National Technical
University of Ukraine
"Igor Sikorsky
Kyiv Polytechnic Institute"

Department of Automation of Electrical and Mechatronic Complexes

Intelligent Decision-Making Systems

Working program of the academic discipline (Syllabus)

Details of the academic discipline	
Level of higher education	*Second (master's degree)*
Branch of knowledge	*14 Electrical engineering*
Specialty	*141 Power engineering, electrical engineering and electromechanics*
Educational program	*Engineering of intelligent electrotechnical and mechatronic complexes*
Статус дисципліни	*Normative*
Форма навчання	*daytime*
Year of preparation, semester	*1 year, autumn semester*
Scope of the discipline	*4,5 credits / 135 hours*
Semester control/ control activities	*Test*
Class schedule	*roz.kpi.ua*
Teaching language	*English*
Information about head of the course / teachers	*Lecturer and practical classes: Ph.D., Assoc. Prof. Leonid Kulakovskyi* *e-mail: kulakovskiyl@ukr.net; ph. +38-06=97-453-65-46 (08:00 – 16:00)*
Placement of the course	*https://classroom.google.com/c/NjE1OTQ1OTk5Njcz*

Program of educational discipline

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

The syllabus of the educational component "Intelligent decision-making systems" is compiled in accordance with the master's education program "Engineering of intelligent electrotechnical and mechatronic complexes" specialty 141 - Power engineering, electrical engineering and electromechanics.

This discipline is a continuation of students' acquaintance with decision making in operation of electrotechnical and mechatronic complexes. Integrated systems of computer mathematics are used to solve various educational, scientific and engineering tasks with the help of special mathematical computer programs. These programs represent a set of theoretical, algorithmic, hardware and software tools and are specially created for the most effective solution of certain mathematical problems. To solve most mathematical problems the decision making is of interest.

The purpose of the educational discipline is to form and consolidate the following competencies in students:

(K11) Ability to apply existing and develop new methods, techniques, technologies and procedures for solving engineering tasks of electric power, electrical engineering and electromechanics.

(K14) Ability to demonstrate knowledge and understanding of mathematical principles and methods required for use in electrical power, electrical engineering, and electromechanics.

(K17) 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.

(K23) Ability to optimize technological processes and build structural diagrams of intelligent automated control systems.

The subject of study of this discipline gives the student the knowledge and skills necessary to solve the problems of intellectual decision-making in the systems of electrotechnical and mechatronic complexes. The discipline is designed to form in students a systematic approach to solving the actual problems of making certain decisions regarding the management and control of the technological process and the optimization of the use of energy resources.

Program learning outcomes, the formation and improvement of which the discipline is aimed at: (PR03) Analyze processes in electric power, electrotechnical and electromechanical equipment and relevant complexes and systems; (PR07) Plan and implement scientific research and innovative projects in the field of electric power, electrical engineering and electromechanics; (PR10) To justify the choice of direction and methodology of scientific research taking into account modern problems in the field of electric power, electrical engineering and electromechanics; (PR13) Identify the main factors and technical problems that may hinder the implementation of modern methods of controlling electric power, electrotechnical and electromechanical systems.

2. of training according to the relevant educational program)

The study of the discipline is based on the knowledge acquired by students in the fundamental and professionally oriented disciplines "Higher Mathematics", "Theoretical Basics of Electrical Engineering", "Electric Machines", "Electric Drive".

The knowledge and skills acquired in the process of studying the credit module "Engineering of electrical and mechatronic systems" are necessary for every specialist of this specialty who solve engineering tasks in the field of decision-making to ensure the functioning of electrotechnical and mechatronic complexes and when completing a master's thesis.

3. Content of the academic discipline

Chapter 1. Basic concepts of decision-making systems.

Topic 1.1. General principles of building Intelligent decision-making systems.

Topic 1.2. Definition and classification of expert systems. Analytical hierarchy method.

Chapter 2. Problems of linear programming in decisions on the management of electrotechnical and mechatronic complexes.

Topic 2.1. Basic theoretical information of linear programming problems to optimize the operation of the electrotechnical and mechatronic complex.

Topic 2.2. Solving problems of linear programming by the graphical method when making decisions on the management of the work of electrotechnical and mechatronic complexes.

Topic 2.3. A simplex method for solving linear programming problems.

Topic 2.4. The simplex method with the introduction of an artificial basis.

Chapter 3. Non-linear programming problems in the decision-making process for managing the work of electrotechnical and mechatronic complexes.

Topic 3.1. Peculiarities of the formation of non-linear programming problems in decision-making on the operation of electrotechnical and mechatronic complexes.

