**MATHEMATICAL MODELLING IN ELECTRIC POWER SYSTEMS**

# GENERAL CHARACTERISTICS OF THE DISCIPLINE MATHEMATICAL MODELLING IN ELECTRIC POWER SYSTEMS

The work programme of the discipline is compiled according to the Federal State Higher Professional Education Standards

|  |  |  |  |
| --- | --- | --- | --- |
| Code of the field of study and attainment level | Field of study | Details of the order of the Ministry of Education and Science of the Russian Federation on approval and commissioning of the Federal State Higher Educational Standard | |
| Date | Date |
| 13.06.01 | Electrical- and Thermal Engineering | 30 July 2014 | 30 July 2014 |

*The order of the Russian Ministry of Education and Science dated 30 July 2014 N 878 On Approval of the Federal State Higher Educational Standard in the Area of Focus 13.06.01 Electrical- and Thermal Engineering (level of training of highly qualified personnel)*

*(Registered in the Russian Ministry of Justice on 20 August 2014 N 33707)*

## Place of the discipline in the structure of the Principal Educational Programme

The purpose of studying the discipline is to obtain by future researchers the theoretical and practical knowledge in professional training for the development and use of computer systems in science and industry, for automation of engineering work and power facilities.

The discipline enables:

* to obtain the knowledge necessary for carrying out design, commissioning, maintenance and research works on the industrial and research power-generating machinery.
* to master the skills of performing PC-based design, commissioning and maintenance.
* to acquire skills in the use of languages and application packages for the development, adaptation and maintenance of CAD and CAD/CAM systems.
* to learn how to operate the existing industrial systems and CAD/CAM packages at all stages of the design, production and use from an idea to operation of a real project.

As a result of mastering the discipline, a postgraduate student should obtain the following competences:

* ***Universal Competencies (UC):***
* the ability to critically analyse and evaluate current scientific achievements, generate new ideas for solving research and practical problems, including in interdisciplinary areas (Universal Competence-1);
* the ability to design and implement complex research including inter-disciplinary one based on a holistic and scientific view of the world using knowledge in the field of history and philosophy of science (UC-2);
* the readiness to engage in the work of Russian and international research teams to tackle academic problems (Universal Competence-3);
* the readiness to use contemporary methods and technologies of scientific communication in the state and foreign languages (Universal Competence-4);
* the ability to follow ethical standards in professional activities (Universal Competence -5);
* the ability to plan and accomplish the professional and personal development tasks (UC-6).
* ***General Professional Competencies (GPC):***
* the knowledge of the theoretical and experimental research methodology in the field of professional activities (GPC-1).
* the knowledge of the research culture including using the latest information and communication technologies (GPC-2).
* the ability to develop new research methods and their application in independent research in the field of professional activities (GPC-3).
* the willingness to arrange for the work of a research team in professional activities (GPC-4).
* the readiness for teaching activities in the key higher educational programmes (GPC-5).
* ***Professional Competences (PC):***
* the ability to plan, prepare and perform experimental studies in the specialty (PC-1).
* the ability to process the experiment results (PC-2).
* the ability to develop mathematical models of individual and aggregate elements of the power system (PC-3).
* the ability to develop algorithms and a mathematical apparatus for solving problems in the electric power industry (PC-4).
* the ability to operate modern software systems designed to solve problems in the electric power industry (PC-5).

## Planned results of mastering the discipline

As a result of mastering the discipline, a postgraduate student should:

**Know:**

* Methods for the critical analysis and assessment of modern scientific achievements as well as methods for generating new ideas in solving research and practical problems, also in inter-disciplinary areas (UC-1).
* Research methods of (UC-2).
* Professional and personal development goal setting, features and ways of implementation in solving professional problems based on the career growth stages and labour market requirements (UC-6).
* Regulatory framework for the teaching activities in the higher education system (GPC-1).
* Methods for planning, preparation and implementation of experimental studies (PC-1).
* Standards and rules for registration of the scientific and technical reports (PC-2).
* Applying a mathematical apparatus to solve new problems of the energy problem (PC-3).

