Hybrid Renewable Energy Systems

Basic information

Field of study Renewable Energy and Energy Management	**Didactic cycle** 2021/2022
Speciality All	**Subject code** EiPEOZS.IIi2S.5ecf6eb5c32c3.21
Department Faculty of Energy and Fuels	**Lecture languages** English
Study level Second-cycle (engineer) programme	**Mandatory** Obligatory
Study form Full-time studies	**Block** Major Modules
Education profile General academic	**Subject related to scientific research** Yes

Subject coordinator	Rafał Figaj
Lecturer	Wojciech Goryl, Krzysztof Sornek, Rafał Figaj, Mateusz Szubel

Period Semester 2	**Examination** Assessment **Activities and hours** Lecture: 15, Laboratory classes: 30, Project classes: 30	**Number of ECTS points** 6.0

Goals

C1	Introduction to the theoretical and practical aspects of the integration of two or more renewable energy sources in simple and complex energy systems.
C2	Transfer of knowledge about the functioning and operation of renewable energy systems dealing with more than one energy source devices in the renewable, by conducting theoretical investigations, practical exercises as well as designing process.
C3	Transfer of knowledge regarding the benefits and limits of hybrid renewable energy systems
C4	Raising awareness about the analysis of systems based on combinations of renewable and conventional energy sources

Subject learning outcomes

Code	Outcomes in terms of	Directional learning outcomes	Examination methods
Knowledge – Student knows and understands:			
W1	the theory and real-world characteristics of hybrid renewable energy systems,	EOZ2A_W01, EOZ2A_W02	Test
W2	how to analyze the operation of hybrid renewable energy systems, including estimation of energy production, planning and development and taking into account technical, social, economic, environmental and legal questions,	EOZ2A_W04, EOZ2A_W05	Test
W3	how to assess the performance of hybrid renewable energy systems using advanced methods of analysis and simulation.	EOZ2A_W03, EOZ2A_W06	Test
Skills – Student can:			
U1	develop models and multi-criteria testing of detailed work and global performance of a hybrid energy system based on renewable and conventional energy sources,	EOZ2A_U01, EOZ2A_U02, EOZ2A_U03, EOZ2A_U04	Report, Engineering project
U2	develop a project, starting from the concept and ending with an advanced feasibility study of the project or improvement of the hybrid energy system.	EOZ2A_U05, EOZ2A_U06, EOZ2A_U07, EOZ2A_U08, EOZ2A_U09	Report, Engineering project
Social competences – Student is ready to:			
K1	constant improvement of theoretical and practical knowledge, raising his professional and personal competences,	EOZ2A_K01	Report, Engineering project
K2	work respecting significance of non-technical aspects and results of the engineer's activity, including environmental impact, as well as the responsibility for decisions taken.	EOZ2A_K02	Report, Engineering project

Programme content that ensure achieving learning outcomes for the module

Lectures given on several aspects of the subject, presentation of case studies, developing of laboratory activities dealing with advanced modelling and simulation of hybrid systerms and development of projects.

Calculation of ECTS points

Activity form	Average amount of hours* needed to complete each activity form
Lecture	15
Laboratory classes	30
Project classes	30
Preparation for classes	30
Preparation of project, presentation, essay, report	30
Realization of independently performed tasks	15
Examination or Final test	2
Contact hours	5
Student workload	**Hours** 157
Workload involving teacher	**Hours** 75