Topic 3.2. Solving the conditional optimization problem using the method of Lagrange multipliers.

Topic 3.3. A simple gradient method.

Topic 3.4. Numerical optimization methods. Method with step splitting. Method of coordinate descent.

Topic 3.5. Method of configurations (Hooke-Jeeves). The method of movement by pattern.

Topic 3.6. Random search method. Cauchy (fastest descent) method.

Chapter 4. Problems of quadratic, convex and heuristic programming.

Topic 4.1. Convex optimization problems with constraints. Methods used for their solution.

Topic 4.2. Frank-Wulf method (conditional gradient method or algorithm of convex combinations) for solving nonlinear function optimization problems.

Topic 4.3. Ravine and multiextremal functions (Ostrovsky's method).
Topic 4.4. Minimization of the additive objective function by the method of dynamic programming.
Chapter 5. Game theory as a model of decision-making.
Topic 5.1. Basic concepts of game theory. Criteria. Game decision concepts.
Topic 5.2. The problem of power distribution in terms of game theory.

4. Educational materials and resources

Primary literature:

1. Jatinder N.D. Gupta, Guisseppi A. Forgionne, Manuel Mora Intelligent Decision-making Support Systems: Foundations, Applications and Challenges, Springer, 2006, 503 p.
2. George B. Dantzig Mukund N. Thapa Linear Programming, Introduction. Series Editor: Department of Operation Research, Stanford, CA 94305, 1997, 474 p.
3. Paul R. Thie, G. E. Keough An introduction to linear programming and game theory, Published by John Wiley & Sons, Inc., Hoboken, New Jersey, 3rd edition, 2008, 476 p.
4. Nonlinear Programming: Theory and Algorithms: Bazaraa, Mokhtar S., Sherali, Hanif D., Shetty, C. M. Published by John Wiley & Sons, Inc., Hoboken, New Jersey, 2006, 853 p.

Secondary literature:

5. Phillips-Wren, Gloria & Ichalkaranje, Nikhil & Jain, Lakhmi. (2008). Intelligent Decision Making: An AI-Based Approach. 10.1007/978-3-540-76829-6.
6. Maryse Salles Decision-Making and the Information System, ISTE Ltd and John Wiley & Sons, Inc., Volume 3, 2015, 211 p.
7. Marco Cavazzuti Optimization Methods:From Theory to Design. Scientific and Technological Aspects in Mechanics, Springer Heidelberg New York Dordrecht London, 2013, 514 p.

Literature, the bibliography of which is provided with a link, can be found on the Internet. Literature, the bibliography of which does not contain references, can be found in the library of KPI named after Igor Sikorsky. Basic literature [1]-[3] is mandatory for learning. All other literary sources are optional, it is recommended to familiarize yourself with them.

Educational content

5. Methods of mastering an educational 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.

№ з/п	*Content of educational work*
1	**Lecture 1.** Topic 1.1. Subject and structure of the course, methods of teaching and assessment of knowledge. General principles of building intelligent decision-making systems. Decision making process. **Literature:** [1].
2	**Lecture 2.** Topic 1.2. Definition and classification of expert systems. Basic functions of the expert system. Models of formalization and solution of practical problems in the environment of expert systems. Analytical hierarchy method **Literature:** [1,6].
3	**Lecture 3.** Topic 2.1. Basic theoretical information of linear programming problems to