**Be able:**

* to follow the basic standards adopted in scientific communication in the state and foreign languages (UC-4).
* to formulate the personal and professional development goals and the conditions for achieving them based on the trends in the field of professional activities, the stages of professional growth and individual personal characteristics (UC-5).
* to individually acquire and use in practical activity new knowledge and skills, also in new areas of knowledge not directly related to the field of activity by means of information and communication technologies (GPC-3).
* to select and use the best teaching methods (GPC-5).
* to use the mathematical apparatus to address new challenges in the energy problem (PC-3).
* to obtain a mathematical solution for the process-related problems of electric power systems (PC-4).

**Master:**

* The skills of reviewing the basic world outlook and methodological problems including those of the inter-disciplinary nature arising in working to solve scientific and educational problems in Russian or international research teams (UC-3).
* Technique and technologies of goal setting, goal implementation and activity outcome evaluation to solve professional problems. (UC-5).
* Basic methods and means of obtaining, storing and processing information, the skills of synchronous perception and documentation of multimedia information in foreign languages (GPC-2).
* The ability to independently organise the work of a team of performers. (GPC-4).
* Contemporary packages of programs for calculating the electric mode, calculating short circuit currents and other standard tasks of the electric power industry (PC-5).
* Basic skills in developing new methods for solving problems arising in the course of research work (PC-4).

## Scope of the discipline

|  |  |  |
| --- | --- | --- |
| Types of the educational work, forms of control | Total, hours | Academic semesters, number |
| 2 |
| In-class learning, hours | 4 | 4 |
| Lectures | 4 | 4 |
| Practical exercises |  |  |
| Laboratory-based work |  |  |
| Self-guided work of students including all types of the current attestation | 104 | 104 |
| Interim assessment | - | Admission to the exam in a special discipline |
| Total scope according to the curriculum, hours | 108 | 108 |
| Total scope according to the curriculum, credits | 3 | 3 |

# DISCIPLINE CONTENT

|  |  |  |
| --- | --- | --- |
| **Code of section and topic** | **Discipline section, topic** | **Content** |
| **Р1** | Visual (graphic) programming Principles, methods and programmes. | |
| **Р1. Т1** | Mastering the Simulink MATLAB software package. Simulation of a three-phase rectifier. | **Simulink** programme isan increment of the MATLAB software package. Create a device model and perform calculations. Control of the transient process.  The additional module ibrary SimPow-erSystems is the simulation of electric power devices.  Simulation of a three-phase rectifier on the Simulink MATLAB software package. Three-Phase Rectifier (4 h). |
| **Р1.Т2** | Modelling the static compensator of reactive power | Modelling the static compensator of reactive power on 300 MVAr (Statcom, SVC) on Simulink MATLAB. A 300-Mvar Static Var Compensator (SVC) regulates voltage on a 6000-MVA 735-kV system (2 ч). |
| **Р1.Т3** | Modelling the power flow control system (СРПМ, UPFC) on Simulink MATLAB | Modelling the power flow control system (UPFC) on Simulink MATLAB. The model A Unified Power Flow Controller (UPFC) is used to control the power flow in a 500 kV transmission system (2 ч). |
| **Р2** | The systems of control and analysis of the modes of the electrical system and its elements. | |
| **Р2.Т1** | Accounting the devices FACTS, АРВ, an actuator and automatics in the stability calculations | Calculation of the electromechanical flow processes with regard to devices FACTS, АРВ, an actuator and automatics on Rustab (2 h) |
| **Р2.Т2** | Emergency file analysis programmes | Software and communication interfaces in the power system infrastructure. Intelligent electronic devices (IED). Integration of the protection, regulation and monitoring functions in conjunction with local area networks and up-to-date telecommunication technologies.  Registration and analysis of the electrical power system modes. The parameter recording devices of electrical power systems. Programmes for analysing the files of emergency modes (2h). |
| **Р2.Т3** | Substation monitoring and control systems | Systems for the collection, processing and control of real equipment processes or their models. The equipment mode parameter sensors. Analogue and digital sensors, optical current transformers and optical voltage transformers (OCT and OVT). Accounting for the characteristics of secondary electrical signals. Substation monitoring and control system (2 h). |
| **Р3** | It systems | |
| **Р3.Т1** | Microprocessor protection monitoring and configuring system | Intelligent electrical network, digital information and technological automated systems, intelligent electronic devices. IEC 60870 and IEC 61850 series of standards. Information exchange protocol in information systems according to IEC 61850. Alstom system for monitoring and configuration of microprocessor protection (system S1), Siemens (DIGSI system) (2 h). |
| **Р3.Т2** | Automated working station (AWS) of the operating teams, AWS of the Relay Protection and Automatic Equipment designer.  Conclusion. | Calculation of short-circuit currents and relay protection and automation settings. Selection of protection and breaker failure protection settings. Protection approval. Terminal configuration and feature determination of the Relay Protection and Automatic Equipment. Software Models of Terminal Logic of EKRA Research and Production Enterprise. AWS of the Relay Protection and Automatic Equipment operation, AWS of the Relay Protection and Automatic Equipment designer (2 h). |

