**SELECTED PARTS OF MATHEMATICS. MATHEMATICAL SUPPORT OF POWER ENGINEERING**

# GENERAL DESCRIPTION OF THE DISCIPLINE

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 | **Number of order** |
| 13.06.01 | Power Engineering and Electrical Engineering | 30 July 2014 | 878 |

*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)*

As a result of mastering the discipline, a post-graduate student should

## Discipline’s role in the structure of the Principal Educational Programme

### As a result of mastering the discipline, a graduate should obtain:

* the universal competencies that do not depend on the specific area of study;
* the general professional competence determined by the area of study;
* the professional competences determined by the focus area (profile)
* the postgraduate programmes in the area of study (hereinafter the programme focus).

The discipline shapes the following competences:

* ***General Professional Competencies (GPC):***
  + mastering the research culture including, also with the latest information and communication technologies (GPC-2).
  + the ability to develop new research methods and apply them in independent research activities in the field of professional activities (GPC-3).

## Planned results of mastering the discipline

**Know:**

* the regulatory and legal framework of the teaching activities in the higher education (GPC-2).
* the key trends in the development of informatics and natural and mathematical knowledge in the relevant field of science. (GPC-3).

**Be able:**

* to use up-to-date computer technology and dedicated software in research (GPC-2).
* to individually acquire by means of information and communication technologies and use in practical activities new knowledge and skills, also in new areas of knowledge not directly related to the area of activity (GPC-3).

**Master:**

* the skills of using software and working in computer networks by using Internet resources (GPC-2).
* the main methods and means of obtaining, storing and processing data as well as the skills of synchronous perception and documentation of multimedia information in foreign languages (GPC-2).
* the ability to individually study and develop new research methods, change the research-and-production profile of activities (GPC-3).

## Work input in mastering the discipline

|  |  |  |
| --- | --- | --- |
| Types of the educational work, forms of control | Total, hours | Course |
| **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 test in a special discipline |
| Total scope according to the curriculum, hours | **108** | **108** |
| Total scope according to the curriculum, credits | 3 | 3 |

