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

Department of theoretical electrical engineering

# INDUSTRIAL ECOLOGY

## Working program of the academic discipline ( Syllabus )

| Details of the academic discipline | |
|---|---|
| **Level of higher education** | ***First (undergraduate)*** |
| **Discipline** | *14 Electrical engineering* |
| **Specialty** | *141 Power engineering, electrical engineering and electromechanics* |
| **Educational program** | *Management, protection and automation of energy systems;*<br>*Non-traditional and renewable energy sources;*<br>*Electric stations;*<br>*Electrical systems and networks;*<br>*Electrotechnical devices and electrotechnological complexes;*<br>*Electric machines and devices;*<br>*Electromechanical automation systems, electric drive and electric mobility* |
| **Discipline status** | *Mandatory* |
| **Form of education** | *Daytime* |
| **Year of training, semester** | *2nd year, autumn semester* |
| **Scope of the discipline** | *2 credits ECTS / 60 hours (18 hours of lectures, 18 hours of seminar classes )* |
| **Semester control/ control measures** | *Test* |
| **Class schedule** | *https://schedule.kpi.ua/*<br>*1 lecture (2 hours) once every two weeks,*<br>*1 seminar class (2 hours) once every two weeks.* |
| **Language of teaching** | *Ukrainian* |
| **Information about the course leader / teachers** | Lecturer: *Ph.D. , associate professor, Trotsenko Yevhenii Oleksandrovych, trotsenko-fea@lll.kpi.ua, +380442048577*<br>Workshops: *Ph.D. , associate professor, Trotsenko Yevhenii Oleksandrovych, trotsenko-fea@lll.kpi.ua, +380442048577* |
| **Placement of the course** | *https://classroom.google.com/c/MTQ0ODY2MTE1NzI3?cjc=xmvx657* |

## Program of educational discipline

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

*The program of the discipline "Industrial ecology" was compiled in accordance with the educational and professional training programs of the bachelor "Management, protection and automation of energy systems"; "Unconventional and renewable energy sources"; "Electrical stations"; "Electrical systems and networks"; "Electrotechnical devices and electrotechnological complexes"; "Electric machines and devices"; "Electromechanical systems of automation, electric drive and electromobility " in the specialty 141 "Electric power engineering, electrical engineering and electromechanics".*

***The purpose of the educational discipline is to form the following*** *abilities in students : K05 – Ability to search, process and analyze information from various sources; K08 – Ability to work autonomously ; K18 – Ability to perform professional duties in compliance with the requirements of the rules of safety, labor protection, industrial sanitation and environmental protection.*

***The subject of the academic discipline*** *is the study of the most acute environmental problems of our time, such as climate change, acid precipitation, general pollution of the environment and a number of others, directly or indirectly related to the production, transmission and use of electrical energy.*

***Program learning outcomes that the discipline aims to improve:*** *PR04 – Know the principles of bioenergy, wind energy, hydropower and solar energy installations; PR12 – Understand the basic principles and tasks of technical and environmental safety of electrical engineering and electromechanics objects, take them into account when making decisions; PR13 – Understand the importance of traditional and renewable energy for the successful economic development of the country.*

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

*The study of the discipline "Industrial Ecology" is based on general knowledge of natural science or general ecology, as well as physics within the framework of the comprehensive general secondary education program. The discipline "Industrial ecology" is a fundamental basis that should ensure students master the basics of industrial ecology as a theoretical basis for environmental protection and further implementation of the concept of sustainable development of society.*

## 3. Content of the academic discipline

*The discipline consists of one section, namely:*

***Chapter 1. Interaction of energy and the environment***

*Topic 1. Basic concepts and tasks of modern ecology*

*Topic 2. Ecological aspects of electricity transmission*

*Topic 3. Environmental aspects of traditional energy*

*Topic 4. Environmental aspects of renewable energy*

*Topic 5. Environmental impact on energy facilities*

## 4. Educational materials and resources

***Main information resources:***


1. *Industrial ecology. Course of lectures [Electronic resource]: ed . help for bachelor's degree holders in the educational programs "Management, protection and automation of energy systems", "Non-traditional and renewable energy sources", "Power stations", "Electrical systems and networks", "Electrotechnical devices and electrotechnological complexes", "Electrical machines and devices" , "Electromechanical systems of automation, electric drive and electromobility " specialty 141 "Electroenergetics, electrical engineering and electromechanics" / KPI named after Igor Sikorskyi; edited by: E. O. Trotsenko, Yu. V. Peretyatko . – Electronic text data (1 file: 2.25 MB ). – Kyiv: KPI named after Igor Sikorsky , 2022. – 86 p. – Name from the screen . https://ela.kpi.ua/handle/123456789/47714*
2. *Industrial ecology. Seminar classes [Electronic resource]: study guide for bachelor's degree holders in the educational programs "Management, protection and automation of power systems", "Non-traditional and renewable energy sources", "Power stations", "Electrical systems and networks", "Electrotechnical devices and electrotechnological complexes", "Electric machines and devices", "Electromechanical systems of automation, electric drive and electromobility " specialty 141 "Electric power, electrical engineering and electromechanics" / KPI named after Igor Sikorskyi; structure. E. O. Trotsenko, Yu. V. Peretyatko . – Electronic text data (1 file: 437 Kbytes ). – Kyiv: KPI named after Igor Sikorskyi, 2022. – 34 p. – Title from the screen. https :// ela . kpi ua / handle /123456789/48870*
3. *Industrial ecology: a study guide / S. O. Apostoliuk , V. S. Dzhigirei , I. A. Sokolovsky and others. - 2nd ed., corrected . and additional - K.: Znannia, 2012. - 430 p. ISBN: 978-966-346-929-4*
4. *Industrial ecology: textbook / Ya. I. Bedriy , B. O. Bilinskyi , R. M. Ivakh, M. M. Kozyar . - Edition 4th, revision. - Kyiv: Condor, 2018. - 374 p. ISBN 978-966-351-314-0*
5. *Wind power plants and climate changes / O. Vasylyuk , M. Kryvokhizha , E. Preskra, K. Norenko - K.: EkG "Pechenyi", NETSU, UNCG, 2015. - 32 c.*

6. *Basics of ecology: a textbook / Ya.B. Oliynyk, P.G. Shishchenko , O.P. Gavrilenko. - K.: Znannia, 2012. - 558 p. ISBN : 978-966-346-933-1*
7. *Zatserklyany , M. M. Environmental protection processes: a textbook / M. M. Zatserklyany , O. M. Zatserklyany , T. B. Stolevych . – Odesa: Phoenix, 2017. – 454 p. ISBN 978-966-928-173-9*
8. *Tsarenko O. M. Fundamentals of ecology and economics of nature use. Course of lectures. Workshop: study guide / Tsarenko O. M., Nesvetov O. O., Kadatskyi M. O. – 3rd edition, revision. and added – Sumy: University Book, 2018. – 592 p. ISBN 978-966-680-337-8*
9. *Environmental law: education . help / T. P. Ustymenko, S. S. Bychkova, I. A. Borovska, O. S. Burlaka, S. V. Gubarev; under the editorship T. P. Ustymenko. – Kyiv: Alerta : Legal Unity, 2016. – 289 p. I SBN 978 - 617 - 566 - 368 - 4*
10. *Human ecology: Study guide / L. I. Solomenko . - K.: "Center for Educational Literature", 2017. - 120 p. ISBN 978-611-01-0943-7*
11. *Engineering ecology: a textbook / V. M. Isaenko, K. O. Babikova , Yu. M. Satalkin , M. S. Romanov; in general ed. Dr. Biol . Sciences, Prof. V. M. Isayenko. — 2nd ed., updated on the principles of facilitation sustainable innovative development and principles of synergistic and competence approaches. — Kyiv: NAU, 2019. – 452 p. ISBN 978-966-932-132-9*
12. *Protection of buildings and electrical systems from the effects of lightning. The nature and parameters of lightning [Electronic resource]: study guide for students of specialty 141 "Electroenergetics, electrical engineering and electromechanics" / KPI named after Igor Sikorskyi; edited by: E. O. Trotsenko, Yu. V. Peretyatko . – Electronic text data (1 file: 4.71 MB ). – Kyiv: KPI named after Igor Sikorskyi, 2023. – 115 p. – Title from the screen. https://ela.kpi.ua/handle/123456789/57033*

