Національний технічний університет України
«КИЇВСЬКИЙ ПОЛІТЕХНІЧНИЙ ІНСТИТУТ
імені ІГОРЯ СІКОРСЬКОГО»

Department of Automation
of Electrical and
Mechatronic Complexes

# Reliability of electrical and mechatronic systems

## Working program of educational discipline (syllabus)

### Requisites of educational discipline

**Higher education level** ***Second (master)***

| | |
|---|---|
| **Knoweledge domain** | **14 Electrical Engineering** |
| **Specialty** | **141 Electric Power Engineering, Electrotechnics and Electromechanics** |
| **Educational program** | **EPP, ESP "Engineering of intelligent electrical and mechatronic complexes"** |
| **Status of the discipline** | *Normative* |
| **Form of education** | *Full-time (day-time)* |
| **Year of** study**, semester** | *I course, autumn semester* |
| **Teaching hours** | *120 hours / 4 credits ECTS (lections – 36 hours, seminars – 18 hours, self students studying – 66 hours)* |
| **Semester control / control activities** | *credit, modular test, calculation and graphical assignment* |
| **Schedule** | *http://rozklad.kpi.ua/* |
| **Language of study** | *English* |
| **Інформація про керівника курсу / викладачів** | Lections and seminars are given by:<br>*PhD, assoc. prof., , assoc. prof. of Department of AEMC Viktor Gorodetskyi, v.gorodetskyi@ukr.net* |
| **Розміщення курсу** | Googleclassroom, oltnw7u |

### Program of educational discipline

#### 1. Description of the discipline, its purpose, subject of study and learning outcomes

The discipline considers the main approaches to assessing the reliability of electrical and mechatronic systems used in energy-intensive industries. The basis of the course is not only the mathematical apparatus for calculating the reliability of these systems, but also the physical basis of operation of such equipment, which affects its reliability.

The **purpose** of the discipline is to form a system of basic knowledge to solve professional problems of reliable operation of specific electromechanical equipment of these industries, the design of such equipment taking into account the reliability factor.

The **subject** of study of the discipline is a set of questions on the theoretical basis of calculating the reliability and methods of improving the reliability of equipment at different stages. As a result of studying the discipline "Reliability of electrical and mechatronic systems" students receive the following **competencies**:

General competencies:

1) Ability to search, process and analyze information from various sources (K01),
2) Ability to apply knowledge in practical situations (K03),
3) Ability to make informed decisions (K05),
4) Ability to identify and assess risks (K07),

Professional competencies:

1) Ability to develop and implement measures to increase reliability, efficiency and safety in the design and operation of equipment and objects of the power industry, electrical engineering and electromechanics (K12).
2) The ability to develop plans and projects to ensure the achievement of a specific goal, taking into account all aspects of the problem being solved, including production, operation, maintenance and disposal of equipment of electric power, electrotechnical and electromechanical complexes (K17).
3) Ability to demonstrate awareness and ability to use normative legal acts, norms, rules and standards in electric power, electrical engineering and electromechanics (K18).
4) The ability, based on the analysis of static and dynamic loads, operating characteristics, to calculate and develop optimal equipment designs and operating modes of simple and complex electromechanical complexes using modern computer methods of mathematical modeling (K24),

Program learning outcomes:

1) Outline a plan of measures to increase the reliability, safety of operation and prolong the resource of electric power, electrotechnical and electromechanical equipment and relevant complexes and systems (PR02),
2) Reconstruct existing electrical networks, stations and substations, electrotechnical and electromechanical complexes and systems in order to increase their reliability, efficiency of operation and extension of the resource (PR04),
3) Perform physical and mathematical modeling, static and dynamic analyzes of structures, mechanisms, materials and processes at the design stage, investigate the reliability of systems, using modern computer tools (PR15),
4) Select the element base of electromechanical and mechatronic systems, complete electric and hydraulic drives, means of control, protection, automation of power supply systems of machines and installations, production sites and enterprises (PR16).

## 2. Prerequisites and post requisites of the discipline (place in the structural and logical scheme of education according to the relevant educational program)

*The study of the discipline is based on the following courses: "Higher mathematics", "Physics", "Electrotechnical materials", "Hydraulics and hydropneumatic drive". "Electrical equipment and power supply machines and installations of electrotechnical complexes". Post-requisite of the discipline is "Pre-diploma practice".*

## 3. The content of the discipline

The discipline consists of 3 sections:

**Section 1.** Mathematical foundations of reliability
Topic1.1. Basic concepts of reliability theory
Topic 1.2. The main quantitative characteristics of the reliability of elements and systems
Topic 1.3. Mathematical apparatus of reliability theory
Topic 1.4. Methods for calculating the reliability for the main connection of elements
Topic 1.5. Analysis of the reliability characteristics of equipment with redundancy
**Section 2.** Physico-chemical bases of reliability
Topic 2.1. Physico-chemical processes of materials destruction
Topic 2.2. Physical and chemical nature of failures of electromechanical systems
**Section 3.** Reliability of equipment in various industries
Topic 3.1. Methods of calculating reliability for complex systems
Topic 3.2. Reliability of equipment for power supply systems
Topic 3.3. Reliability of mine equipment
Topic 3.4. Reliability of quarry electromechanical equipment
Topic 3.5. Reliability of equipment of oil pumping stations
Topic 3.6. Reliability of control systems
Topic 3.7. Methods to increase reliability

## Training materials and resources

### *Basic literature*


1. Patrick D. T. O'Connor, Andre Kleyner. Practical Reliability Engineering. Fifth Edition. A John Wiley & Sons, Ltd.
2. Kailash C. Kapur, Michael Pecht. Reliability Engineering. Wiley. Springer Series in Reliability Engineering
3. A.P. Teixeira, Carlos Guedes Soares. Fundamentals of Reliability. In book: Thermal Power Plant Performance Analysis. DOI: 10.1007/978-1-4471-2309-5_5.


### *Additional literature*


1. J.W. McPherson. Reliability Physics and Engineering. Springer New York Dordrecht Heidelberg London, 2010.
2. Alessandro Birolini. Reliability Engineering: Theory and Practice. Springer-Verlag Berlin Heidelberg, 2007.
3. DSTU 2860-94. Reliability of equipment. Terms and definitions.
4. Marek Sokolski. Mining Machines and Earth-Moving Equipment. Springer. – 2020, 226 p.


### *Information resources*

https://aemk.kpi.ua/

## Educational content

### 4. Methods of mastering the discipline (educational component)

Active learning strategies are applied, which are determined by the following methods and technologies: problem-based learning methods (research method); person-oriented technologies based on such forms and methods of learning as visualization and information and communication technologies, in particular electronic presentations for lectures. Teaching is conducted in the form of lectures and practical classes. The problem-search method is used in practical classes and when performing calculation work.

- **Distribution of study time**

| Titles of sections and topics | Number of hours | | | |
|---|---|---|---|---|
| | Total | Including | | |
| | | Lectures | Practical | SSS* |
| 1 | 2 | 3 | 4 | 5 |
| **Section 1.** Mathematical foundations of reliability | | | | |
| Topic1.1. Basic concepts of reliability theory | 4 | 2 | - | 2 |
| Topic 1.2. The main quantitative characteristics of the reliability of elements and systems | 8 | 4 | 2 | 2 |
| Topic 1.3. Mathematical apparatus of reliability theory | 6 | 4 | 2 | - |
| Topic 1.4. Methods for calculating the reliability for the main connection of elements | 12 | 6 | 4 | 2 |
| Topic 1.5. Analysis of the reliability characteristics of equipment with redundancy | 10 | 4 | 4 | 2 |
| **Total for section 1** | 40 | 20 | 12 | 8 |
| **Section 2.** Physico-chemical bases of reliability | | | | |
| Topic 2.1. Physico-chemical processes of materials destruction | 4 | 2 | - | 2 |
| Topic 2.2. Physical and chemical nature of failures of electromechanical systems | 4 | 2 | - | 2 |
| Modular test (part 1) | 4 | 1 | | 3 |

| | | | | |
|---|---|---|---|---|
| **Total for section 2** | 12 | 5 | | 7 |
| **Section 3.** Reliability of equipment in various industries | | | | |
| Topic 3.1. Methods of calculating reliability for complex systems | 4 | - | 4 | - |
| Topic 3.2. Reliability of equipment for power supply systems | 6 | 2 | 2 | 2 |
| Topic 3.3. Reliability of mine equipment | 4 | 2 | - | 2 |
| Topic 3.4. Reliability of quarry electromechanical equipment | 4 | 2 | - | 2 |
| Topic 3.5. Reliability of equipment of oil pumping stations | 2 | 2 | - | - |
| Topic 3.6. Reliability of control systems | 2 | - | - | 2 |
| Topic 3.7. Methods to increase reliability | 4 | 2 | - | 2 |
| Modular test (part 2) | 4 | 1 | | 3 |
| **Total for section 3** | 30 | 11 | 4 | 13 |
| Calculation work | 8 | | | 8 |
| Exam | 30 | | | 30 |
| Total | 120 | 36 | 18 | 66 |

