**ELECTROMECHANICAL COMPLEXES AND SYSTEMS** GENERAL CHARACTERISTICS OF THE DISCIPLINE POWER ENGINEERING 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 | **Number of order** |
| 13.06.01 | Electrical- and Thermal 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)*

* 1. **Abstract of the discipline content**

The course *Modern Trends in the Electromechanical System Controls* provides an insight into the main current problems of control of modern electric drives and electromechanical systems.

As a result of mastering the discipline, a student should possess the competencies as follows:

* the ability to critically analyse and evaluate current scientific achievements, generate new ideas for solving research and practical problems, including in interdisciplinary areas (UC-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 both scientific and academic problems (UC-3);
* the readiness to use contemporary methods and technologies of scientific communication in the state and foreign languages (UC-4).
* the ability to follow ethical standards in professional activities (UC-5);
* the ability to plan and accomplish the professional and personal development challenges (UC-6).
* the knowledge of the theoretical and experimental research methodology in the 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 readiness 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).
* 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).
* the ability to collect, process, analyse and systematise information on the research topic, carry out a choice of methods and means for solving research problems (PC-6);
* the readiness to use the latest achievements of science and advanced technologies in the electric power research (PC-7).

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

**Know:**

* the modern natural-science and applied problems of the electrical engineering system control, methods and means for their solution in research, design, production, process-related and other types of professional activity,
* the potential areas of development of domestic and foreign management technologies used in the electrical equipment.

**Be able:**

* to use innovative management technologies to the reconstructed and newly constructed power engineering facilities.

**Demonstrate skills and experience:**

* in mastering methods for improving the electrical system control systems of and.

## Scope of the discipline

|  |  |  |
| --- | --- | --- |
| **Types of educational activity, forms of control** | **Total, hours** | **Term,**  **number** |
| **6** |
| **In-class learning, hours** | **4** | **4** |
| Lectures, hours | 4 | 4 |
| Practical exercises | - | - |
| Laboratory research | - | - |
| **Self-guided** **of graduate students including all the types of the current attestation** | **104** | **104** |
| **Interim attestation** | **test** | **test** |
| **Total work input by curriculum, hours** | 108 | 108 |
| **Total work input by curriculum, credits** | 3 | 3 |

**2. DISCIPLINE CONTENT**

|  |  |  |
| --- | --- | --- |
| Code of section, topic | Discipline section, topic\* | **Content** |
| Р1 | Theory of electric drive | The established modes of operation of the electric drive. Frequency and spectral analysis. The account of elastic links and connections. Allowance for non-linearities. Construction of adequate models with computer technology.  Transient processes in electric drives. Linear and non-linear systems, transfer and transient functions of the electric drive. Examples of the optimal transients during acceleration and braking with the electric processes in the operating mechanism.  Regulation of the electric drive coordinates. The characteristics of electric drive systems: a controlled inverter-DC motor, a frequency converter - an asynchronous motor, a frequency converter - a synchronous motor, systems with step motors, systems with linear motors and their applications. |
| Р2 | Automatic control of the electric drive | Basic functions and structures of the automatic control of the electric drive. Typical functional schemes and typical systems that perform automatic starting, speed stabilisation, reverse and stopping of electric motors. The principles of choosing the element base. General questions of the theory of closed systems of automatic control of an electric drive with a given working mechanism.  Methods of analysis and synthesis of the closed, linear and non-linear, continuous and discrete automated control systems. Application of the variational methods and software packages for computers. |
| РЗ | Theory and principles of operation of the complex electrical machinery modules | The scientific principles and principles of operation of the most common complete units of the electrical machinery (by industry). Voltage converters including: generators and electromechanical converters, controlled rectifier and ac converter inverters, inverters, direct frequency converters of alternating current etc. |

\* The discipline may contain division into only sections, without specifying topics, or only topics

# STUDY TIME ALLOCATION

## Allocation of the classroom load and independent work by disciplines

Scope of discipline (credits) 3

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Discipline section | | | In-class load  (hours) | | | | Self-guided work - type, quantity and scope of activities | | | | | | | | | | | | | | | | | | | | | | | | |
| Code of section, topic | Name of section, topic | Total of section, topic (hours) | Total | Lectures | Practical exercises | Laboratory-based work | Self-guided work, total | Preparation for in-class learning (hours) | | | | | Total (hours) | Performing independent extracurricular activities (scope) | | | | | | | | | **Preparation for test activities (quant.)** | | | **Preparation for the discipline attestation activities (hour)** | | | **Preparation for attestation activities by the module in the discipline (hours)** | | |
| Total | Lectures | Practical seminar classes | Laboratory-based work | Research seminars, conference seminars and colloquiums | Homework\* | Graphical work\* | Research paper, essay, creative work\* | Individual or group project\* | Translation of foreign literature\* j | Calculation wok, programme development\* | Calculation and graphical work\* | Term paper/ multi-disciplinary term work\* | Term paper/ multi-disciplinary term project\* | Total | Test work\* | Colloquium \* | Test given there is an exam | Test if there is no exam | Exam | Integrated assessment of the results of mastering the module disciplines | Integrated module exam | Execution and defence of the project by module |
| P1 | Theory of electric drive | 30 | 2 | 2 |  |  | 28 | 28 | | 28 |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |
| P2 | Automatic control of the electric drive | 29 | 1 | 1 |  |  | 28 | 28 | | 28 |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |
| P3 | Theory and principles of operation of the complex electrical machinery modules | 13 | 1 | 1 |  |  | 12 | 12 | | 12 |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |
|  | Total (hour), excluding preparation for the attestation activities: | 72 | 4 | 4 | 0 | 0 | 68 | 68 | | 68 |  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
|  | Discipline, total (hours) | 108 | 4 |  | | | 104 |  | | | | | | | | | | | | | | | | | | 0 | 0 | 36 | 0 | 0 | 0 |