***Additional information resources:***

13. *Scientific magazine " Energy : economy , technologies , ecology " . http://energy.kpi.ua/issue/archive*
14. *Scientific journal Visnyk Kremenchutskyi national university named after Mykhailo Ostrogradsky ". http://visnikkrnu.kdu.edu.ua/arhiv.php*
15. *Scientific and applied magazine "Renewable energy" . https://ve.org.ua/index.php/journal/issue/archive*

## Educational content

### 5. Methods of mastering an educational discipline (educational component)

**Lecture classes**

| No. z/p | The name of the topic of the lecture and a list of main questions (list of didactic tools, links to information sources) |
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| 1. | *Topic 1. Basic concepts and tasks of modern ecology .*<br>***Basic concepts and tasks of modern ecology.*** *Introduction, purpose and tasks of the academic discipline. Basics of ecology. Systematic ecology. Direct and feedback. Four laws of ecology. Concept of ecological boomerang. Applied ecology. Ecology and international grant activity. The main goal of environmental education. World production of electricity. Energy and ecology: an overview of the problem. Literature: [1], [3], [7], [8], [9].* |
| 2. | *Topic 2. Environmental aspects of electricity transmission.*<br>***Environmental aspects of electrical energy transmission by overhead power lines.*** *Impact of overhead power lines on the ecological, social and economic subsystem. Ecological aspects of the influence of the electromagnetic field of overhead power lines of ultra-high voltage on the environment. Deforestation and restrictions on land use in the area of overhead power lines. Compact supports of overhead power lines and reduction of the risks of negative impact of the electromagnetic field on the environment. Emergency outages of overhead power lines associated with birds and bird pollution: global experience and solutions. Risks of bird death on overhead* |

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| | *power lines due to contact with wires or electrocution. Means for protecting birds on overhead power lines. Literature: [1], [3], [13], [14].* |
| 3. | *Topic 3. Environmental aspects of traditional energy.*<br>***Environmental aspects of thermal power engineering.*** *Energy and global greenhouse gas emissions. Production of electricity from fossil fuels. General information about thermal power engineering. General information about thermal power stations (TPP). Risks of environmental problems during the operation of thermal power stations. Tericons of coal mines and cuts. General information about nuclear energy. Basic information about nuclear power plants (NPP). Risks of environmental problems in the operation of nuclear power plants. Literature: [1], [3], [4], [5].* |
| 4. | ***Environmental aspects of operation of cooling towers in circulating water supply systems.*** *General information about cooling towers and water cooling with atmospheric air. Risks of environmental problems when using cooling towers in thermal energy. Evaporation of water and formation of water vapor. Impact on the microclimate, formation of clouds and fog. Risks of pollution by salt emissions. Risks of thermal and chemical pollution. Mechanical stability of the cooling tower structure. Literature: [1], [3], [4], [11], [1 3 ].* |
| 5 . | ***Cleaning of flue gases at thermal power plants.*** *The concept of industrial dust. Flue gas cleaning and ash capture in cyclone dust collectors. General information about electrostatic gas purification based on gas ionization. Structure and principle of operation of an electrostatic filter of a thermal power plant. Constructive designs of electrostatic filters. Tubular electrostatic filter. Plate electrostatic filter. Wet electrostatic filters. Dispersal of emissions into the atmosphere at thermal power plants (TPS). Literature: [1] , [3], [4].* |
| 6 . | *Topic 4. Environmental aspects of renewable energy.*<br>***Environmental aspects of hydropower.*** *General information about hydropower. Hydropower and reduction of greenhouse gas emissions. Basic information and principle of operation of a hydroelectric power plant (HPP). Hydro turbine. Risks of environmental problems when using hydropower. Construction of dams, reservoirs and changes in the natural hydrological regime of rivers. Risks of obstacles to fish migration and ways to solve them. Fish passage facilities at hydroelectric power stations. Types of fish passage structures. References: [1], [3], [15].* |
| 7. | ***Environmental aspects of wind energy.*** *General information about wind energy. General information about wind power plants. Wind power plants as a tool in the fight against climate change. Wind power plants and changing the natural appearance of landscapes. Risks of noise pollution. Analysis of possible impacts on biological diversity. Consideration of the potential hazards to birds and bats associated with the risk of collision with turbine blades during their flight. Production, transportation and disposal of wind turbines. References: [1], [6], [14].* |
| 8. | ***Environmental aspects of solar energy.*** *General information about solar energy. Basic information and types of solar power plants. Solar power plants as a tool in the fight against climate change. Solar power plants using photovoltaic modules. Tower-type solar power plants. Environmental aspects of production and disposal of spent solar panels. Analysis of possible impacts on habitats of local flora and fauna. References: [1], [3], [12], [15].*<br>***Environmental aspects of bioenergy.*** *Biogas plants as a tool to reduce the use of fossil fuels. Using biomass and reducing greenhouse gas emissions and mitigating climate change. Analysis of emissions during biomass burning. Risks of soil depletion and reduction of biological diversity when growing biomass. References: [11], [13], [14], [15].* |
| 9. | *Topic 5. Environmental impact on energy facilities* ***.***<br>***Lightning and electricity.*** *The formation of a thunderstorm cloud and the occurrence of a lightning discharge. A direct lightning strike to the structure. Concepts of lightning protection zones. Lightning damage to overhead power lines. Analysis of the effectiveness of external protection against direct lightning strikes for overhead power lines. Protection of transformer substations against direct lightning strikes. Lightning damage to wind power plants. Protection of wind power plants from direct lightning strikes. Wind turbine blade lightning protection. Lightning protection zoning concept for wind turbine blades. Protection of solar power plants using photovoltaic modules from a direct lightning strike. Protective grounding systems. Literature: [12] , [13], [14] .* |