# STUDY TIME ALLOCATION



# ORGANISATION OF PRACTICAL LESSONS, SELF-WORKING AND ATTESTATION BY DISCIPLINE

## Laboratory-based work

Not applicable

## Practical exercises

Not applicable

## Example topics of the self-guided work

Self-study of the theoretical and practical sections of the discipline.

### Indicative list of topics of research papers

Not applicable

### Indicative list of homework topics

Not applicable

### Indicative list of tests

Not applicable

### Indicative list of calculation work topics

Not applicable

### Indicative list of calculation and graphical work topics

Not applicable

### Indicative list of colloquium topics

Not applicable

### Indicative list of the term project (work)

Not applicable

# RELATION BETWEEN THE DISCIPLINE SECTIONS AND THE APPLIED EDUCATION METHODS AND TECHNOLOGIES

| Discipline section | Education technology | Forms of educational sessions and types of educational activities | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Lecture | Practical exercise | Laboratory research | Colloquium | Term project | Term work (paper) | Calculation and graphical work | Calculation work | Homework | Research paper | Preparation for in-class learning |
| Р1 | Interactive learning Technologies |  |  |  |  |  |  |  |  |  |  |  |
| Project work |  |  |  |  |  |  |  |  |  |  |  |
| Case studying |  |  |  |  |  |  |  |  |  |  |  |
| Simulation exercises (games etc.) |  |  |  |  |  |  |  |  |  |  |  |
| Problem learning methods (discussions, exploratory work, research method etc.) | 1 |  |  |  |  |  |  |  |  |  |  |
| Teamwork |  |  |  |  |  |  |  |  |  |  |  |
| Other (please specify) |  |  |  |  |  |  |  |  |  |  |  |
| Distance learning technologies and e-learning |  |  |  |  |  |  |  |  |  |  |  |
| Network training courses |  |  |  |  |  |  |  |  |  |  |  |
| Virtual workshops and simulators |  |  |  |  |  |  |  |  |  |  |  |
| Webinars and videoconferences |  |  |  |  |  |  |  |  |  |  |  |
| Asynchronous web-conferences and seminars |  |  |  |  |  |  |  |  |  |  |  |
| Collaboration and content development |  |  |  |  |  |  |  |  |  |  |  |
| Other (please specify) |  |  |  |  |  |  |  |  |  |  |  |
| Р2 | Interactive learning technologies |  |  |  |  |  |  |  |  |  |  |  |
| Project work |  |  |  |  |  |  |  |  |  |  |  |
| Case studying |  |  |  |  |  |  |  |  |  |  |  |
| Simulation exercises (games etc.) |  |  |  |  |  |  |  |  |  |  |  |
| Problem learning methods (discussions, exploratory work, research method etc.) | 2 |  |  |  |  |  |  |  |  |  |  |
| Teamwork |  |  |  |  |  |  |  |  |  |  |  |
| Other  Accomplishment of an online task following an individual learning path |  |  |  |  |  |  |  |  |  |  |  |
| Distance learning technologies and e-learning |  |  |  |  |  |  |  |  |  |  |  |
| Network training courses |  |  |  |  |  |  |  |  |  |  |  |
| Virtual workshops and simulators |  |  |  |  |  |  |  |  |  |  |  |
| Webinars and videoconferences |  |  |  |  |  |  |  |  |  |  |  |
| Asynchronous web-conferences and seminars |  |  |  |  |  |  |  |  |  |  |  |
| Collaboration and content development |  |  |  |  |  |  |  |  |  |  |  |
| Other (please specify) |  |  |  |  |  |  |  |  |  |  |  |
| Р3 | Interactive learning technologies |  |  |  |  |  |  |  |  |  |  |  |
| Project work |  |  |  |  |  |  |  |  |  |  |  |
| Case studying |  |  |  |  |  |  |  |  |  |  |  |
| Simulation exercises (games etc.) |  |  |  |  |  |  |  |  |  |  |  |
| Problem learning methods (discussions, exploratory work, research method etc.) | 1 |  |  |  |  |  |  |  |  |  |  |
| Teamwork |  |  |  |  |  |  |  |  |  |  |  |
| Other  Accomplishment of an online task following an individual learning path |  |  |  |  |  |  |  |  |  |  |  |
| Distance learning technologies and e-learning |  |  |  |  |  |  |  |  |  |  |  |
| Network training courses |  |  |  |  |  |  |  |  |  |  |  |
| Virtual workshops and simulators |  |  |  |  |  |  |  |  |  |  |  |
| Webinars and videoconferences |  |  |  |  |  |  |  |  |  |  |  |
| Asynchronous web-conferences and seminars |  |  |  |  |  |  |  |  |  |  |  |
| Collaboration and content development |  |  |  |  |  |  |  |  |  |  |  |
| Other (please specify) |  |  |  |  |  |  |  |  |  |  |  |

# SCORE AND RAITING CONTROL PROCEDURES

Not applicable.

# PROCEDURES FOR EVALUATING THE LEARNING OUTCOMES AS PART OF THE INDEPENDENT TEST CONTROL

Not applicable.

# SET OF APPRAISAL TOOLS FOR THE CURRENT AND INTERIM ATTESTATION BY DISCIPLINE

Annex 1

## Databases, information and reference systems and search engines

Not applicable

## Electronic educational resources

http://msdn.microsoft.com

<http://www.gotdotnet.ru>

<http://www.rsdn.ru>

http://study.ustu/ru

http://lib.urfu.ru/

**ANNEX 3**

**to the Discipline Work Programme**

**8**. **SET OF APPRAISAL TOOLS FOR THE CURRENT AND INTERIM ATTESTATION BY DISCIPLINE**

**8.1. CRITERIA FOR EVALUATION OF RESULTS OF THE CONTROL AND EVALUATION ACTIVITIES FOR THE CURRENT AND INTERMEDIATE ATTESTATION BY DISCIPLINE**

