance and methodology of the planned research;

- problem/thematic essay reflecting various aspects of scientific knowledge in the subject area.

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 electric networks. Classification of electric networks. Basic information about the development of electric networks of power systems.

**Topic:** Design and operating conditions of overhead power lines

*Subtopics:* Basic information. General characteristics of overhead lines and main elements. Overhead line supports. Overhead line wires. Lightning protection cables. Overhead line insulators. Line fittings. Brief information on the operation of overhead lines.

**Topic:** Cable power transmission lines.

*subtopics:* Basic information. Cable line designs. Cable marking. Laying cable lines. Busbars, busbars and internal wiring.

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

*Subtopics:* General information. Distributed parameters of overhead and cable lines for AC. Overhead line with solid wires. Double-circuit transposed overhead line. Cable lines. Equivalent circuit diagrams for transmission lines. Operating characteristics of the line. Vector diagrams of current and voltage. Determination of steady-state parameters of the line. Calculations of line mode based on parameters at the receiving or sending end. Power diagrams. Influence of substitution circuit parameters on operating parameters. Effect of the ratio of active to inductive resistance. Effect of charging power.

**Topic:** Principles of electrical network design

*Subtopics:* Power balance development during design. Selection of nominal voltage. Development of optimal network configuration. Selection of cross-sections for transmission lines. Principles for choosing conductor and cable sizes. Economic criteria for cross-section selection. Quality criteria for cross-section selection.

**Discipline: Power Stations and Substations**

**Topic:** Modern and prospective sources of electricity

*subtopics:* Basic concepts and definitions. General characteristics of energy sources. Environmental impact and roles of HPP, PSPP, TPP. Types and usage of renewable energy sources. Load schedules of power systems: filling in daily load curves. Categories of power consumers.

**Topic:** Electrical circuits and equipment of power stations

*subtopics:* Electrical schemes of power plants. Equipment of power stations. Auxiliary systems and their schemes. Distribution devices and their configurations. Selection of communication and auxiliary transformers. Switching devices: types of schematic notations and purposes. High-voltage switchgear with voltage above 6–10 kV. Switchgear schemes, applications, indoor and outdoor types, structural execution. Layouts of outdoor substations. High-voltage switchgear connection schemes: types and applications. Integrated switchgear and substations: GIS, AIS, MTS, etc. Electrical connection design between transformers and switchgear.

**Topic:** Power equipment of power plants

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

**Topic:** Earthing devices and lightning protection

*subtopics:* Purpose of grounding; grounding devices and earthing devices; grounding circuit; grounding resistance; ground resistance; vertical electrode spreading resistance; thermal resistance of grounding conductors; grounding of electrical networks. Earthing devices and lightning protection. Purpose, design, and selection conditions. Step tension. The tension of touch. Requirements of the PUE for the design of the grounding device. Lightning protection of OPW at power plants and substations. The layout of lightning protection devices at the substation. Lightning rod placement options. Connection to the grounding device. PUE requirements for substation lightning protection.

## Discipline: Electrical Machines

**Topic:** Transformers

*Subtopics:* General information about transformers. Electromagnetic processes in transformers at no-load. Electromagnetic processes under load. Transformation of three-phase currents. Determination of transformer parameters and losses. Transformer voltage regulation.

**Topic:** Autotransformers

*subtopics:* Electromagnetic processes in autotransformers. Application areas and operational features of autotransformers.

**Topic:** Parallel operation of transformers

*subtopics:* Use of parallel connection of transformers. Conditions for parallel operation. Equalizing currents in case of different transformation ratios.

**Topic:** Synchronous and asynchronous machines

*subtopics:* General information about synchronous and asynchronous machines. Purpose and application areas. Design of squirrel-cage asynchronous motors. Design of asynchronous motors with phase-wound rotor.

## Discipline: High Voltage Electrical Apparatus

**Topic:** General information on electrical apparatus. Classification of electrical apparatus

*subtopics:* Main requirements for electrical apparatus. Parameters and characteristics that define selection and use. Rated parameters and operating modes. Parameters that characterize operational reliability of devices.

**Topic:** General patterns for determining electrodynamic forces.

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

**Topic:** Heating of electrical devices.

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

**Topic:** Electric arc.

*subtopics:* Electric arc. Electric arc – causes of occurrence, conditions for extinguishing DC and AC arcs. Arc extinguishing devices and spark extinguishing circuits. Thermal stability of electrical devices.

**Topic:** Switching devices.

*subtopics:* Circuit breakers. Fuses. Purpose, designs, 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 limiters. Reactors. Purpose, principle of operation, requirements, device, main parameters and characteristics. Shunt reactors. Purpose, designs, basic parameters, principle of operation.