**Seminar classes**

| No. z/p | Name of the subject of the lesson and list of main questions |
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| 1. | ***Challenges and opportunities of modern ecology: an analysis of key concepts.*** *A list of topics for preparing reports for the seminar session: 1) Discussion of the main concepts and tasks of modern ecology: how do priorities change depending on the region and economic development? 2) Analysis of the four laws of ecology: examples of their manifestation in the real world. 3) The role of the systems approach in ecology: what are the advantages and limitations of the system analysis of environmental problems? 4) Direct and feedback in ecosystems: how feedback can lead to ecological crises? 5) Environmental boomerang: discussion of examples from various industries. 6) Applied ecology: how does the application of ecological knowledge help to solve specific practical tasks? 7) Ecology and international grant activity: overview of current programs and funding opportunities. 8) The impact of global electricity production on the environment: comparison of traditional and renewable sources. 9) Energy and ecology: discussion of specific problems related to various types of energy. 10) Analysis of environmental education in different countries: how does education affect the environmental awareness of society? 11) Modern challenges of applied ecology: what environmental problems are on the agenda in the world community? 12) Discussion of the concept of ecological boomerang in the context of climate change: how are these processes interconnected? 13) The systemic nature of ecology and its application in urban planning: what tools are used to predict environmental consequences? 14) Feedback in natural systems: how can anthropogenic factors change the balance of ecosystems? 15) Environmental Consequences of the Energy Boom: A discussion of the environmental impact of global demand for electricity. 16) Global initiatives in the field of energy and ecology: which international agreements and projects are most influential today? 17) Applied ecology and technological innovation: how can the latest technologies help in solving environmental problems? 18) International grant activity in ecology: review of successful projects and analysis of their impact on the environment. 19) The biggest accidents in electric power systems and their consequences. 20) Changing paradigms in environmental education: how do modern teaching methods contribute to the formation of an environmentally responsible society? 21) Energy and ecology: the role of renewable energy sources in reducing anthropogenic impact on the environment. 22) The four laws of ecology as a basis for the development of environmental policies and practices. 23) Discussion of the role of energy in modern environmental conflicts: examples from different regions of the world. 24) Problems and prospects of applied ecology: what should be expected in the near future? Literature: [2], [ 3 ], [ 7 ], [ 8 ], [ 9 ], [13], [14], [15] .* |
| 2. | ***Impacts on the biosphere of power lines, electric substations and open switchgear .*** *List of topics for preparation of reports for the seminar session: 1) Environmental consequences of the influence of the electromagnetic field of overhead power lines of ultra-high and / or ultra-high voltage: assessment of risks and ways of their minimization. 2) Deforestation for the construction of overhead power lines: impact on biological diversity and ecosystems as a whole. 3) Socio-economic consequences of placing overhead power lines in populated areas: analysis of benefits and challenges for local communities. 4) Impact of the electromagnetic field on the health of people and animals: modern research, standards and regulatory acts. 5) Compact overhead power line supports: innovations to reduce environmental impact. 6) Emergency situations on overhead power lines due to interaction with birds: analysis of world experience and possible solutions. 7) The role of bird protection devices on overhead power lines: evaluating the effectiveness of different approaches. 8) Environmental aspects of expanding the network of overhead power transmission lines to support the growing share of renewable energy sources: challenges and solutions. 9) Collision of birds with overhead power lines: biological and ecological aspects of the problem. 10) Methods of minimizing the risk of death of birds on overhead power lines: a comparative analysis of world practices. 11) High-voltage electrical equipment in energy systems, as a potential source of acoustic noise, radio interference, dangerous influences and disturbances. 12) Restrictions on land use in the area of overhead power lines: legal aspects and environmental consequences. 13) Impact of overhead power lines on bird migration routes: risk assessment and measures to minimize them. 14) Electromagnetic field of overhead lines and its impact on soil and water resources: modern research. 15) Means for protecting birds on overhead power lines: technical solutions and their implementation. 16) Environmental risks associated with emergency shutdowns of overhead* |

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| | *power lines: risk assessment and management. 17) Comparison of the impact of different types of overhead power line supports on the environment: traditional and compact supports. 18) International experience in reducing the environmental impact of overhead power lines: best practices and new technologies. 19) Prohibited use of electrically insulating materials and substances (in particular, dichlorodiphenyl-trichloroethane , aldrin , dieldrin , endrin , chlordane , mirex , toxaphene , heptachlor, polychlorinated diphenyls, hexachlorobenzene, polychlorinated dibenzodioxins , polychlorinated dibenzofurans ). 20) Environmental and economic problems of corrosion of metal pipelines and cables: assessment and strategies for reducing losses. 21) Mechanisms of propagation of electromagnetic disturbances in urbanized areas: analysis and solutions to reduce the impact. 22) Mechanisms of propagation of electromagnetic disturbances: theoretical foundations and practical aspects of control. 23) Ecological aspects of electromagnetic compatibility: the impact of electromagnetic interference on the environment and living organisms. 24) Impact of overhead power lines on rare and endangered species: risk analysis and development of protection strategies. 25) Reducing risks to birds on overhead power lines: modern approaches and their effectiveness. Literature: [2], [ 3 ] , [13 ] , [ 14 ].* |
| 3. | ***Anthropogenic pollution of the biosphere due to the generation, transmission and use of electrical energy.*** *The list of topics for preparing reports for the seminar session: 1) Cumulative impact of humanity on the air, water and geological environment of the planet. 2) Impact of thermal power plants on the environment: analysis of emissions and risk reduction methods. 3) Global greenhouse gas emissions from thermal power generation: causes, consequences and reduction strategies. 4) Environmental problems associated with the use of fossil fuels at thermal power plants: management strategies and solutions. 5) Impact of coal mine tericons on the environment: ecological consequences and possible solutions. 6) Environmental challenges of nuclear energy: waste management and accident risks. 7) Thermal power stations and climate change: analysis of the contribution to global carbon dioxide emissions. 8) Nuclear power plants and safety: environmental aspects and risk management. 9) Technical and ecological aspects of modernization of thermal power plants to reduce emissions of pollutants. 10) Reducing the impact of thermal power plant waste on the environment: new technologies and approaches. 11) Analysis of environmental risks during the operation of nuclear power plants: methods of monitoring and management. 12) Environmental consequences of using alternative fuel sources at thermal power plants: comparison of gas turbine and coal power plants. 13) Sustainable development in thermal energy: integration of renewable energy sources and reduction of environmental impact. 14) Environmental aspects of the disposal of coal mine tailings: strategies for land restoration and soil quality improvement. 15) Nuclear power and radioactive waste management: environmental solutions and technologies. 16) Impact of thermal energy on water resources: cooling systems of thermal power plants and their environmental consequences. 17) Environmental safety during the operation of thermal power plants: modern approaches to monitoring and pollution reduction. 18) Analysis of the ecological and social consequences of the location of nuclear power plants in densely populated areas. 19) The role of modern emission reduction technologies in reducing the environmental impact of thermal power stations. 20) Nuclear power and its impact on local ecosystems: assessment of environmental risks and mitigation measures. 21) Electricity generation from fossil fuels: are there environmental strategies to reduce the impact? 22) Environmental problems and waste management at thermal power plants: impact on air, water and soil. 23) Analysis of ecological aspects of restoration of territories after coal mining: modern practices and problems. 24) Energy and the greenhouse effect: reducing carbon dioxide emissions and switching to renewable energy sources. 25) Greenhouse effect: formation mechanisms, impact on climate and global warming. 26) Sustainable development in energy: how to reduce the environmental impact of traditional coal and nuclear power plants? Literature: [2], [ 3 ] , [13 ] , [ 14 ].* |
| 4. | ***Environmental aspects of electric power generation at thermal and nuclear power plants.*** *List of topics for preparing reports for the seminar: 1) The role of cooling towers in circulating water supply systems: advantages and disadvantages from an ecological point of view. 2) Evaporation of water in cooling towers: impact on the atmosphere and the formation of clouds and fog. 3) Assessment of environmental risks associated with the use of cooling towers in thermal energy. 4) Analysis of the impact of cooling towers on water resources and water balance. 5) Local and global climate changes. 6) Pollution of the environment by chemical substances. 7) Maximum permissible* |