|  |  |  |  |
| --- | --- | --- | --- |
| Competence components | Features of the level of mastering competence components | | |
| threshold level | higher level | high level |
| Knowledge | A post-graduate student demonstrates the acquaintance knowledge, copy knowledge, i.e. recognises objects, phenomena and concepts, finds some differences in them, shows the knowledge of the sources of information, can independently carry out reproductive actions on knowledge by self-reproduction and application of the information. | A post-graduate student demonstrates the analytical knowledge, i.e. confidently reproduces and understands the acquired knowledge, assigns them to one or another classification group, independently arranges them, establishes interrelations between them and effectively applies them in familiar situations. | A post-graduate student can independently obtain new knowledge from the surrounding world and creatively use it to make decisions in new and unusual situations. |
| Skills | A post-graduate student is capable of correctly performing the prescribed actions following the instructions and/or an algorithm in a known situation, independently performing actions to address typical issues that require a choice from among the known methods, in predictably changing situations | A post-graduate student is capable of independently performing the actions (techniques, operations) to solve non-standard problems that require selection based on a combination of known methods, in an unpredictably changing situation | A post-graduate student is capable of independently performing the actions associated with solving research problems, demonstrates the creative use of skills (technologies) |
| Personal qualities | A post-graduate student has a low learning motivation, shows an indifferent, irresponsible attitude to studying and/or the assigned task. | A post-graduate student has a pronounced learning motivation and demonstrates a positive attitude towards learning and future activities, and is active. | A post-graduate student has a developed motivation for training and work, shows perseverance and enthusiasm, hard work, independence and creativity. |