	optimize the operation of the electrotechnical and mechatronic complex. General canonical linear programming problem. Basic properties of linear programming problem solutions. Geometric interpretation of the problem of linear programming. **Literature:** [2].
4	**Lecture 4.** Topic 2.2. Solving problems of linear programming by the graphical method when making decisions on the management of the work of electrotechnical and mechatronic complexes. Geometric interpretation of the method. General properties of problems. Basic analytical properties. **Literature:** [2,3].
5	**Lecture 5.** Topic 2.3. A simplex method for solving linear programming problems. Work with simplex tables. Stability of the simplex method. Degeneracy and looping. Unlimited extremum **Literature:** [2,3].
6	**Lecture 6.** Topic 2.4. The simplex method with the introduction of an artificial basis. Duality in linear programming. The concept of reciprocal dual problems. **Literature:** [2,3].
7	**Lecture 7.** Topic 3.1. Peculiarities of the formation of non-linear programming problems in decision-making on the operation of electrotechnical and mechatronic complexes. Geometric interpretation of the nonlinear programming problem. The main difficulties of solving nonlinear programming problems **Literature:** [4].
8	**Lecture 8.** Topic 3.2. Solving the conditional optimization problem using the method of Lagrange multipliers. Necessary conditions for the existence of a saddle point Literature: [4].
9	**Lecture 9.** Topic 3.3. Application of unconditional optimization methods for finding optimal solutions for managing the work of electrotechnical and mechatronic complexes. A simple gradient method. **Literature:** [4,5].
10	**Lecture 10.** Topic 3.4. Numerical optimization methods. Method with step splitting. The method of coordinate descent. Geometric interpretation **Literature:** [4,5].
11	**Lecture 11.** Topic 3.5. Method of configurations (Hooke-Jeeves). The method of movement by pattern. Search algorithm. Geometric interpretation. **Literature:** [4,7].
12	**Lecture 12.** Topic 3.6. Random search method. Cauchy (fastest descent) method. Search algorithm. Geometric interpretation. **Literature:** [4,7].
13	**Lecture 13.** Topic 4.1. Convex optimization problems with constraints. Methods used for their solution. Karush-Kuhn-Tucker conditions **Literature:** [4,7].
14	**Lecture 14.** Topic 4.2. Frank-Wulf method (conditional gradient method or algorithm of convex combinations) for solving nonlinear function optimization problems. Subgradient method **Literature:** [4,7].
15	**Lecture 15.** Topic 4.3. Ravine and multiextremal functions (Ostrovsky's method). Quadratic and convex programming. Quadratic form and its properties. A method of solving quadratic programming problems **Literature:** [4,6].

16	**Lecture 16.** Topic 4.4. Heuristic programming. Minimization of the additive objective function by the method of dynamic programming **Literature:** [4,6].
17	**Lecture 17.** Topic 5.1. Basic concepts of game theory. Criteria. Game decision concepts. The method of finding Nash equilibrium **Literature:** [1,5].
18	**Lecture 18.** Topic 5.2. The problem of power distribution in terms of game theory. The method of finding the Pareto optimum. The method of finding the Stackelberg solution and Stackelberg equilibrium **Literature:** [1,5].

Practical classes:

Practical classes in the discipline are conducted by the leacturer according to the curriculum. **The main goal** of practical classes is to consolidate theoretical provisions and acquire the ability to apply them in practice by performing certain tasks formulated accordingly.

№ з/п	The name of the topic submitted for practical study
Practical class №1	Application of decision-making methods in production systems based on the results of expert evaluation
Practical class №2	Application of the graphical method in optimization problems of linear programming for decision-making in production systems
Practical class №3	Application of the simplex method in optimization problems of linear programming for decision-making in production systems
Practical class №4	Application of the method of Lagrange multipliers in solving nonlinear programming problems for decision-making in production systems
Practical class №5	Numerical optimization methods. The method of coordinate descent
Practical class №6	Random search method. Cauchy method (fastest descent)
Practical class №7	Application of the Frank-Wulf method as one of the methods of convex optimization.
Practical class №8	Application of the dynamic programming method
Practical class №9	Test

6. Student individual work

The student's independent work involves:
preparation for classroom and practical classes – 71 hours;
preparation for the modular control work – 6 hours;
preparation for credit assessment – 4 hours

Policy and control

7. Policy of academic discipline (educational component)

The policy of the educational discipline "Intelligent decision-making systems" is based on the corporate policy of KPI named after Igor Sikorsky.

KPI named after Igor Sikorskyi is a free and autonomous center of education, which is called to give adequate answers to the challenges of modern times, to nurture and protect the spiritual freedom of a person, which makes him able to act according to his own conscience; its civil freedom, which is the basis of the formation of a socially responsible personality, and academic freedom and integrity, which are the main driving factors of scientific progress. The internal atmosphere of the University is built on the principles of openness, transparency, hospitality, and respect for the individual.

Studying the educational discipline "Intelligent decision-making systems" requires: preparation for practical classes; performance of an individual task according to the curriculum; elaboration of the recommended basic and additional literature.

Preparation and participation in practical classes involves: familiarization with the program of the academic discipline and plans of practical classes; study of theoretical material; performance of tasks proposed for independent study.

The result of preparation for the class should be the acquisition of skills and abilities to work with computer mathematics systems. The applicant's answer must demonstrate signs of independent performance of assigned tasks, absence of signs of repetition and plagiarism.

The presence of students of higher education at practical classes is mandatory. Lessons missed for valid reasons must be made up.

A student of higher education must adhere to educational and academic ethics and the schedule of the educational process; to be considered, attentive.