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| | *concentrations of harmful substances. 8) Aerosol, chemical and radiation pollution of the environment due to the generation of electrical energy. 9) Energy and thermal pollution of the atmosphere: mechanisms of influence and measures to reduce it. 10) Water cooling with atmospheric air: effectiveness of cooling towers and are there alternative methods? 11) Composition and characteristics of organic fuel. 12) The main types of organic fuel used in the energy industry. 13) Regulation of the content of harmful substances in organic fuel combustion products. 14) Atmospheric air pollution due to fuel oil combustion. 15) The main causes of depletion of the ozone layer of the atmosphere: can it be affected by greenhouse gas emissions? 16) Analysis of emergency situations related to the physical operation of the main equipment of thermal power plants. 17) The role of technical maintenance in reducing physical failure and increasing the reliability of thermal power plant equipment. 18) Physical operation and wear of the main equipment of thermal power plants: causes and consequences. 19) Methods of assessing physical wear and tear of turbines and boilers at thermal power plants. 20) Innovative materials and technologies to reduce the tripping of thermal power plant equipment. 21) Methods of increasing the service life of the main equipment of thermal power plants through engineering solutions and technologies. 22) Analysis of the impact of emergency modes on the physical operation of thermal power plant equipment. 23) Ecological consequences of the Chernobyl disaster for Ukraine. 24) Ecological consequences of the Chernobyl disaster for other countries of the world. Environmental consequences of the accident at the First Fukushima nuclear power plant for Japan and other countries of the world. References: [1], [3], [4], [11], [13].* |
| 5. | ***Cleaning of flue gases at thermal power plants: technologies, efficiency and environmental challenges.*** *List of topics for preparing reports for the seminar: 1) Efficiency of cyclone dust collectors in flue gas cleaning systems: analysis and optimization of work. 2) Comparison of different types of electrostatic filters for cleaning flue gases at thermal power plants. 3) Ionization of gases in the cleaning process: mechanisms and applications at thermal power plants. 4) Design features of tubular electrostatic filters: impact on cleaning efficiency. 5) Plate electrostatic filters: principle of operation, design and effectiveness of ash capture. 6) Wet electrostatic filters: advantages and disadvantages compared to other cleaning systems. 7) Technologies for dispersing emissions into the atmosphere at thermal power plants: environmental impact and control methods. 8) The role of electrostatic filters in reducing air pollution: technologies of the future. 9) Analysis of ash capture efficiency in different types of dust collectors at thermal power plants. 10) Flue gas cleaning: comparative analysis of methods based on efficiency and cost. 11) Influence of design features of electrostatic filters on their durability and reliability. 12) Application of wet electrostatic filters in various industrial sectors: experience and prospects. 13) Cleaning of flue gases at thermal power plants: international experience and best practices. 14) Innovative approaches to increasing the efficiency of electrostatic filters at thermal power plants. 15) Gas and aerosol emissions at nuclear power plants: assessment of the impact on the environment and means of reducing risks. 16) Radioactive emissions into the atmosphere from nuclear power plants: mechanisms of formation, distribution and environmental consequences. 17) Transformation of flooded coal pits into environmentally friendly energy hubs: floating solar power plants. 18) Floating solar power plants in submerged coal pits and other technical reservoirs: technical aspects and environmental benefits. 19) The effect of the size of dust particles on the efficiency of flue gas cleaning in various cleaning systems. 20) Disposal of sulfur oxides and nitrogen oxides at thermal power plants. 21) Analysis of the effectiveness of the application of combined methods of cleaning flue gases at thermal power plants. 22) Problems of dispersion of emissions in urban and industrial zones: ecological aspects. 23) Environmental monitoring of emissions at thermal power plants: tools and methods. 24) Problems of ash and slag after flue gas cleaning: utilization and recycling. 25) Analysis of the impact of flue gas cleaning on air quality in the areas adjacent to the thermal power plant. Literature: [2], [ 3] , [4] , [ 13 ] , [ 14] .* |
| 6. | ***Environmental safety of the use of electrical energy.*** *The list of topics for preparing reports for the seminar session: 1) General characteristics of emergency situations of natural and man-made nature. 2) Causes and consequences of the largest cascading blackouts: impact on the economy, society and the environment. 3) Cascade blackouts in electric power systems: study of the largest incidents and ways of prevention. 4) Causes of accidents and fires at electrical substations, their consequences, impact on ecology and human health. 5) Extinguishing fires in electrical installations,* |

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| | *power stations and substations: general characteristics and main challenges. 6) Ecological consequences of forest, steppe and peat fires. 7) Environmental consequences of oil and petroleum product fires. 8) Impact of hydroelectric power stations on the hydrological regime of rivers and ecosystems. 9) Environmental risks and benefits of building dams and reservoirs. 10) Fish migration and fish passage facilities at hydroelectric power stations: solutions for preserving biological diversity. 11) Can hydropower help reduce the effects of climate change on the planet? 12) Impact of hydroaccumulating power plants on the environment. 13) Ecological consequences of cascading use of rivers for hydropower. 14) Fire and environmental safety during the operation of high-voltage switches (oil, vacuum and electric gas switches ). 15) Use of vegetable oil as an ecological alternative in electrical insulating liquids. 16) Dangers of breaching dams at hydroelectric power stations: analysis of world experience. 17) Environmental consequences of transformer oil spills at energy facilities. 18) Environmental assessment of the impact of small hydropower plants on river ecosystems. 19) Problems of disposal and processing of spent transformer oil. 20) Impact of hydroelectric power plants on the biological diversity of aquatic ecosystems. 21) Advantages and disadvantages of dry power transformers. 22) Advantages and disadvantages of hydropower in conditions of global warming. 23) Environmental consequences of natural gas production and transportation. 24) Impact of climate change on the operation of hydroelectric power stations. 25) Ecological aspects of the use of hydropower in mountainous regions. 26) Problems of environmental safety when developing the energy potential of small rivers. References: [2], [3], [13], [14], [15].* |
| 7. | ***Technical challenges and environmental aspects of wind energy.*** *List of topics for preparing reports for the seminar: 1) Environmental assessment of the impact of wind power plants on local biological diversity. 2) Noise pollution from wind turbines: scale of the problem and ways to reduce it. 3) Wind energy as a tool to combat climate change: environmental and economic aspects. 4) Analysis of the risks for birds and bats associated with the operation of wind power plants. 5) Onshore wind farms and their impact on the natural landscape: issues of aesthetics and ecology. 6) Production, transportation and disposal of wind turbines: environmental challenges and solutions. 7) Environmental sustainability of wind energy: comparison with other sources of renewable energy. 8) Effectiveness of measures to reduce the negative impact of wind turbines on birds and bats. 9) Social and environmental consequences of wind energy development in rural and remote areas. 10) Wind energy problems in the context of climate change: new challenges and opportunities. 11) Impact of wind power plants on bird migration routes: analysis of world experience. 12) Life cycle assessment of wind turbines: from production to disposal. 13) Environmental aspects of reuse and recycling of materials from dismantled wind turbines. 14) The role of wind energy in achieving the goals of sustainable development of society. 15) The impact of wind energy on local climatic conditions: myths and reality. 16) Environmental aspects of offshore wind energy development. 17) Wind energy problems in densely populated areas: experience and solutions. 18) Comparative analysis of environmental impacts of offshore and land-based wind power plants. 19) The role of onshore and offshore wind power plants in the global energy system. 20) Comparative analysis of economic costs and benefits of offshore and onshore wind power plants. 21) Prospects for the development of floating wind power plants in the context of global trends in renewable energy. 22) The role of floating wind farms in achieving global goals of reducing greenhouse gas emissions. 23) Comparison of floating and stationary wind power plants: efficiency and environmental impact. 24) Floating wind farms: advantages and disadvantages in the context of marine ecosystems. 25) Integration of offshore and onshore wind power plants into the energy system: main challenges. Literature: [2], [3], [4], [9], [13].* |
| 8. | ***Solar energy and bioenergy in the conditions of climate change.*** *List of topics for preparing reports for the seminar: 1) Ecological consequences of the introduction of solar power plants on local ecosystems. 2) Solar power plants and their role in combating climate change: environmental aspects. 3) Analysis of environmental risks in the production and disposal of solar panels. 4) Photoelectric modules: environmental challenges and prospects. 5) Tower solar power plants: ecological and technological aspects. 6) Biogas plants as an ecological alternative to fossil fuels. 7) Impact of biomass use on global warming and climate change. 8) Environmental challenges when growing biomass for energy needs. 9) Risks of reducing biological diversity due to intensive use of biomass. 10) Solar energy and environmental protection: balance between economy and ecology. 11) Comparison of environmental aspects of different types of solar power plants. 12) Solar energy* |