# DISCIPLINE CONTENT

|  |  |  |
| --- | --- | --- |
| **Section and topic code** | **Discipline section, topic** | **Contents** |
| **Р1** | **Introduction** | The discipline’s role in the curriculum, the course structure. The features of problems solved in the design and operation of power plants and systems, classification of them. The modes of operation of electrical systems, classification of them. |
| **Р2** | **Mathematical description of steady-state modes of electrical systems** | |
| **Р2.Т1** | **Types of matrices and their properties.** | Characteristic types of matrices used in the electric power industry. The matrices are Hadamard, Hankel, Gilbert, Pascal, Teplitz and Wilkinson. Their properties. Matrix functions. Matrix inversion. |
| **Р2.Т2** | **Matrix operations of linear algebra.** | Operations with matrices. Algorithms for computing the inverse matrix. Recording linear equation systems in matrix form. Solution of linear equation systems. The calculation of matrix condition number. The determinant and rank of the matrix. Definition: vector and matrix norms; orthonormal basis of the matrix; an angle between two subspaces; the matrix trace; eigenvalues and singular numbers. |
| **Р2.Т3** | **Matrix transformations** | The functions of reducing a matrix to a triangular shape. Cholesky decomposition. LU and QR decomposition. Matrix reduction to the Schur and Hessenberg form. |
| **Р2.Т4** | **Sparse matrix functions** | Elementary sparse matrices. Transformation of sparse matrices. Working with non-zero elements of sparse matrices. Visualisation of sparse matrices. Ordering algorithms. Norm, condition number and the rank of sparse matrices. Calculation of eigenvalues and singular numbers of sparse matrices. |
| **Р2.Т5** | **Matrix transformations in problems of the electric power industry** | Linear approximation of non-linear objective functions and constraint systems in the optimal load distribution and power flow problems in electrical networks. Linearisation of non-linear systems of differential equations in the analysis of transient processes in electrical systems. Algorithms for solving the matrix problems of the electric power industry. |
| **Р3** | **Linear transformations of space** | |
| **Р3.Т1** | **Concepts and definitions** | Linear transformation and its relation to the matrix. Eigenvalues, eigenvectors and matrix norms. The geometric meaning of a degenerate linear transformation. |
| **Р3.Т2** | **Solution accuracy** | The accuracy of solving linear equation systems and the matrix condition. Number condition. Error estimation in solving systems of linear equations. |
| **Р4** | **Solution of non-linear equation systems by iterative methods** | |
| **Р4.Т1** | **Concepts, definitions** | Classification of iterative methods. Recurrent transformations. Acceleration of convergence. Methods of descent. |
| **Р4.Т2** | **Solution of a non-linear equation** | Solution of a non-linear equation: ambiguity, convergence and convergence criteria. Calculating zeros of a one-variable function |
| **Р4.Т3** | **Graphic illustration** | Graphical illustration of the iterative process |
| **Р4.Т4** | **Solution of non-linear systems of nodal stress equations** | Vector notation of systems of non-linear equations. Residual function. Expansion of the vector function in a Taylor series. Newton’s method. Z-matrix method. The conjugate gradient method. Bidirectional method of conjugate gradients. A method for optimising a generalised discrepancy. Quasi-minimisation of the discrepancy. |
| **Р5** | **Linear and non-linear programming** | |
| **Р5.Т1** | **Definition of mathematical programming** | Typical optimisation tasks of the electric power industry. Elements of a convex analysis. The general problem of mathematical programming. Possible directions of optimization. Linear and non-linear programming. |
| **Р5.Т2** | **Linear programming** | The general and standard problem of linear programming, its mathematical notation and decision algorithms. Transport problem. Simplex algorithm: statement, expression of dependent variables through independent, change of basis. Geometric interpretation. An auxiliary problem of linear programming, solution, analysis and use of the result as an initial admissible basic solution. Linear programming solvers. |
| **Р5.Т3** | **Non-linear programming** | Non-linear programming problems, its mathematical notation and decision algorithms. Extremal properties on convex sets. Sufficient conditions for optimality. Lagrange function. Optimality condition. Method of penalty functions. Relaxation methods for solving extremal problems. Relaxation processes. The conjugate direction method. Methods: gradient projections; conditional gradient; possible directions; statistical optimisation. Stability and convergence. Non-linear programming solver. |
| **Р6** | **Methods for solving differential equations** | |
| **Р6.Т1** | **Linear differential equations** | Linear differential equations. Solution of a system of linear differential equations. The notion of sustainability. Existing solvers of ordinary differential equations. Discriminator support for the solver options. Partial Differential Equations Toolbox. |
| **Р6.Т2** | **Non-linear differential equations** | Solution of non-linear differential equations. Numerical methods. Euler’s method. The Runge-Kutta method. The Adams-Buffer method. |
| **Р7** | **New technologies for solving mathematical problems of the electric power industry** | |
| **Р7.Т1** | Fuzzy sets | Basic concepts of the theory of fuzzy sets. Basic operations. Membership function. The decision-making logic. Control scheme based on the fuzzy logic. Application of the theory of fuzzy sets for solving problems of the electric power industry. |
| **Р7.Т2** | Artificial neural networks (ANN) | The essence of neural networks. Biological neuron: Soma; Axon; Synaptic contacts; Axon hill; Dendrides. Features of neural network modelling. Activation functions. Multi-layered networks: direct distribution; Kohonen; Hopfield; Hopfield-Lagrange. Training ANN Synthesis of a neural network. Hardware support for neural network models. Use of ANN for selecting operational switching and evaluating the state of EPS. Calculations of steady-state EPS modes using INN. Load prediction. INN solvers. |
| **Р720**  **20.Т3** | Genetic algorithm | The mathematical essence of the genetic algorithm. Fitness function. Chromosome. Population selection.  Crossing. Mutation. Examples of the use of genetic algorithms in solving problems of the electric power industry. GA solvers. |
| **Р9** | **Conclusion** | Review of scientific and technical problems of the electric power industry by using the studied mathematical methods |

