Reliability and energy efficiency of electrical and mechatronic complexes

Working program of educational discipline (syllabus)

Requisites of educational discipline

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

Knoweledge branch	**G Engineering, Manufacturing and Construction**
Specialty	**G3 Electrical Engineering**
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, spring semester*
Teaching hours	*120 hours / 4 credits ECTS (lectures – 30 hours, seminars – 16 hours, laboratory works - 14 hours, self students studying – 60 hours)*
Semester control / control activities	*credit, modular test, calculation and graphical assignment*
Schedule	*http://rozklad.kpi.ua/*
Language of study	*English*
Course Leader/Teacher Information	Lectures and seminars are given by: *PhD, assoc. prof., , assoc. prof. of Department of AEMC Viktor Gorodetskyi, v.gorodetskyi@ukr.net, laboratory works are given by senior lecturer Volodymyr Dubovyk, processor-wl@ukr.net*
Course Location	https://classroom.google.com/c/Nzg2NDg4Njc3ODkx?cjc=57733od3

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**:

Professional competencies (PC):

1) Ability to develop and implement measures to improve reliability, efficiency and safety in the design and operation of equipment and facilities of Electric Power Engineering, Electrotechnics and Electromechanics (PC 02).

2) Ability to demonstrate knowledge and understanding of the mathematical principles and methods required for use in the Electric Power Engineering, Electrotechnics and Electromechanics industries. (PC 04).
3) Ability to develop intelligent solutions to increase the efficiency of electrical and mechatronic systems. (PC 12),

Program learning outcomes:

1) Outline an action plan to improve the reliability, operational safety, and resource extension of electric power, electrical and electromechanical equipment, and related complexes and systems. (PLO 02),
2) To reconstruct existing electrical networks, stations, and substations, electrotechnical and electromechanical complexes and systems in order to improve their reliability, operational efficiency and service life extension. (PLO 04),
3) Perform physical and mathematical modeling, static and dynamic analyses of structures, mechanisms, materials, and processes at the design stage, and investigate the reliability of systems, using modern computer tools. (PLO 15),
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 2 sections:

Section 1. Basic concepts of reliability and energy efficiency
Topic1.1.The relationship between reliability and energy efficiency of electrical equipment
Topic1.2. Basic concepts of reliability theory
Topic 1.3. The main quantitative characteristics of the reliability of elements and systems
Topic 1.4. Mathematical apparatus of reliability theory
Topic 1.5. Methods for calculating the reliability for the main connection of elements
Topic 1.6. Analysis of the reliability characteristics of equipment with redundancy
Section 2. Reliability of equipment in various industries
Topic 2.1. Methods of calculating reliability for complex systems
Topic 2.2. Reliability and energy efficiency of power supply system equipment
Topic 2.3. Reliability and energy efficiency of geotechnical equipment
Topic 2.4. Reliability and energy efficiency of control systems
Topic 2.5. Reliability and energy efficiency of the electric drive

4. Training materials and resources

Basic references

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.
4. Sumper, Andreas, and Angelo Baggini. Electrical energy efficiency: technologies and applications. John Wiley & Sons, 2012.

5. Gilbert M. Masters. Renewable and Efficient Electric Power Systems. IEEE PRESS. Wiley. 2013

6. Zhong, Qing-Chang, and Tomas Hornik. Control of power inverters in renewable energy and smart grid integration. John Wiley & Sons, 2012.