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| | *in urban areas: opportunities and challenges. 13) Bioenergy as part of the strategy of sustainable development. 14) Impact of solar power plants on the natural landscape and biological diversity. 15) Analysis of the environmental efficiency of solar energy in comparison with other renewable energy sources. 16) Ecological aspects of using agricultural waste for biogas production. 17) Environmental advantages and disadvantages of the combined use of renewable energy sources. 18) Solar energy and water resources: impact analysis. 19) Prospects for the development of solar energy in the conditions of global environmental challenges. 20) Analysis of environmental safety during the operation of solar power plants. 21) Impact of spent solar panels on the environment and strategies for their disposal. 22) The role of bioenergy in achieving the goals of the Paris Agreement. 23) Using biomass: is it always ecological? 24) Reduction of greenhouse gases using biogas plants: ecological analysis. Literature: [1], [3], [11], [12], [13], [14], [15].* |
| 9. | ***Protection of energy objects from environmental influences: lightning and electric power.*** *List of topics for preparing reports for the seminar: 1) Mechanisms of damage to people and animals by lightning: physiological and biological aspects. 2) Analysis of people struck by lightning: statistics, causes and medical consequences . 3) Strategies for preventing lightning damage in agriculture: protection of animals and property. 4) Specificity of lightning damage to farm animals: prevention and treatment. 5) The role of technology in preventing lightning damage: external lightning protection systems and devices for protection against secondary manifestations of lightning. 6) Statistical analysis of cases of lightning damage to people and/or animals: comparison in different regions of the world and seasons. 7) Analysis of the effectiveness of lightning protection systems for overhead power lines: methods and results. 8) Concepts of lightning protection zones: comparative analysis of standards and practical recommendations. 9) Impact of direct lightning strike on transformer substations: technical solutions and environmental consequences. 10) Lightning protection systems for wind power plants: technical aspects and efficiency. 11) Lightning damage to wind turbines: problems and protection strategies. 12) Protection of wind turbine blades from lightning: comparison of traditional and modern methods. 13) Different aspects of protection of solar power plants against direct lightning strikes: approaches and solutions. 14) The role of protective grounding systems in lightning protection: principles of operation and effectiveness. 15) Lightning protection methods for overhead power lines in different climatic zones. 16) Analysis of the impact of lightning on the power system: comparison of research results and recommendations. 17) Technical solutions for protection against lightning and induced overvoltage of elements of solar photovoltaic plants: efficiency and innovation. 18) Classification of lightning discharges. 19) Protection against lightning and overvoltage for biogas plants. 20) Lightning protection of overhead power lines of different voltage classes. 21) Protection of transformer substations from direct lightning strikes and dangerous overvoltage: modern technologies and practical recommendations. 22) The problem of corona discharge in electric power: environmental consequences, technical and economic aspects of the problem. 23) Automated systems for remote registration and location of lightning discharges. 24) External lightning protection system for an industrial building and a residential building: general features and differences. Literature: [2], [ 7] , [9] , [10] , [11 ] .* |

**Laboratory classes (computer workshop)**

*The curriculum does not include laboratory classes (computer workshop) for this credit module.*

**Control works**

*At the end of the lecture course, seminar classes and students' independent processing of the proposed topics, the program provides for a modular test, which includes questions on all topics of the course. The purpose of the modular control work is to determine the degree of students' assimilation of the taught and independently worked out material.*

**Individual tasks**

*The program provides for the writing and defense of an essay by the student.*

*The purpose of writing an essay is to verify the student's independent creative work, which certifies his knowledge of the literature of the academic discipline, understanding of the most acute environmental problems directly or indirectly related to the production, transmission and use of electrical energy, as well as*

*reflects his own professional views of the future specialist and demonstrates his the ability to realize personal responsibility for the state of the environment based on the acquired theoretical knowledge.*