# STUDY TIME ALLOCATION

## Distribution of the classroom load and individual work activities by the discipline section



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

## Laboratory practicum

Not applicable

## Practical exercises

Not applicable

## Sample topics of the self-guided work

It involves self-study of the theoretical sections of the discipline

### An indicative list of research paper topics

Not applicable

### An indicative list of homework topics

Not applicable

### An indicative list of test topics

Not applicable

### An indicative list of calculation work topics

Not applicable

### An indicative list of calculation and graphical work topics

Not applicable

### Sample topics of the colloquiums

Not applicable

### Sample topics of the term project (work)

Not applicable

# RATIO 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 |
| Р5 | Interactive learning Technologies |  |  |  |  |  |  |  |  |  |  |  |
| Project work |  |  |  |  |  |  |  |  |  |  |  |
| Case studying |  |  |  |  |  |  |  |  |  |  |  |
| Simulation exercises (games etc.) |  |  |  |  |  |  |  |  |  |  |  |
| Problem learning methods (discussions, exploratory work, research method etc.) | 4 |  |  |  |  |  |  |  |  |  |  |
| Teamwork |  |  |  |  |  |  |  |  |  |  |  |
| Other  Running an online task on the individual training 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) |  |  |  |  |  |  |  |  |  |  |  |

# PROCEDURES FOR THE TRAINING RESULTS MONITORING AND EVALUATION

Not applicable

# PROCEDURES FOR EVALUATING THE TRAINING RESULTS WITHIN THE INDEPENDENT TEST CONTROL

Not applicable

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

Annex 3

## Methodological developments

## Software

The packages Excel, MatCad, MatLab, Mathematica.

## Databases, information, reference and search systems

Not applicable

## Electronic educational resources

http://study.ustu/ru

## Information services that support the learning process

Not applicable

**ANNEX 3**

**to the work programme of the discipline**

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

**8.1. CRITERIA FOR THE EVALUATION OF RESULTS OF THE TEST AND EVALUATION ACTIVITIES OF 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 EVALUATING THE RESULTS OF INTERMEDIATE ATTESTATION DURING THE USE OF INDEPENDENT TESTING CONTROL**