**Topic:** Measuring transformers.

*subtopics:* Current and voltage transformers. Purpose, types, requirements, device, modes of operation. Selection conditions.

## Discipline "High voltage technique"

**Topic:** General characteristics of external insulation

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

**Topic:** Corona discharge on power transmission lines

*subtopics:* General information. The crown is on the wires at constant voltage. The crown is on the wires at alternating voltage. Split wires. Corona energy loss at alternating voltage.

**Topic:** Insulation of overhead power transmission lines and distribution

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

**Topic:** General characteristics of internal insulation

*subtopics:* Features of internal insulation. Regulation of electric fields in internal insulation.

**Topic:** Protection from direct lightning strikes

*subtopics:*General information. Lightning rod protection zones. Lightning protection features of high objects.

**Topic:** Earthing in high voltage electrical installations

*subtopics:* General information. Requirements for grounding 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:* Purpose of relay protection. Analysis of damages and abnormal operating modes of electrical installations and electrical networks. The ways of switching on the relay and the image of the protection circuits in the drawings. Power supplies for RS devices.

**Topic:** Relays and other electrical devices used in RE devices.

*subtopics:* General principles of relay performance and their main types. Current and voltage transformers, information circuits.

**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. Time exposure selection. MTZ schemes. Coordination of protection sensitivity. MTZ assessment. Current cut-off. Purpose and principle of operation of the. Instant maintenance on one-way power lines. Instant maintenance on two-way power lines. THEN with a time delay. Voltage start-up (blocking)

**Topic:** Differential, remote, and high-frequency line protection

*subtopics:* Purpose and types of differential line protection. Longitudinal differential protection of lines. The principle of protection. Definition of the protection trigger parameter. Performing longitudinal differential line protection and its evaluation. Transverse differential protection of lines. 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 protection part. Evaluation and applications of high-frequency protection

**Topic:** Protection of power transformers

*subtopics:* The main types of damage and abnormal operating modes of transformers. Protection of transformers from phase-to-phase short circuits in windings and on 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. Overload protection of transformers. 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

reserve activation

*subtopics:* Purpose and basic requirements for APV devices. Classification and characteristics of APV devices. Acceleration of relay protection in case of 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. The choice of single-power supply settings for single-power lines. The purpose of AVR devices and the basic requirements for them. The principle of operation and circuits of the ATS on the sectional circuit breaker. The principle of operation and the scheme of

the AVR line. The principle of operation and the scheme of AVR transformers. Features of AVR execution in the presence of synchronous load High-speed AVR.

## The 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. The structure of global energy consumption. The 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. The influence of geographical coordinates, orientation of the radiation receiver in space, time of day and time of the year. Conversion of solar energy into electrical energy. The physical basis of the conversion of solar radiation energy into electrical energy. Schemes, operating principle and characteristics of thermodynamic cycle solar power plants.

**Topic:** Using wind energy.

*subtopics:* Wind energy and methods of its transformation. Features of the circulation of the Earth's atmosphere. Factors affecting wind speed and direction. General characteristics of wind power plants.

**Topic:** The use of biomass.

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

**Topic:** Geothermal energy.

*subtopics:* The structure of the earth and temperature changes 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. The basic principles of using the energy of "falling" water. The ideal and real power of hydro turbines. Active and reactive turbines. Types and classification of small hydroelectric power plants.

**Topic:** Using ocean thermal energy.

*subtopics:* The energy potential of the world ocean and ways of its development. Thermodynamic fundamentals of ocean thermal energy use. The ideal and real heat exchanger, its calculation. The working body of a steam turbine installation. The use of wave energy. Wave motion. The energy and power of the wave. Advantages and disadvantages of wave energy. Features of real waves. Devices for converting wave energy.

## The discipline "Electromagnetic compatibility"

**Topic:** Sources of influence

of the sub-topic: General information about electric and magnetic fields. High-voltage alternating current lines. High-voltage direct current lines. Lightning discharges. 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:** The impact of overhead power transmission lines and substation switchgear on the environment

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

## III. List of sources used

Main:

1. Lykin A.V. Electrical systems and networks: textbook - Novosibirsk: NSTU Publishing House, 2017. 361 p.

2. Starshinov V.A. The electrical part of power plants and substations: a textbook, Moscow: Publishing House of the MEI, 2016 - 296 p.

3. V.M. Ignatovich, S.S. Roiz Electric machines and transformers, 6th ed., ispr. and add. The training manual. Moscow: Yurait. 2016 – 186 p.