### 8.1. List of essay topics

1. *Climate change and its impact on global ecosystems: Analysis of the main causes, consequences and possible solutions.*
2. *Ocean Pollution and Its Impact on Marine Life: A Review of Plastic Waste, Oil Spills, and Other Pollutants.*
3. *Biodiversity Losses and Their Consequences for Ecosystems: A Study of the Causes and Effects of Declining Species on the Planet.*
4. *The reduction of natural resources and the problem of resource depletion: Analysis of the consequences of excessive use of water, minerals and other resources.*
5. *Environmental Consequences of Urbanization and Urban Expansion: How urban growth affects the environment and what strategies are available to mitigate negative impacts.*
6. *Impact of intensive agriculture on ecosystems and human health: Examining issues such as soil erosion, pesticide and fertilizer use.*
7. *Renewable energy sources and their role in the fight against global warming: Assessment of the impact of solar, wind and other forms of renewable energy on environmental problems.*
8. *Changes in Arctic and Antarctic ecosystems due to global warming: Analysis of impacts on glaciers, sea level and native flora and fauna.*
9. *Ecological consequences of deforestation and deforestation : Consideration of the problems of reducing forest areas and their impact on climate and biodiversity.*
10. *Changes in the aggregation and distribution of global ecosystems due to anthropogenic influence: Studying how human activities affect the distribution of ecosystems at the global level.*
11. *Atmospheric Effects of Burning Fossil Fuels: An Analysis of Pollutant Emissions Such as Carbon, Sulfur, and Nitrogen Oxides and Their Effects on Global Warming and Acid Rain.*
12. *Environmental consequences of oil production and processing: Study of oil and oil spills, soil and water pollution, and effects on local ecosystems.*
13. *Consequences of coal energy for human health and the environment: Impact of emissions of carbon dioxide, heavy metals and fine dust on health and ecosystems.*
14. *Accidents at nuclear power plants and their environmental consequences: Analysis of catastrophic events, such as the Chernobyl and Fukushima accidents, and their impact on the environment and human health.*
15. *Problems of water conservation and pollution of water resources due to hydroelectric power plants: Study of ecological effects of dams, effects on fish populations and aquatic ecosystems.*
16. *Impact of traditional energy on climate change: Assessment of the contribution of traditional energy sources to global warming and climate change.*
17. *Energy Sector Waste Issues: Consideration of waste generated during the extraction and processing of traditional energy resources and their impact on the environment.*
18. *Environmental Consequences of Shale Gas and Oil Extraction: Examining the Effects of Hydraulic Fracturing on Water Resources and the Environment.*
19. *Biodiversity loss due to traditional energy: An analysis of how expansion of areas for energy extraction affects flora and fauna.*
20. *The energy sector and social conflicts: environmental consequences for local communities: An examination of how the extraction and use of traditional energy resources leads to conflicts with local communities and how this affects the environment.*
21. *Impact of energy sectors on global carbon dioxide emissions: An analysis of the main sources of carbon dioxide emissions in the energy sector and their contribution to global warming.*
22. *Environmental Consequences of Using Fossil Fuels in Transportation: Assessing the Impact of Cars, Airplanes, and Ships Using Gasoline, Diesel, and Other Fossil Fuels.*
23. *The Role of Wind and Solar Energy in Reducing Greenhouse Gas Emissions: Investigating the Efficiency of Renewable Energy Sources Compared to Traditional Energy Sources.*
24. *The effect of the transition to electric vehicles on greenhouse gas emissions: An analysis of the impact of electric vehicles on the total level of carbon dioxide emissions, taking into account the sources of electricity.*

25. *Methane emissions from transport and their role in global warming: Study of the impact of methane emissions from transport on the greenhouse effect.*
26. *Management decisions in the field of energy and their impact on reducing greenhouse gas emissions: Analysis of national and international energy policies and their effectiveness in the fight against global warming.*
27. *Greenhouse gas emissions as a result of fuel production and processing: Study of the stages of the production process that contribute to the increase in carbon dioxide emissions.*
28. *Comparison of the impact of different types of transport on greenhouse gas emissions: Analysis of emissions from road, rail, aviation and sea transport.*
29. *Impact of climate change on the energy sector: How changes in temperature and weather conditions affect the efficiency of energy systems and greenhouse gas emissions.*
30. *Technical innovation to reduce greenhouse gas emissions in transport and energy: Exploring new technologies and solutions that can help reduce emissions and improve environmental sustainability.*
31. *Emissions of radioactive materials from nuclear power plants: Assessment of the impact on the environment from normal and emergency releases of radioactive substances.*
32. *Nuclear Energy Waste Management: Study of methods of storage and disposal of nuclear fuel waste, as well as their long-term environmental consequences.*
33. *Impacts on local ecosystems near nuclear power plants: Analysis of the impact on flora and fauna in areas where nuclear installations are located.*
34. *Risks of radioactive contamination during transportation of nuclear fuel: Study of potential threats and environmental impact during transportation of nuclear materials.*
35. *Environmental advantages and disadvantages of nuclear energy compared to other energy sources: Comparison of nuclear energy with coal, oil and renewable energy sources in terms of their impact on the environment.*
36. *Social and environmental aspects of closure and dismantling of nuclear installations: Study of the impact on the environment and local communities during the closure and dismantling of old nuclear power plants.*
37. *Innovative flue gas cleaning technologies at thermal power plants: analysis of efficiency and development prospects: Study of new technological solutions for flue gas cleaning, their efficiency and opportunities for future improvement.*
38. *Environmental challenges and solutions in flue gas cleaning at thermal power plants: Analysis of environmental problems arising in flue gas cleaning and existing approaches to their solution.*
39. *Efficiency of electrostatic filters in flue gas cleaning systems at thermal power plants : Review of principles of operation, designs and efficiency of electrostatic filters in removing polluting particles.*
40. *Comparison of Flue Gas Treatment Technologies: Cyclones vs. Electrostatic Filters: Analysis of different flue gas treatment technologies, comparison of their effectiveness, costs, and environmental impact.*
41. *The impact of flue gas cleaning on the overall environmental situation in the region: cases and solutions: An examination of how flue gas cleaning affects the environment and human health, with examples of real cases and possible ways to improve the situation.*
42. *Basic principles of operation of hydroelectric power plants: technological process and efficiency: An overview of the principles of operation of hydroelectric power plants (HPP), including the main elements of the system and their efficiency.*
43. *Greenhouse Gas Emissions Impact of Hydroelectric Power: Comparison with Traditional Energy Sources: An analysis of how hydroelectric power reduces greenhouse gas emissions compared to other forms of energy.*
44. *Construction of dams and reservoirs: ecological consequences and changes in the hydrological regime of rivers: Overview of the ecological consequences of the construction of dams and reservoirs, including changes in the hydrological regime of rivers.*
45. *Environmental Risks of Hydropower: Cases and Solutions: An examination of potential environmental problems arising from the use of hydropower and possible solutions to overcome them.*
46. *Types of hydro turbines and their effect on the efficiency of hydroelectric power plants: Analysis of different types of hydro turbines, their designs and their effect on the overall efficiency of hydroelectric power plants.*