* hour means 45 minutes

Study content

No.	Course content	Subject learning outcomes	Activities

1.	The lectures are focused on the following topics: - Methods of generating electrical and thermal energy using renewable energy sources. - Technical, energy and economic aspects of integrating renewable energy sources in simple and complex systems. - Hybrid systems based on the use of only renewable energy sources. - Systems combining renewable and conventional energy sources. - Examples of hybrid renewable energy systems application and characteristics of operation. - Energy storage in hybrid configurations. - Design and performance assessment of hybrid systems. - Control and operation strategies of simple and complex systems.	W1, W2, W3, K1	Lecture
2.	The laboratory activities are dedicated to the development of simulation models of simple and complex energy systems dealing with the integration of one of more renewable energy sources and/or conventional energy sources. The activities are based on the use of dedicated software for the modelling and simulation of such systems. The possible technologies/systems involved in the laboratory activities are: - solar thermal collectors (concentrated and non), photovoltaic panels, photovoltaic/thermal collectors; - ground heat exchangers and heat pumps, geothermal wells; - wind turbines, from micro to large scale; - biomass boilers; - cogeneration units (steam turbines, gas turbines, ORC, engines); - fuel cells and electrolysers; - energy storage (thermal and electrical); - HVAC units.	W3, U1, K1, K2	Laboratory classes

3.	The classes will be devoted to the development of projects regarding the following systems, mentioned only as example: - photovoltaic-wind system for households, commercial buildings, industry, small appliances, etc.; - solar thermal-biomass systems for residential buildings, third sector utilities, sport centers, etc.; - solar-geothermal plants for space heating and cooling; - cogeneration, trigeneration and polygeneration plants based on hybridization of energy sources.	U1, U2, K1, K2	Project classes

Course advanced

Teaching methods:

Lectures, Laboratory classes, Multimedia presentation, Discussion, Project assignments, E-learning, Case study, Group work method, Design thinking, Problem based learning, Project based learning, Brainstorming

Activities	Examination methods	Credit conditions
Lecture	Test	Passing the test with a positive score (higher than 3.0)
Lab. classes	Report	Positive score for each report as well as for the final test (higher than 3.0)
Project classes	Engineering project	Positive score for each project report (higher than 3.0)

Requirements and method of completing particular forms of classes

Lectures:
During lectures students are getting familiar with the material presented by the teacher in the form of slides presentation or practical examples, also the field visits. Students have to contribute actively in lectures in case of running discussion/debate form of classes. Lecture classes attendance is not compulsory, however it can positively influence on the final grade (additional points for active contribution, attendance lists etc).
Laboratory classes:
As a part of laboratory, students have to go through the series of practical studies using dedicated experimental stations and/or advanced computer software. Students carry out exercises in small groups. Then they prepare reports that must be delivered to the teacher bofore the set date. Laboratory classes are summarized by final test regarding knowledge acquired during the semester. Attendance in this form of classes is compulsory.
Project classes:
Students practice developing and calculating the models related to information obtained during lectures and laboratories. Furthermore, they broaden their knowledge based on materials provided by the teacher. Then have to prepare original projects of selected hybrid renewable energy systems, inlcuding technical and economic issues associated with their application. Attendance in this form of classes is compulsory.

Method of calculating the final grade

The final grade (FG) is determined on the basis of AGH regulations regarding assessment thresholds and using the following equation:
FG=0,3*T*R + 0,30*P + 0,40*L*R
T - grade for the lecture test
P - project classes grade
L - laboratory classes grade
R: 1 - for 1st test, 0,9 - for 1st retake, 0,8 - for 2nd retake.

The final grade is determined to two decimal places without rounding, in accordance with the following rule depending on the numerical value: 1) from 3.00 verbal rating: sufficient (3.0) 2) from 3.21 verbal mark: plus sufficient (3.5) 3) from 3.71 verbal mark: good (4.0) 4) from 4.21 verbal mark: plus good (4.5) 5) from 4.71 verbal mark: very good (5.0).

The grade indicate that a student is able to think beyond the boundaries and explore the possibilities for solving problems related to the integration of renewable-based hybrid energy system (in reference to EIT OLO 3), i.e. is able to:
5,0 - find solutions to address all problems related to the integration of considered RES-based hybrid energy system,
4,5 - find solutions to address and solve main problems related to the integration of considered RES-based hybrid energy system,
4,0 - find solutions to address and solve some problems related to the integration of considered RES-based hybrid energy system,
3,5 - combine a collection of available ideas to address and solve some problems related to the integration of considered RES-based hybrid energy system,
3,0 - reformulate and apply available ideas to address and solve some problems related to the integration of considered RES-based hybrid energy system,
2,0 - no evidence of the Learinig Outcomes shown.