\*The total amount in hours for an activity is indicated in the line ‘Total (hour), excluding preparation for the attestation activities’

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

## 4.1 Laboratory practicum

Not applicable.

## 4.2 Practical exercises

Not applicable

***4.3 Sample topics of the self-guided work***

### ***An indicative list of homework topics***

### Not applicable

### ***An indicative list of graphical work topics***

### Not applicable

### ***An indicative list of research paper topics (essays, creative work)***

### Not applicable

### ***An indicative list of computational work topics (software products)***

### Not applicable

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

### Not applicable

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

### Not applicable

### ***Sample topics of the colloquiums***

### Not applicable

# RELATION BETWEEN THE DISCIPLINE SECTIONS AND APPLIED TEACHING TECHNOLOGIES\*

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Code of section, discipline topics** | **Active learning methods** | | | | | | **Distant learning technologies and e-learning** | | | | | |
| Project work | Case studying | Business games | Problem training | Teamwork | Other (please specify) | Network training courses | Online workshops and simulators | Webinars and videoconferences | Asynchronous web-conferences and seminars | Collaboration and content development | Other (please specify) |
| Р1 |  |  |  | \* |  |  |  |  |  |  |  |  |
| Р2 |  |  |  | \* |  |  |  |  |  |  |  |  |
| Р3 |  |  |  | \* |  |  |  |  |  |  |  |  |

\*mark with an asterisk or another symbol the applied teaching technologies by the discipline section and topic.

# PROCEDURES FOR MONITORING AND EVALUATION OF THE LEARNING OUTCOMES

Not applicable

1. **PROCEDURES FOR EVALUATING THE LEARNING OUTCOMES WITHIN THE INDEPENDENT TEST CONTROL**

Not applicable

# SET OF EVALUATION TOOLS FOR THE CURRENT AND INTERIM ATTESTATION BY THE DISCIPLINE (Annex 1)

# ACADEMIC AND INFORMATION SUPPORT TO THE DISCIPLINE

## 9.1. Recommended literature

1. Astrom K.J., Wittenmark В. Adaptive control. Second edition. Dover Publications, Inc., Mineoia, New York, 2008. 573 p.
2. Ackermann J. Robust control: system with uncertain physical parameters. New York: Springer-Verlag, 1993.406 pp.
3. Dullerud G.E., Paganini F. A Course in Robust Control Theory: A Convex Approach. Ser. Texts in Applied Mathematics, vol. 36. New York: Springer, 2000. 379 pp.
4. Feng Lin. Robust Control Design. An Optimal Control Approach. John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, England, 2007. 364 pp.
5. Green М., Limebeer D.J.N. Linear robust control. Englewood Cliffs, HJ: Prentice Hall, 1995. 265 pp.
6. Gu D.-W., Petkov P.Hr., Konstantinov M.M. Robust Control Design with MATLAB. London: Spring­er, 2005. 389 pp.
7. Ioannou P., Fidan B. Adaptive Control Tutorial. Philadelphia: SIAM, 2006. 387 pp.
8. Morari М., Zafiriou M. Robust process control. Englewood Cliffs, HJ: Prentice-Hall, 1989. 512 pp.
9. Scherer C. Theory of Robust Control. The Netherlands: Delft University of Technology, 2001. 160 pp.
10. Tao G. Adaptive Control Design and Analysis. Hobocken, NJ: Wiley, 2003. 618 pp.
11. Zhong Q.-C. Robust Control of Time-delay Systems. London: Springer, 2006. 242 pp.
12. Zhou K., Doyle J.C., Glover K. Robust and Optimal Control. Engelwood Cliffs, NJ: Prentice Hall,

1996. 586 pp.

**Databases, information, reference and search systems**

http://lib.urfu.ru UrFU Library Site

http://study.urfu.ru UrFU Portal of the Information and Educational Resources

**ANNEX 1**

**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**

The criteria approved at the Chair for assessing the students’ achievements per each monitoring and evaluation activity. The set of evaluation criteria as well as during the intermediate certification on a module is based on three levels of mastering the competence components, i.e. threshold, higher and high.

|  |  |  |  |
| --- | --- | --- | --- |
| 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. 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 test topics**

Not applicable

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

Not applicable

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

The structure and main elements of the automated electric drive. The equation of motion of a multimass mechanical part, the mechanical part of an electric drive as a control object, a block diagram, transfer functions and frequency characteristics.