47. *Risks of Impediments to Fish Migration at Hydroelectric Power Plants: Analysis of Problems and Possible Solutions: An overview of the problems posed to fish by hydroelectric power plants and possible technical solutions to address them.*
48. *Fish passage structures at hydroelectric power stations: types, designs and efficiency: Study of different types of fish passage structures, their designs and effectiveness in ensuring fish migration.*
49. *Technologies for reducing the environmental impacts of hydroelectric power plants: An analysis of modern technologies used to reduce the negative environmental impacts of hydroelectric power plants.*
50. *Construction and operation of reservoirs: impact on the local ecosystem and neighboring territories: Review of the impact of construction and operation of reservoirs on the local ecosystem and neighboring territories, including socio-economic aspects.*
51. *Wind farms as a means of reducing the carbon footprint: comparison with traditional energy sources: An analysis of how wind farms help reduce the carbon footprint compared to traditional energy sources such as coal and oil.*
52. *Offshore wind farms: benefits for reducing greenhouse gas emissions and mitigating global warming: An overview of how offshore wind farms contribute to reducing greenhouse gas emissions and mitigating global warming.*
53. *Impact of onshore wind farms on local and global climate conditions: Research on how onshore wind farms affect local and global climate conditions.*
54. *Environmental benefits of wind farms in the fight against climate change: case studies of successful projects: An analysis of specific examples of wind farms that have demonstrated success in reducing the impact of climate change.*
55. *Energy Balance of Wind Farms: Energy Produced and Its Impact on Reducing Greenhouse Gases: An overview of the energy balance of wind farms and how this energy helps reduce greenhouse gas emissions.*
56. *Technical aspects of integration of wind power plants into national energy systems to reduce carbon dioxide emissions: Analysis of technical and infrastructural aspects of integration of wind power plants into national energy systems in order to reduce carbon dioxide emissions.*
57. *Sustainable development and wind farms: How wind energy contributes to climate goals: An overview of the contribution of wind farms to sustainable development and the achievement of global climate goals.*
58. *Offshore Wind Farms: Environmental Benefits and Challenges in the Context of Climate Change: Exploring the Environmental Benefits and Challenges of Offshore Wind Farms in the Context of Climate Change.*
59. *Impact of wind farms on emissions of methane and other greenhouse gases in agricultural and industrial regions: Analysis of how wind farms affect the reduction of emissions of methane and other greenhouse gases in agricultural and industrial regions.*
60. *Energy storage systems coupled with wind farms: impact on greenhouse gas emission reductions: Review of the role of energy storage systems coupled with wind farms and their impacts on greenhouse gas emission reductions.*
61. *Environmental benefits and challenges of solar energy: An overview of the main environmental aspects of using solar energy, its role in reducing greenhouse gas emissions, and possible environmental challenges.*
62. *Types of solar power plants: from photovoltaic to tower systems: Comparison of different types of solar power plants, their technological features and environmental consequences.*
63. *Solar power plants as a strategic tool in the fight against climate change: An analysis of the role of solar energy in global initiatives to reduce carbon emissions and combat global warming.*
64. *Photovoltaic modules: technology, efficiency and environmental aspects: Study of the technology of photovoltaic modules, their efficiency, impact on the environment during production and operation.*
65. *Tower solar power plants: principle of operation and environmental aspects: Overview of tower solar power plants, their technological features and environmental impacts.*
66. *Environmental Aspects of Solar Panel Production: From Raw Material Extraction to Disposal: Study of environmental issues related to solar panel production, including material extraction and energy intensity of production.*

67. *Disposal of used solar panels: environmental challenges and solutions: Analysis of the problems of disposal of old solar panels and the search for environmentally safe solutions for their recycling and reuse.*
68. *Impact of solar power plants on local flora and fauna: Study of possible impacts of the location and operation of solar power plants on local ecosystems, flora and fauna.*
69. *The Water Footprint of Solar Energy: How Much Water Do Solar Power Plants Need?: An Assessment of Water Use in the Production and Operation of Different Types of Solar Power Plants.*
70. *Social and environmental benefits of integrating solar power plants into urban environments: An analysis of how solar power plants can be integrated into cities to reduce the ecological footprint and increase the resilience of urban ecosystems.*
71. *Environmental Aspects of Bioenergy: Benefits and Challenges: An overview of the main environmental benefits of bioenergy, such as reduced greenhouse gas emissions, as well as potential environmental risks.*
72. *Biogas plants as a tool to reduce the use of fossil fuels: Analysis of the effectiveness of biogas plants in reducing dependence on fossil fuels and reducing carbon dioxide emissions.*
73. *The use of biomass for energy production and its impact on climate change: Exploring the role of biomass in reducing greenhouse gas emissions and mitigating the effects of climate change.*
74. *Analysis of Pollutant Emissions During Biomass Combustion: Study of the types and amounts of pollutants produced during biomass combustion and their impact on the environment.*
75. *Risks of soil depletion when growing biomass for energy purposes: Assessment of the impact of intensive biomass cultivation on soil quality and potential for soil depletion.*
76. *Biodiversity loss through energy crop cultivation: An analysis of the impact of monoculture energy crop cultivation on local ecosystems and biodiversity.*
77. *Comparing the environmental aspects of bioenergy and other renewable energy sources: Assessing the environmental performance of bioenergy compared to other renewable sources such as solar and wind energy.*
78. *Environmental efficiency of different types of biomass for energy production: An overview of different types of biomass such as wood, agricultural waste, and their environmental impacts.*
79. *Impact of bioenergy projects on socio-economic development of local communities: Analysis of social and ecological consequences of bioenergy development in rural regions.*
80. *The Future of Bioenergy: Environmental Perspectives and Innovations: An overview of promising bioenergy technologies that can reduce its environmental impact.*
81. *Ecological impacts of tidal power plants on marine ecosystems: Analysis of the impact of tidal power plants on marine ecosystems, including flora, fauna, and fish migration routes.*
82. *Effects of Tidal Power Plants on Hydrologic Regimes and Water Quality: A Study of How Tidal Power Plants Change Currents, Water Levels, and Water Quality in Coastal Zones.*
83. *Socio-ecological challenges of the construction of tidal power plants in coastal regions: Assessment of the impact of tidal power plants on local communities, taking into account ecological, economic and social aspects.*
84. *Possibilities and limitations of biodiversity conservation in the development of tidal power plants: An overview of strategies that can be used to minimize the negative impact of tidal power plants on the biodiversity of coastal ecosystems.*
85. *A comparative analysis of the environmental impact of tidal power plants and other types of renewable energy: An examination of the environmental advantages and disadvantages of tidal power plants compared to other types of renewable energy such as wind and solar energy.*
86. *Comparative analysis of the environmental impact of electrical insulating fluids of vegetable origin and mineral oil: Assessment of the impact on the environment of the production, use and disposal of liquids of vegetable origin in comparison with traditional transformer oil.*
87. *Biodegradability and environmental benefits of plant-based electrical insulating liquids: Research on the biodegradability of plant-based liquids and their reduced impact on soil and water pollution in case of leaks.*
88. *The Impact of Using Plant-Based Electrical Insulating Fluids on Reducing the Carbon Footprint of the Energy Sector: An Analysis of How Switching to Plant-Based Fluids Can Reduce Greenhouse Gas Emissions and Other Environmental Impacts.*

89. *Environmental Life Cycle Assessment of Plant-Based Electrical Insulating Fluids: An overview of the complete life cycle of plant-based fluids, from raw material cultivation to disposal, and comparison with traditional mineral oils.*
90. *The Use of Vegetable Oils as Electrical Insulating Fluids: Environmental Benefits and Technical Challenges: A Study of the Technical Characteristics of Vegetable Oils, Their Suitability as Mineral Oil Substitutions, and Related Environmental Benefits.*
91. *Destruction of Natural Ecosystems: Causes, Consequences and Recovery Pathways: An examination of the main drivers of ecosystem degradation, such as deforestation, urbanization and pollution, and methods of ecosystem restoration.*
92. *Causes and Consequences of Ozone Layer Depletion: Analysis of ozone-depleting chemicals (for example, chlorofluorocarbons ) and their effects on human health and the environment, in particular on increasing the level of ultraviolet radiation.*
93. *History of Ozone Depletion: From Discovery to the Montreal Protocol: An overview of the history of ozone depletion, key scientific research, and international efforts to protect it.*
94. *Effects of Ozone Depletion on Marine and Terrestrial Ecosystems: Study of the impact of ozone depletion on the biodiversity and functioning of marine and terrestrial ecosystems, particularly on phytoplankton and terrestrial plants.*
95. *Strategies to Prevent Further Ozone Depletion: Global and Local Approaches: A review of existing measures and policies aimed at protecting the ozone layer and an assessment of their effectiveness in preserving this important atmospheric layer.*
96. *Causes of acid rain: the role of anthropogenic emissions and natural factors: Analysis of the main sources of pollutants, such as sulfur and nitrogen oxides, which lead to the formation of acid rain, and the influence of natural phenomena on their formation.*
97. *Acid Precipitation and Soil Degradation: Implications for Agriculture and Forest Ecosystems: A study of the effects of acid precipitation on soil fertility, soil structure, and the health of plants and forest ecosystems.*
98. *Effects of Acid Precipitation on Aquatic Ecosystems: Changing Acidity and Threats to Aquatic Organisms: Studying how acid precipitation changes the pH of water in rivers, lakes and seas and how this affects aquatic fauna, including fish and other organisms.*
99. *Erosion and damage to architectural monuments due to acid rain: An analysis of how acid rain affects the structure of buildings, architectural monuments and sculptures, causing them to corrode and erode.*
100. *Strategies to combat acid precipitation: international experience and national-level measures: An overview of global and local measures to reduce pollutant emissions and their effectiveness in reducing the frequency and intensity of acid precipitation.*