The system of requirements that the lecturer sets before the student:

- rules for attending classes: it is forbidden to evaluate the presence or absence of the winner in the classroom class, including the awarding of incentive or penalty points. According to the RSO of this discipline, points are awarded for the relevant types of educational activity in lectures and practical classes.
- rules of behavior in classes: the student has the opportunity to receive points for the appropriate types of educational activity in lectures and practical classes, provided for by the RSO of the discipline. The use of means of communication to search for information on the teacher's Google Drive, on the Internet, in a distance course on the Sikorsky platform is carried out under the condition of the teacher's instructions;
- policy of deadlines and rescheduling: if a student does not pass or does not appear at the MCR (without a good reason), his result is evaluated at 0 points. Recompilation of MCR results is not provided for;
- policy on academic integrity: the Code of Honor of the National Technical University of Ukraine "Kyiv Polytechnic Institute" https://kpi.ua/files/honorcode.pdf establishes general moral principles, rules of ethical behavior of individuals and provides a policy of academic integrity for persons working and studying at the university, which they should be guided by in their activities, including when studying and preparing control measures in the discipline "Intelligent decision-making systems";
- during using digital means of communication with the teacher (mobile communication, e-mail, correspondence on forums and social networks, etc.), it is necessary to observe generally accepted ethical norms, in particular, be polite and limit communication to the working hours of the teacher.

8. Types of control and grading system for evaluating learning outcomes (GSE)

Current control: MCW (modular control work) is conducted before the second calendar control in the lecture class in the presence of the teacher (28 points), 8 practical classes (9 points per practical class = 8 x 9 = 72). MCW is performed in the form of an answer to a theoretical question from the lecture material and one practical work. At the end of the class, the work on the MCW ends and cannot be rewritten. McR is estimated at 18 points according to the following criteria:

- "excellent" – a complete answer to the theoretical question (at least 90% of the required information), relevant justifications and a personal view are provided, and the problem is solved correctly - 28-23 points;

- "good" – a sufficiently complete answer to the theoretical question (at least 75% of the required information), which is completed in accordance with the requirements for the "skills" level or contains minor inaccuracies, the course of solving the problem is correct, but contains minor inaccuracies, mostly in the calculation - 22 -17 points;

- "satisfactory" – an incomplete answer to a theoretical question (at least 60% of the required information), completed in accordance with the requirements for the "stereotypical" level and contains some errors, significant errors are observed in solving problems – 16-11 points;

- "unsatisfactory" – unsatisfactory answer and incorrectly solved problem -0 points.

Tasks within the framework of a practical lesson are evaluated in 9 points according to the following criteria:

- "excellent" – fully completed work (at least 90% of the required information), appropriate justifications and personal opinion provided – 9 points;

- "good" – the work contains certain inaccuracies (at least 75% of the required information), the justifications provided are not complete enough – 8-7 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 task was not solved correctly – 6-5 points.

Calendar control: conducted twice a semester as a monitoring of the current status of meeting 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: test. A necessary condition for admission to credit evaluation is the writing of a modular control paper and a starting rating of at least 30 points.

RC(max) = 28 + 72 =100 points

RC(min) = 30 points.

Final test evaluation. Students who have met all the admission requirements and have a rating of 60 or more points receive a rating corresponding to the rating without additional tests. The sum of the rating points received by the student during the semester is transferred to the final grade according to the table.

If the sum of points is less than 60, but the practical, MCR tests are completed and credited, the student completes credit work. Credit work is estimated 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 question is valued at 13 points (task of 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" – sufficiently complete answer (at least 75% of the required information) completed according to the requirements for the "skills" level or contains minor inaccuracies – 11-12 points;

- "satisfactory" – an incomplete answer (at least 60% of the required information), completed in accordance with requirements to the "stereotypical" level and contains some errors – 10 or less points;

- "unsatisfactory" – unsatisfactory answer – 0 points.

Incentive points are set for:

Completion of an individual semester task	depending on the difficulty, but no more than 10 points
Presentation at relevant student conferences on the subject of the discipline and participation in work competitions	up to 5 points
Preparation of an abstract work on the topic of the lesson missed by the student, or on the topic proposed by the teacher (volume up to 10 sheets)	depending on the disclosure of the chosen topic by the student, the validity of the conclusions, but no more than 3 points

For correspondence education

Current control: MKR (conducted directly during the lecture session, in the presence of the teacher, 20 points), practical works (4 works of 5 points each). The structure of MKR and practical work, requirements for them and evaluation criteria are similar to those for full-time education and are given above.

Semester control: test assessment. Conditions for admission to the semester control: completed and credited MKR and a starting score of 50% of the maximum number of points (20 points).

Students who have fulfilled the conditions for admission to credit, perform credit work. The sum of points for MKR and practical work is transferred to the final grade according to the table.