4. Kurbatova P.A. Electrical devices. Textbook and workshop for universities. Publisher: Yurait. 2021-250 p.

5. V.F. Vazhov, V.A. Lavrinovich. High voltage technology. Textbook – Moscow: Infra-M Publishing House, 2020. – 262 p.

6. Kireeva, E. A. Tsyruk S.A. Relay protection and automation of electric power systems. Moscow: Publishing Center "Academy", 2017. - 288 p.

7. Filipova T.A. Energy modes of both electric power plants and electric power systems. Moscow, Yurait Publishing House, 2017 - 293 p.

8. Yudaev I.V., Daus Yu.V., Gamaga V.V. Renewable sources of electricity: textbook. Lan Publishing House 2020-328 p.

9. A.F. Dyakov, B.K. Maksimov, R.K. Borisov, I.P. Kuzhekin, A.G. Temnikov, A.V.

Zhukov. Electromagnetic compatibility and lightning protection in the electric power industry. Textbook for universities— Moscow: MEI, 2016— 543 p.

10. Klimova G.N. Electric power systems and networks. Energy saving. Textbook for applied Bachelor's degree. Publishing house: Yurait. 2017 – 180 p.

11. Lebedev V.I. Microprocessor-based electricity meters. Textbooks and studies. the manual.d/ higher schools(universities) — Publishing house: DMK PRESS, 2017. — 195 p.

Additional information:

1. I. G. Karapetyan, D. L. Faibisovich, I. M. Shapiro. Handbook on the design of electrical networks. Edited by Faibisovich D.L. - 4th edition. Moscow: Publishing house of NC ENAS, 2012. 376c.

2. Rozhkova L.D., Karneeva L.K., Chirkova T.V. Electrical equipment of power plants and substations. Publishing Center "Academy", 2013. -449s.

3. A. I. Grin, H. M. Mustafaev. The electrical part of stations and substations. Textbook, Stavropol, 2002.

4. Aliev, I.I. Electric machines / I.I. Aliev. Vologda: Infra-Engineering, 2014. 448 p.

5. Katsman, M.M. Electric machines: Textbook / M.M. Katsman. Moscow: Academia, 2017. 320c.

6. Alexandrov G.N. Electrical devices of high voltage. / G.N. Alexandrov et al. Edited by G.N. Alexandrov. – Ed. 2-E. – St. Petersburg: Publishing House of St. Petersburg State Technical University, 2000. – 503s.

7. Electrical and electronic devices. / P. A. Kurbatov et al. Edited by P. A. Kurbatov. Moscow: Yurait Publishing House, 2016. 440 p.

8. Vazhov, V. F. High voltage technique: textbook / V.F. Vazhov, V.A. Lavrinovich. Moscow: INFRA-M, 2018. 262 p.

9. Kireeva, E. A. Relay protection and automation of electric power systems: textbook. / E. A. Kireeva, S. A. Tsyruk. - 5th ed. – Moscow: Akademiya, 2016. - 287 p.

10. Andreev V.A. Relay protection and automation of power supply systems. – 4th ed., revised and supplemented – Moscow: Higher School, 2006. -639 p.

11. Tsygankov V.M. Reliability of electrical systems and networks. Minsk: BNTU Publ., 2001.150s.

12. Renewable sources of electricity: a textbook / B.V. Lukutin. Tomsk: Publishing House of Tomsk Polytechnic University, 2008. 187 p.

13. Gorodov R.V. Non-traditional and renewable energy sources: a textbook / R.V. Gorodov, V.E. Gubin, A.S.Matveev. - 1st ed. - Tomsk: Publishing House of Tomsk Polytechnic University, 2009. - 294 p.

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16. Volkov N.G. Quality of electric power in power supply systems. Tomsk: Tomsk Polytechnic University, 2010. 152s.

17. Idelchik V. I. Electrical systems and networks: A textbook for universities. Moscow: Energoatomizdat, 1989. 592 p.: ill.

18. L. Wrote.S., V. And Shumno.M., S. Tishinya.G. Non-thermal nuclear power plants: A textbook for higher education. - M.: Publishing House of the MEI,

19. Afonin, V.V. Non-Electric stations message: 2 parts of the textbook / V.V. Afonin, K.A. Nabatova. – Tambov: Tambov State Technical University, 2017. – P. 2. – P. 98.

20. Kopylov, Year.Very. Electric T. V. 2 cars. Volume 1: Textbook for academic Baccalaureate / year.Very. Kopylov. Lyubertsy: Yurai, 2016. 267 p.

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