## 6. Student's independent work

| *No* | *Names of topics and questions submitted for independent study* | *Number of hours of independent student work* |
|---|---|---|
| *1* | *Preparation for classroom classes* | *17.0* |
| *2* | *Preparation for modular control work* | *1.0* |
| *3* | *Preparation and defense of the abstract* | *4.0* |
| *4* | *Preparation for the test* | *2.0* |

## Policy and control

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

*The system of requirements that the teacher sets for students:*

- *rules for attending classes: in accordance with Order 1-273 dated 14.09.2020, it is prohibited to evaluate the presence or absence of the winner at the classroom class, including the awarding of*

*incentive or penalty points. According to the RSO of this discipline, points are awarded for the corresponding types of educational activity in lectures and practical/seminar classes.*

- *rules of behavior in classes: a student/postgraduate student has the opportunity to receive points for the appropriate types of educational activity in practical/seminar 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 on the condition that the teacher instructs;*
- *deadline and rescheduling policy: assignments that are submitted late without good reason will be assessed at 60% of the maximum possible points for the scoring activity. Rescheduling of work takes place if there are good reasons (for example, illness);*
- *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 for the discipline;*
- *when 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 rating system for evaluating learning outcomes (RSO)

*Credit module rating is a quantitative assessment on a multi-point scale of the student's level of mastery of a certain credit module, taking into account the quality of educational activities during the semester. The distribution of study hours of the credit module is carried out in accordance with the working curricula of bachelors in the specialty 141 "Electrical power engineering, electrical engineering and electromechanics" (Faculty of Electrical Engineering and Automation).*

*The student's rating in the discipline consists of the points he/she receives for:*

*1) reports (speeches) at seminar classes;*

*2) one modular control work;*

*3) one essay.*

**System of rating (weighted) points and evaluation criteria**

**8.1. Seminar classes**

*Weighted point: 20. The maximum number of points for all reports (speeches) at seminar classes is: 80 points.*

*Evaluation criteria:*

- *Full disclosure of the topic of the report (speech). At least 90% of the required information is revealed. Speech in the format of an oral report without reading the text "from the letter". Such a report is characterized by a creative approach to revealing the problem and a deep disclosure of the topic: reflecting one's own position, using an electronic presentation to demonstrate objects and events that cannot be directly presented to the audience during the speaker's speech. The duration of the performance with the report is not less than 8 minutes. The number of points received for such a report is: +18...+20 points;*
- *Sufficient full disclosure of the topic of the report (speech). The duration of the performance with the report is not less than 7 minutes. At least 75% of the required information has been disclosed or minor inaccuracies have been made. The number of points received for such a report is: +15...+17 points;*
- *Incomplete disclosure of the topic of the report (speech). At least 60% of the required information was revealed and some mistakes were made. The duration of the performance with the report is not less than 6 minutes. The number of points received for such a report is: +12...+14 points;*
- *Unsatisfactory disclosure of the topic of the report (speech). The topic of the report (speech) has not been disclosed. Less than 60% of the required information was disclosed or significant errors were made. Such a report cannot be counted, the number of points is equal to zero.*

*Notes:*

*A student can make one report for one seminar session.*

*In case of cancellation of educational, cultural, sports and other mass events in the premises and on the territory of the university (due to an epidemic situation, abnormal temperature regime, etc.), seminar*

*(practical) classes are conducted using remote forms of education and consultations of students via the Internet and local university network.*

**8.2. Modular control work.**

*Weighted point: 10. The maximum number of points for one modular control work: 10 points.*

*Evaluation criteria:*

- *Complete answer (at least 90% of the required information): +9...+10 points;*
- *Sufficiently complete answer (at least 75% of the required information or minor inaccuracies): +8 points.*
- *Incomplete answer (at least 60% of the required information and some errors): +6...+7 points.*
- *Unsatisfactory answer (less than 60% of the required information or significant errors): 0 points.*

**8.3. Abstract**

*Weighted point: 10. Maximum number of points for one essay: 10 points.*

*Evaluation stages and criteria*

*8.3.1. Checking the text of the essay for relevance to the topic:*

- *The text of the essay fully corresponds to the topic of the essay (at least 90% of the required information): +9...+10 points;*
- *The text of the abstract fully corresponds to the topic of the abstract (at least 75% of the required information or minor inaccuracies): +8 points.*
- *The text of the essay does not fully correspond to the topic of the essay (at least 60% of the required information and some errors): +6...+7 points.*
- *The text of the essay does not correspond to the topic of the essay (less than 60% of the required information or significant errors): 0 points.*

*8.3.2. Checking a fragment of the abstract text for uniqueness (plagiarism check) using free programs (https://smallseotools.com or https://plagiarismdetector.net) and determining the uniqueness of the text in percent (%). In the case of using another program for checking texts for uniqueness, the teacher warns students in advance. Each student sends the abstract file in docx or doc format to the teacher for checking in Google Classroom .*

*8.3.3. Calculation of total points for the abstract: the points obtained in clause 8.3.1 are multiplied by the number obtained in clause 8.3.2, divided by 100 and rounded to a whole number according to the rounding rules.*

*The total amount of points for the current and semester control is transferred to the final grade according to the table:*

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

| *Number of points* | *Rating* |
|---|---|
| *100-95* | *Perfectly* |
| *94-85* | *Very good* |
| *84-75* | *Good* |
| *74-65* | *Satisfactorily* |
| *64-60* | *Enough* |
| *Less than 60* | *Unsatisfactorily* |
| *Admission conditions not met* | *Not allowed* |

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

*Each student must work on the essay independently. It is recommended to choose the topic of the essay at the end of October. Within one study group, each student should have different essay topics. Essays that contain signs of academic dishonesty are subject to rejection, and points for them to be canceled. For example, if the teacher in different study groups finds the same essays (or essays that contain the same text fragments), then all such essays are subject to rejection, and the points for them are canceled.*

**The working program of the academic discipline ( syllabus ):**

***Folded*** *Ph.D. , Associate Professor of the Department of Theoretical Electrical Engineering, Faculty of Electrical Power Engineering and Automation Trotsenko E.O.*

***Approved by*** *the Department of Theoretical Electrical Engineering (protocol No. 14 dated 06/19/2024).*

***Agreed by*** *the Methodical Commission of the Faculty of Electrical Power Engineering and Automation (protocol No. 10 dated 06/20/2024).*