*) SSS - self students studying

- **Practical lessons**

The main task of the series of practical classes is to consolidate the knowledge gained in lectures

| Назва теми заняття та перелік основних питань |
|---|
| **Practical lesson 1**. Quantitative characteristics of the reliability of non-repairable systems. |
| **Practical lesson 2**. Calculation of system reliability at different distributions. |
| **Practical lesson 3.** Calculation of system reliability at the main (series) connection of elements. Exponential distribution. |
| **Practical lesson 4.** Calculation of system reliability at the main (series) connection of elements. Types and stages of calculations. |
| **Practical lesson 5.** Calculation of reliability of systems with redundancy. |
| **Practical lesson 6.** Calculation of reliability of systems with redundancy. |
| **Practical lesson 7.** Calculation of reliability of complex systems. The method of minimum paths and minimum cross sections. |
| **Practical lesson 8.** Calculation of reliability of complex systems. Decomposition method in relation to a special element. |
| **Practical lesson 9.** Reliability of power supply equipment. |

- **Calculation and graphical assignment**

During the semester, students perform calculation and graphical assignment on the topic "Reliability of electrical and mechatronic systems." To perform this assignment, students are required to study topic 3.1.

### 5. Self students studying

The self students studying includes preparation for surveys, preparation for practical work, performance and defense of calculation work, as well as preparation for modular control work and exam.

## Policy and control

### 1. Policy of academic discipline (educational component)

Study of the educational discipline "Reliability of electrical and mechatronic systems" requires from the applicant of higher education:

- observance of educational and academic ethics;
- compliance with the schedule of the educational process;

- be balanced, attentive in classes;
- systematically study theoretical material;
- compliance with the schedule for the protection of calculation and laboratory work. The applicant's answer must show signs of independent performance of the assigned task, absence of signs of repetition and plagiarism.

If the student of higher education was absent from the lecture, then he should practice this lecture at another time (with another group, at a consultation). If the student of higher education was absent from practical classes, he should complete these classes at another time (with another group, at a consultation).

## 7. Types of control and rating system for evaluating learning outcomes (RSO)

**On-going monitoring**: MKR is conducted before the calendar monitoring in the lecture session in the presence of the teacher. MKR is performed in the form of answers to theoretical questions from the lecture material. At the end of the class, the work on the MKR ends and cannot be rewritten. MKR is estimated at 14 points according to the following criteria:

- "excellent" - a complete answer (at least 90% of the required information), relevant justifications and a personal opinion are provided - 14-13 points;
- "good" - a sufficiently complete answer (at least 75% of the required information), which is completed in accordance with the requirements for the "skills" level or contains minor inaccuracies - 12-10 points;
- "satisfactory" - an incomplete answer (at least 60% of the required information), completed in accordance with the requirements for the "stereotypical" level and containing some errors - 9-8 points;
- "unsatisfactory" - unsatisfactory answer - 0 points.

Tasks within the framework of a practical lesson are evaluated in 4 points according to the following criteria:

- "excellent" - fully completed work (at least 90% of the required information), appropriate justification and personal opinion provided - 4 points;
- "good" - the work contains certain inaccuracies (at least 75% of the required information), the justifications provided are not complete enough - 3 points;
- "satisfactory" - the work contains significant inaccuracies (at least 60% of the required information), the work is performed in accordance with the requirements for the "stereotypical" level and contains significant errors - 2 points;
- "unsatisfactory" - the answer indicates the student's unpreparedness - 0 points.

**Calendar control**: is conducted twice a semester as a monitoring of the current state of fulfillment of the syllabus requirements. The condition for a positive first and second calendar control is to obtain at least 50% of the maximum possible rating at the time of the corresponding calendar control.

**Semester control**: exam.

A prerequisite for admission to the exam is full completion of the curriculum, as well as a preliminary rating of at least 36 points and at least one positive certification.

At the exam, students perform a written test. The exam paper is valued at 40 points. The control task of this work consists of two theoretical questions from the list provided in the appendix to the syllabus and task. Each theoretical question is valued at 15 points (10-point problem) according to the following criteria:

- "excellent" - a complete answer (at least 90% of the required information), relevant justifications and a personal opinion are provided - 15-13 points;
- "good" - a sufficiently complete answer (at least 75% of the required information), which is completed in accordance with the requirements for the "skills" level or contains minor inaccuracies - 12 - 11 points;
- "satisfactory" - an incomplete answer (at least 60% of the required information), completed in accordance with the requirements for the "stereotypical" level and containing some errors - 10-9 points;
- "unsatisfactory" - unsatisfactory answer - 0 points.

The student's credit module rating consists of the points he receives for:

1) execution of 1 modular control work;
2) answers in practical classes;
3) execution and protection of settlement work;
4) the answer to the exam.