Additional references

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

5. 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			
		Lec-tures	Prac-tical	Labo-ratory	SSS*
1	2	3	4	5	6
Section 1. Mathematical foundations of reliability					
Topic 1.1. The relationship between reliability and energy efficiency of electrical equipment	4	2			2
Topic1.2. Basic concepts of reliability theory	4	2			2
Topic 1.3. The main quantitative characteristics of the reliability of elements and systems	6	2	2		2
Topic 1.4. Mathematical apparatus of reliability theory	6	2	2		2
Topic 1.5. Methods for calculating the reliability for the main connection of elements	12	4	4		4
Topic 1.6. Analysis of the reliability characteristics of equipment with redundancy	10	2	4		4
Modular test (part 1)	6	1			5
Total for section 1	48	15	12		21
Section 2. Reliability and energy efficiency of equipment in various industries					
Topic 2.1. Methods of calculating reliability for complex systems	10	2	4		4
Topic 2.2. Reliability and energy efficiency of equipment for power supply systems	6	4			2
Topic 2.3. Reliability and energy efficiency of geotechnical equipment	12	4	-	4	4
Topic 2.4. Reliability and energy efficiency of control systems	14	2	-	8	6
Topic 2.5. Reliability and energy efficiency of the electric drive	6	2	-	2	2

Modular test (part 2)	6	1			5
Total for section 2	54	15	4	14	23
Calculation and graphical work	10				10
Test	6				6
Total	120	30	16	14	60

*) SSS - self students studying

- **Practical lessons**

The main task of the series of practical classes and laboratory works 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. Determining energy-efficient modes of a conveyor system.

- Laboratory work

№	Name	Topic
Лабораторна робота 1	Research on the energy efficiency of a switching power supply	2.4
Лабораторна робота 2	Research on the energy efficiency of a pump unit with a frequency converter	2.3
Лабораторна робота 3	Research on the energy performance of an asynchronous motor using a frequency converter and a voltage converter	2.5
Лабораторна робота 4	Research on the energy performance of a fan unit with a valve motor	2.3
Лабораторна робота 5	Research on the energy performance of a bridge rectifier	2.4
Лабораторна робота 6	Research on the transient processes of the «Frequency converter-asynchronous motor» system (4 hours)	2.4

- **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 2.1.

6. 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.

7. 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).

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

On-going monitoring: Modular test (MT) is conducted before the calendar monitoring in the lecture session in the presence of the teacher. MT 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. MT is estimated at 20 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 – 16-18 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 - 14-15 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 - 12-15 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 - 5 points;
- "good" - the work contains certain inaccuracies (at least 75% of the required information), the justifications provided are not complete enough - 4 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 - 3 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.

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

1) execution of 1 Modular test (20 points);
2) answers in practical classes (5 points);
3) execution and defense of laboratory work (5 points);
4) execution and defense of calculation and graphical work (15 points).

The system of rating points and evaluation criteria:

Types of work	Timely passing the test

1. Modular test:	
- completely done work	20
- the work is done with minor errors	18
- work is not credited	0
2. Answers to practical classes:	
- the answer demonstrates excellent mastery of the material	5
- the answer indicates minor gaps in material ownership	4
- the answer indicates the unpreparedness of the student	0
3. Захист лабораторних робіт:	
- the answer demonstrates excellent mastery of the material	5
- - відповідь свідчить про незначні прогалини у володінні матеріалом	4
- відповідь свідчить про неготовність студента	0
4. Performing calculation and graphical work:	
- the task is defended with excellent mastery of the material	15 балів
- the task is defended with minor errors	12 балів
- the task is not completed	0

Calculation of the rating scale during semester (RS)

RS (max)=3*5+6*5+1*15+2*20=100 балів
RS (min)= 60 балів

Translation of rating points to grades on a university scale

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

9. 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 path and minimum cut sets
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
40. Features of calculating electricity losses in low-voltage SEPs
41. Indicators of electricity use in lifting installations
42. Energy indicators of electricity use in fan installations
43. Range of effective electricity consumption in water drainage installations
44. Features of using compressor installations in energy-efficient modes
45. Criteria for energy-efficient use of electricity in conveyor installations
46. Rational regulation of fan installations
47. Features of controlling the performance of pump installations
48. Conditions for energy-efficient regulation of the speed of conveyor installations
49. Features of regulating the speed of lifting machines
50. Use of energy storage devices to increase energy efficiency
51. Conditions for using conversion equipment in SEPs

Work program of the discipline (syllabus):
Compiled by Ph.D., Assoc. Prof. Gorodetskyi Viktor G.
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Approved by the Methodical Commission of the ER IEE Institute (Protocol № 30 of 25.06.2025)