**8.2. CRITERIA FOR ESTIMATING THE RESULTS OF INTERMEDIATE ATTESTATION WITH THE INDEPENDENT TESTING CONTROL**

Not applicable

**8.3. APPRAISAL TOOLS FOR CONDUCTING THE CURRENT AND INTERMEDIATE ATTESTATION**

**8.3.1.** **Exemplary tasks for conducting mini-tests in the framework of training sessions**

Not applicable

**8.3.2**. **Exemplary test tasks in the framework of training sessions**

Not applicable

**8.3.3.** **Exemplary test cases**

Not applicable

**8.3.4.** **List of exemplary tests**

Not applicable

**8.3.5. List of exemplary questions to prepare for the discipline attestation.**

* Scientific and industrial tools and equipment (UC-2).
* Automatic and automated control of the scientific and production equipment (UC-6).
* Integration of automation systems for the scientific, research and production equipment (PC-3).
* Labour automation at the development, manufacture and operation stages (UC-1).
* Hardware and software implementation of the automation of the scientific and industrial instruments and equipment.
* Systems for data collection, data processing and process control of the real equipment or its models (PC-5).
* Automation of the data collection, data processing and process control systems (UC-2).
* Equipment mode parameter sensors. Primary and secondary sensors. Analogue and digital sensors, their advantages and disadvantages (GPC-3).
* Accounting for the characteristics of secondary electrical signals, current and voltage sensors, optical current transformers and optical voltage transformers (OCT and OVT) (GPC-5).
* Information input-output levels (control mode and execution of control commands), lower control loops and automated control (GPC-1).
* Packages of data collection and control programmes developed for process automation (PC-1).
* Implementation of algorithms in digital signal processing processors (DSP) (GPC-2).
* Accounting for the characteristics of secondary signals of electrical devices in algorithms (PC-4).
* Software development kits for describing the logic of operation of industrial automation systems, the scientific and industrial tools and equipment (GPC-2).
* Industrial packages for the development of process automation systems (PC-1).
* Major firms’ SCADA systems (ABB, Siemens, Iconics, Advantech, Imagination Sistems) (GPC-3).
* Visual terminology, graphical programming language LabVIEW, graphical symbols of the IEC languages 1131-3 (UC-3).
* Visual terminology, graphical programming language Matlab (PC-4).
* Viewing and processing of simulation results, processing of simulation results graphs (GPC-2).
* Standards for presenting data at various stages of processing the experimental and process information (GPC-4).
* Traditional means of displaying the results of modelling, an experiment, or an object mode. The expansion of the composition and forms of displaying the state and mode of the scientific and industrial tools and equipment (PC-4).
* Visualisation of the experimental, calculated and operational data (PC-2).
* Use of the content and forms of presentation of typical modes of electric power systems in the emergency mode treatment programmes of power systems (GPC-1).
* Methods for displaying dangerous modes (sections) in complex power systems (GPC-2).
* Telemechanics information processing terminal (TMIPT), purpose, hardware, software (GPC-5).
* Information service terminal (IST) of the dispatch service of an energy company. The purpose of the operation and information system of IST, interaction with telecomplexes (PC-2).
* Composition and functions of the basic version of the IST. The operative information processing server. Signaling system, subsystems of information transfer to telemechanics channels, information display (PC-1).
* COSMOS programme system, assignment, task composition, communication with the telemetric information (PC-3).
* Key objectives of the COSMOS system: the generation of a calculation scheme; assessment of the status; constructing a mode model using the extended scheme (PC-4).