Not applicable

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

**8.3.1.** **Sample tasks for conducting mini-control in the training sessions**

Not applicable

**8.3.2**. **Sample test problems as part of the classroom sessions**

Not applicable

**8.3.3.** **Sample test cases**

Not applicable

**8.3.4.** **A list of sample questions for a test**

Not applicable

**8.3.5. A list of sample questions for preparation for the discipline attestation.**

* Basic concepts and definitions. Electrical system. Steady-state mode (SSM). SSM parameters. Steady-state mode equations (SSME) (concept). (GPC-2)
* SSME classification: by the parameter setting method and by the laws of writing equations. (GPC-2)
* Nodal voltage equations (NVE) for an arbitrary node (output). (GPC-3)
* NVE of the DC network in the form of the current balance of the nodes. (GPC-2)
* NVE of the DC network in the form of the power balance of the nodes. (GPC-3)
* NVE of the DC network in the form of the current balance (complex and real, linear). (GPC-2)
* Non-linear NVE of the DC network in the form of the current balance. (GPC-2)
* Non-linear algebraic NVE of the DC network in the form of the power balance. (GPC-2)
* Nonlinear trigonometric NVEs in the form of power balances. (GPC-2)
* A mathematical model of a network containing nodes with a fixed voltage module. (GPC-2)
* Classification of the methods of solution of a system of linear equations. (GPC-2)
* The inverse matrix method for solving of a system of linear equations. (GPC-2)
* The simplest Gauss method for solving of a system of linear equations. (GPC-3)
* Triangulation method: idea, macro algorithm. (GPC-3)
* Triangulation of the conductivity matrix by the elimination of nodes. Optimal (ordered) exclusion of nodes. (GPC-2)
* Application of the triangulation method: calculation of the inverse matrix and determinant. (GPC-2)
* Solving systems of linear equations with a weak main diagonal with the selection of the main element. (GPC-2)
* Statement of the mathematical programming problem. (GPC-3)
* The general problem of linear programming by the example of the energy transport problem. (GPC-2)
* Standard linear programming problems. Basic ideas of its solution. (GPC-3)
* Geometric interpretation of a simplex algorithm. (GPC-2)
* Simplex-algorithm of the solution of standard linear programming problems. (GPC-3)
* Auxiliary problem (GPC-2)
* The dual problem of linear programming. (GPC-2)
* The macro algorithm of the solution for standard linear programming problems. (GPC-2)
* Reduction of a standard linear programming problem to a standard form: eliminating the functional limitations of inequalities and simple constraints of inequations. (GPC-3)
* Eigenvalues, vectors, matrix norms. (GPC-2)
* The concept of iterative methods and their classification. (GPC-2)
* Advantages, disadvantages and problems of iterative methods. (GPC-3)
* Solving systems of linear equations by the iterative methods: general approach. (GPC-2)
* The fixed point iteration and Gauss-Seidel methods for solving systems of linear equations. (GPC-2)
* Acceleration of convergence of the fixed point iteration method and Seidel (GPC-2)
* Solving the systems of non-linear SSM: statement of the problem and the classification of methods. (GPC-3)
* Newton’s method for solving a system of non-linear SSM. Modified method. (GPC-2)
* Descent methods for solving non-linear SSM systems. The optimal step in the increment vector direction. (GPC-3)
* Gradient methods of descent with optimal pitch. (GPC-2)
* Transformation of sparse matrices. Working with non-zero elements of sparse matrices. (GPC-2)
* Sparse matrix ordering algorithms. (GPC-2)
* Norm, condition number, and the rank of sparse matrices. Calculation of eigenvalues and singular numbers of sparse matrices. (GPC-2)
* Linear approximation of non-linear objective functions and constraint systems in optimisation problems. (GPC-3)
* Linearisation of non-linear systems of differential equations in the analysis of transient processes in electrical systems. (GPC-3)
* Typical optimisation problems of the electric power industry. (GPC-2)
* Lagrange function. Optimality condition. (GPC-2)
* Relaxation methods for solving extremal problems. Relaxation processes. Penalty function method. The conjugate directions method. Methods: gradient projections; conditional gradient; possible directions; statistical optimisation.
* Non-linear programming solvers (GPC-2)
* Stability and convergence problems. (GPC-3)
* Basic concepts of the theory of fuzzy sets. The membership function. (GPC-2)
* The application of the theory of fuzzy sets to solve the problems of the electric power industry. (GPC-2)
* The essence of neural networks. Features of neural network modelling. Activation functions. (GPC-2)
* Multilayer networks: direct distribution; Kohonen; Hopfield; Hopfield-Lagrange. (GPC-2)
* ANN training Neural network synthesis. (GPC-2)
* Calculations of steady-state EPS regimes using INN. Load Forecasting. (GPC-3)
* INN solvers. (GPC-2)
* The mathematical essence of the genetic algorithm. Chromosome. (GPC-2)
* Population selection. Crossing. Mutation. (GPC-2)
* Examples of the use of genetic algorithms in solving the electric power industry problems. (GPC-3)
* GA solvers. (GPC-2)

**8.3.6. A** **list of sample questions for the exam**

Not applicable

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

Not applicable

**8.3.8**. **Federal exam in vocational education resources** **for independent testing**

Not applicable

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

Not applicable