The credit work is estimated at 60 points.

Each question and task is evaluated out of 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 – 20-18 points;
- "good" – a sufficiently complete answer (at least 75% of the required information), completed in accordance with the requirements for the "skills" level or containing minor inaccuracies – 17-14 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 – 14-10 points;
- "unsatisfactory" – unsatisfactory answer – 0 points.

The student's rating (RC) is defined as the sum of ratings for each type of educational activity, both the main (mandatory) and additional types of work for the credit module during the semester, taking into account incentive and penalty points. The evaluation criteria are listed below.

The sum of the starting points and the points for the exam work is transferred to the test grade according to the table.

Table of correspondence of rating points to grades on the university scale

Rating points	Evaluation according to the university scale
95…100	excellent
85…94	very good
75…84	good
65…74	satisfactory
60…64	acceptable
Менше 60	unsatisfactory
Failure to meet the conditions for admission to the test	not allowed

9. Additional information on the discipline (educational component)

As a semester control, according to the curriculum, students pass test. The list of questions submitted for semester control is given in the appendix to the syllabus.

Working program of the academic discipline (syllabus):

Compiled by: candidate of technical sciences**, Assoc. Prof. Leonid Kulakovskyi**

Approved by: AEMC department **(protocol No.** №17 dated 05/31/23)

Agreed: Methodical commission of the faculty NN IEE (**protocol No.** 9 dated 06/22/2023)

Appendix to the syllabus of the educational component of the course

"Intelligent decision-making systems"

The list of tasks submitted for semester control

1. Describe the features of assessment and the choice of decision support methods
2. Formulate the general principles of building intelligent decision-making systems
3. Describe the decision-making process.
4. To describe the application of decision-making methods in production systems based on the results of expert evaluation
5. Describe the decision-making procedure in the work of electrotechnical and mechatronic complexes using the analytical hierarchy method
6. Formulate an algorithm for solving decision-making problems using the analytical hierarchy method
7. Formulate the basic principles of constructing the objective function
8. Formulate the objective function and constraints of a mathematical problem.
9. Formulate the basic theoretical information of linear programming problems to optimize the operation of the electrotechnical and mechatronic complex.
10. Formulate the main properties of linear programming problem solutions. Give a geometric interpretation of the problem of linear programming.Сформулювати алгоритм розв’язування задач лінійного програмування графічним методом
11. Formulate an algorithm for solving linear programming problems using the simplex method
12. Formulate the peculiarities of bringing the objective function and constraints to the canonical form
13. Characterize the concepts of stability of the simplex method, degeneracy and looping, unbounded extremum
14. Formulate an algorithm for solving linear programming problems using the simplex method with the introduction of an artificial basis.
15. Give a characteristic of duality in linear programming and the concept of reciprocal-dual problems.
16. Formulate the general characteristics and properties of the problem of nonlinear programming in the decisions made to manage the work of electrical and mechatronic complexes.
17. State the main difficulties of solving nonlinear programming problems.
18. Formulate an algorithm for solving the conditional optimization problem using the method of Lagrange multipliers.
19. Formulate the characteristics of problems with many extremes
20. Describe the features of the application of unconditional optimization methods for finding optimal solutions for managing the work of electrotechnical and mechatronic complexes.
21. Give a graphic interpretation and algorithm of the simple gradient method.
22. Formulate an algorithm for solving the problem of nonlinear programming by the fastest descent method (Cauchy method).
23. Formulate an algorithm for solving the problem of nonlinear programming by the method of configurations (Hooke-Jives).
24. Describe the algorithm for finding optimal solutions using the method of step splitting and the method of movement along a pattern.
25. Formulate the general properties of the convex optimization problem with constraints. Give the methods used to solve them.
26. Formulate the Karush-Kun-Tucker conditions
27. Describe the dynamic programming algorithm.
28. Formulate an algorithm for solving nonlinear function optimization problems using the Frank-Wulf method (conditional gradient method or convex combinations algorithm)
29. Formulate the properties of extreme and multiextremal functions (Ostrovsky's method).
30. State the general properties of quadratic and convex programming. State the quadratic form and its properties.
31. Describe the methods of solving quadratic programming problems

32. Describe the basic properties of heuristic programming
33. Formulate the basic concepts of game theory.
34. List the criteria and concepts of game decisions. Describe the method of finding the Nash equilibrium.
35. Formulate the problem of power distribution in terms of game theory and the method of finding the Pareto optimum.
36. Formulate the method of finding the Stackelberg solution and the Stackelberg equilibrium.