* Key objectives of the COSMOS system: calculation of steady-state and self-adjusting frequency modes; weighting according to the specified trajectories; optimisation by reactive power, data preparation for CPAA (UC-2).
* Main software packages for calculating and analysing steady-state conditions: RASTR, Rustab, DAKAR, Mustang, COSMOS. General characteristics of the programmes (UC-3).
* General requirements for software packages for the calculation and analysis of electromagnetic transients, the scope of tasks, data exchange, complex operation management and displaying the calculation results (PC-4).
* Main software packages for the calculation and analysis of electromagnetic transients: DAKAR, TKZ 3000, RTKZ, Anares, ETAP PowerStation, NETOMAC (PC-3).
* Displaying the results of calculating the damage mode in software packages for calculating and analysing electromagnetic transient processes. The construction of a stress vector diagrams in the nodes and currents of the circuit branches (GPC-2).
* Software systems for the calculation and analysis of electromechanical transient processes, analysis of static and dynamic stability (PC-3).
* General requirements for software systems for calculating and analysing electromechanical transients, the scope of tasks, data exchange, complex operation management and displaying the calculation results (GPC-2).
* General requirements for software systems for the calculation and analysis of electromechanical transient processes: introduction of mode-related and dispatching changes into the electrical scheme of the power system, accounting of relay protection and automatic control systems, static characteristics in frequency and voltage (PC-3).
* Main software systems for the calculation and analysis of electromechanical transient processes: Мустанг, Rustab DAKAR, ANARES, PSSE, EUROSTAG, ETAP PowerStation, NETOMAC (PC-1).
* General requirements for the software systems for calculating, analysing and setting relay protection settings, task scope, data exchange, complex operation control and display of calculation results (UC-6).
* Main software packages for calculating, analysing and setting relay protection settings: TKZ 3000, Tkz3000win, relay protection and automation workstation, RTKP, ETAP PowerStation, Power Plot (UC-3).
* Software systems for calculating short-circuit currents, specifying the type and location of a short circuit, calculating and coordinating the relay protection settings (UC-4).
* Modification of the algorithm of digital relay protection and electroautomatics devices in software systems for calculating, analysing and setting relay protection settings. Analysis of computational resources and methods of entering results in relay protection and electroautomatics devices (UC-2).
* Testing systems. An increase in the degree of automation of test result verification and processing. A decrease in weight dimensions. Modelling various modes of operation of power systems in case of accidents. Reproduction of real emergency modes (PC-4).
* Registration of emergency processes and operating modes of EPS. General requirements for hardware and software, scope of tasks, data exchange, work control, and display of results (PC-3).
* Main hardware and software systems: AURA, BRIZ, Bresler, RES-3, Parma RP4, Neva-Oc. Analysis and programmes for analysing emergency register records (GPC-4).
* Automatic excitation regulators and their effect on the transient process (GPC-2).
* Modelling the change and regulation of the EPS frequency (UC-3).
* Study of the induction motor characteristics (UC-4).
* Programme model of the logic of the terminal of protection of ShE type2607 016 (PC-5).
* Emergency electrical parameter recorder (GPC-3).
* Data collection from analogue input signals (PC-1).

**8.3.6. List of sample questions for the exam**

Not applicable

**8.3.7.** **UrFU attestation-pedagogical measuring materials and means of control of educational achievements for conducting the test control within the current and intermediate attestation**

Not applicable

**8.3.8**. **Federal online exam in the field of vocational education for independent testing**

Not applicable

**8.3.9.** **Internet simulators**

Not applicable