The electromechanical properties of engines. The generalised electric machine. Modes of energy conversion.

The mathematical description and electromechanical properties of DC motors with independent excitation of direct current motors with series excitation, asynchronous motors with a short-circuited rotor and a phase rotor, synchronous motors etc.

The electric drive energetics. Evaluation of the efficiency of conversion and electricity consumption. Losses in the steady-state and transient modes. Methods for reducing losses in the drive. Energy saving with an electric drive.

The basics of choosing the installed engine power for various operating modes of the electric drive.

The dynamics of the generalised open-circuit electromechanical system. The mathematical description and block diagrams. Dynamic properties and frequency characteristics. Transient processes in the electromechanical system when using different types of electric motors and with different laws of changing control actions.

The electric drive speed regulation. The regulatory quality indicators. The range of regulation. The main ways to regulate the speed of DC motors, their features and comparative evaluation. Basic ways to regulate the speed of the AC electric drive, their features and comparative evaluation.

The structure of the electric drive as an automatic system and its main elements. The problems and principles of automatic control of the electric drive.

The systems of semiconductor control of DCelectric drives. Mathematical models and structures of the power part of the electric drive. Control systems for DC electric drives along the armature circuit and the excitation circuit. Features of building control systems with subordinate variable control. The synthesis of contour regulators. Frequency characteristics and transient functions under various optimisation criteria for systems with subordinate control. The features of construction and calculation of armature current regulators, single and double speed controllers, two-zone speed control systems and automatic position control systems.

The semiconductor control systems of AC electric drives. Basic types of adjustable AC electric drives. The modern approach to analysis and synthesis of the automatic control of AC electric drives with semiconductor converters. The systems of asynchronous electric drives with amplitude (phase) control. The structures of automatic control systems (ACS). The features of the analogue and synthesis of control systems, dynamic and static characteristics of an asynchronous electric drive with the phase control. The rational fields of application.

The control systems for the frequency-controlled asynchronous electric drives. Modes of operation of an asynchronous motor with a frequency method of speed regulation, the main law of frequency control. The principles of construction, features of analysis and synthesis of scalar and vector control systems. The concept of the orientation of the coordinate system and the selection of the rational coordinate system for the synthesis of ACS by an asynchronous frequency-controlled electric drive. The structures of systems of the frequency-controlled asynchronous electric drives with controlled slip, with frequency-current control, with the ‘Transvektor’ system. The features of structures and qualitative indicators of systems of frequency-controlled asynchronous electric drives with direct torque control. The features of the application of various types of frequency-controlled asynchronous electric drives.

The control systems for frequency-controlled synchronous electric drives. The structure of the automatic control system for a synchronous electric drive. The regulator synthesis features, static and dynamical indicators, the scope of application.

Digital (microprocessor) systems for the automatic control of electric drives. Converting continuous signals into digital form. Quantisation by level and time. Frequency spectrum of a discrete signal. The mathematical description of one-dimensional and multidimensional discrete systems. Frequency characteristics and dynamic properties. A description of discrete systems in the state space. The functional and structural diagrams of digital speed controllers, speed ratios and positions of the automated electric drives. The specific features of analysis and synthesis of digital systems in comparison with continuous one. Discrete analogues of estimates and criteria adopted for continuous automatic systems. The optimality criteria of the automated electric drives. The principles of analysis and synthesis of optimal discrete electric drive systems.

Converters for the electric drives with DC motors. Three-phase rectifier-inverter converter with zero wire. Intermittent and continuous current mode. The adjustment and external characteristics of the thyristor converter-motor system. The inverter mode of the converter, the main properties of the inverter mode.

Three-phase bridge converter. A schematic diagram and an analysis of its operation. The concept of a generalised converter. Reversible converters. The coordination of the control angles of the valve sets. Basic circuits of two-component converters with the combined and separate control.

The converter power coefficient, methods for its increase, the effect of converters on the supply network, ways to improve the electromagnetic compatibility of semiconductor electric drives with the supply network.

Converters for electric drives with AC motors. Two-link frequency converters with an autonomous voltage inverter (AVI) and an autonomous current inverter (ACI). An analysis of electromagnetic processes. The basic properties of transducers, a comparative analysis.

Direct frequency converters (DFC) for supplying asynchronous motors (AM). The power circuit schemes. Advantages and disadvantages of DFC. Areas of use.

Thyristor voltage converters (TVC) for supplying stator circuits of asynchronous motors. Adjustment characteristics. The main operating modes of the TVC-AM system. Advantages and disadvantages of the asynchronous electric drives with TVC.

Electricity converters with pulse regulation. Pulse-width converters (PWC) for DC motors. An analysis of the operation of single-key and four-key PWC. Autonomous inverters of two-link frequency converters with pulse-width modulation of the output voltage. Autonomous current inverter with the pulse-width modulation (PWM). Two-level three-phase AVI.

The elements of electric drive control systems. Operational amplifiers, the design features, varieties, use for the construction of ACS regulators. The elements of digital control systems. Microcontrollers. Logic controllers. Analogue-digital converters (ADCs) and digital-to-analogue converters (DACs). Sensors of the electric drive systems.

**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