The system of rating points and evaluation criteria:

| **Types of work** | Timely passing the test |
|---|---|
| ***1. Modular control work:*** | |
| - completely done work | 14 |
| - the work is done with minor errors | 12 |
| - work is not credited | 0 |
| ***2. Answers to practical classes:*** | |
| - the answer demonstrates excellent mastery of the material | 4 |
| - the answer indicates minor gaps in material ownership | 3 |
| - the answer indicates the unpreparedness of the student | 0 |
| ***3. Performing calculation work:*** | |
| - the task is defended with excellent mastery of the material | 8 |
| - the task is defended with minor errors | 6 |
| - the task is not completed | 0 |

**Calculation of the rating scale during semester (RS)**

**RS (max)=6*4+1*8+14*2=60 points**
**RC(min)= 36 points**

**At the exam,** students perform a written test. Each task contains two theoretical questions and one problem. Each theoretical question is evaluated at 15 points, the problem - at 10 points.

Theoretical questions evaluation system:
- "excellent", complete answer (not less than 90% of the required information) - 15 points;
- "good", a sufficiently complete answer (at least 75% of the required information), or a complete answer with minor inaccuracies - 12 points;
- "satisfactory", incomplete answer (not less than 60% of the required information) and minor errors - 9 points;
- "unsatisfactory", unsatisfactory answer (does not meet the requirements for "satisfactory") - 0 points.

**Rating score scale and exam evaluation criteria (RE):**

| | Points |
|---|---|
| - Completely correct answer | 40...38 |
| - Answer with minor errors | 37...30 |
| - Answer with errors | 29...20 |
| - Answer is not credited | 19-0 |

**The rating scale of the discipline is R=RS+RE=60+40=100 points**

**Translation of rating points to grades on a university scale**

| *Rating points, RP* | *A mark on a university scale* |
|---|---|
| $95 \le RP \le 100$ | Exellent |
| $85 \le RP \le 94$ | Very good |
| $75 \le RP \le 84$ | Good |
| $65 \le RP \le 74$ | Satisfactory |
| $60 \le RP \le 64$ | Sufficient |
| $RP < 60$ | Unsatisfactorily |

A necessary condition for admission to the exam is the full implementation of the curriculum, as well as a preliminary rating of at least 36 points. Students who complete additional tasks and show creative initiative receive incentive points from 1 to 10.

## 8. Additional information on the discipline (educational component)

Control questions in the discipline "Reliability of electrical and mechatronic systems"

1. Definition of reliability and the concept of failure
2. The concept of service life, limit state and maintainability
3. The concept of the probability of failure
4. The concept of failure rate
5. The concept of failure rate. The relationship between the main quantitative characteristics of the reliability of non-renewable systems in the general case
6. The concept of average uptime
7. The concept of average failure time, coefficients of readiness and coefficients of forced downtime
8. Exponential distribution
9. Normal distribution
10. Weibull distribution
11. Ratios for calculation for the main connection of elements
12. The concept of estimated calculation of reliability
13. The concept of approximate calculation of reliability
14. The concept of the final calculation of reliability
15. The sequence of reliability calculation
16. Structural, functional, time, load and information redundancy
17. Multiplicity of redundancy, redundancy with integer and fractional multiplicity
18. General and element-by-element reservation, permanent reservation and reservation with replacement
19. Analysis of reliability characteristics with a permanently included reserve in the case of general redundancy
20. Analysis of reliability characteristics with a permanently included reserve in the case of element-by-element redundancy
21. Analysis of the characteristics of reliability in general and element-by-element redundancy
22. Internal defects of materials
23. The concept of diffusion and sorption
24. Destruction of materials under mechanical stress
25. Destruction of materials during their aging
26. Electrical destruction of materials
27. Failures in terms of strength
28. Tribological failures
29. Failures on corrosion parameters
30. Reliability of overhead power lines in EPS
31. Reliability of cable power lines in EPS
32. Reliability of power lines with SIW (Self-supporting insulated wire)
33. Reliability of power transformers and switching devices in EPS
34. The method of minimum paths and minimum cross sections
35. Using graphs to assess the reliability of systems
36. Using algebra of logic to evaluate the reliability of systems
37. Kolmogorov-Chapman equation
38. The method of decomposition of a relatively special element
39. The rule of determining the minimum cross sections of complex systems

Work program of the discipline (syllabus):
Compiled by Ph.D., Assoc. Prof. Gorodetskyi Viktor G.
Approved by the Department of Automation of Electrical and Mechatronic Complexes
(Protocol № 18 of 24.06.2024)
Approved by the Methodical Commission of the IEE Institute (Protocol № 21 of 25.06.2024)