Method and procedure for compensating for missed coursework resulting from student absence from classes

One missed exercise - no sick leave receipt required.
Two or more absences - catching up all the backlog, based on individual guidelines from the teacher. Sick leave receipt required.
Less that 51% of attendance during classes disqualifies the student to get the course credit.

Entry requirements

Student enrolling the course has to be familiar with:
- energy conversion methods,
- energy and mass balance calculations,
- fundamental principles of fluid dynamics and thermodynamics,
- basic knowledge regarding renewable energy sources and technologies.
Additionally, student enrolling the course is obliged to have the UPeL (AGH e-learning plaftorm) account. The account has to be activated not later than before the first classes.

Attendance requirements for particular classes, with indication whether student attendance is compulsory

The teacher gives a detailed form of tests and reports during organizational classes and - if required - before each form of assessment as part of group or individual consultations.

Literature

Obligatory

1. Fathima, H., Prabaharan, N., Palanisamy, K., Kalam, A., Mekhilef, S., & Justo, J. J. (Eds.). (2018). Hybrid-Renewable Energy Systems in Microgrids: Integration, Developments and Control. Woodhead Publishing.
2. Rekioua, D. (2019). Hybrid Renewable Energy Systems: Optimization and Power Management Control. Springer Nature.

Optional

1. R. D. Figaj, L. Vanoli, Chapter 13: Hybrid and novel solar hydrogen systems, Solar Hydrogen Production: Processes, Systems and Technologies, 1st Edition, Academic Press, ISBN: 9780128148532, Published Date: 1st August 2019;
2. R. D. Figaj, M. La Palma, L, Vanoli, Chapter 7: Novel and hybrid biomass-based polygeneration systems, Biomass in Small-Scale Energy Applications: Theory and Practice, 1st Edition, CRC Press/Taylor & Francis, ISBN: 9780367251055, Published Date: October 11, 2019.

Research and publications

Research

1. Research on the configurations, operation characteristics and energy, economic and environmental performance of novel, complex and hybrid renewable energy systems.

Publications

1. Figaj, R., Szubel, M., Przenzak, E., & Filipowicz, M. (2019). Feasibility of a small-scale hybrid dish/flat-plate solar collector system as a heat source for an absorption cooling unit. Applied Thermal Engineering, 163, 114399.
2. F. Calise, R. D. Figaj, L. Vanoli, Optimization of a novel polygeneration system integrating photovoltaic/thermal collectors, solar assisted heat pump, adsorption chiller and electrical energy storage, IOP Conference Series: Earth and Environmental Science, 214(1),012115
3. F. Calise, R. D. Figaj, L. Vanoli, Energy and economic analysis of energy savings measures in a swimming pool centre by means of dynamic simulations, Energies, 11(9),2182,
4. S. Di Fraia, R. D. Figaj, N. Massarotti, L. Vanoli, An integrated system for sewage sludge drying through solar energy and a combined heat and power unit fuelled by biogas, Energy Conversion and Management 171, pp. 587-603, 2018
5. A. Carotenuto, R. D. Figaj, L. Vanoli, A novel solar-geothermal district heating, cooling and domestic hot water system: Dynamic simulation and energy-economic analysis. Energy, Volume 141, 15 December 2017, Pages 2652-2669

Directional learning outcomes

Code	Content
EOZ2A_K01	Is aware of the need to critically assess the information received and knowledge acquired, recognizes the importance of knowledge in addressing cognitive and practical problems, in particular in the field of energy.
EOZ2A_K02	Is aware of responsibility for the tasks performed, is willing to think and act in an entrepreneurial and professional manner, is aware of compliance with the principles of professional ethics and the cultivation and dissemination of appropriate practices, as well as initiation of actions for the benefit of the social community and public interest, including the rational use of energy and provision of the national energy security.
EOZ2A_U01	Is able to use knowledge of basic sciences, thermodynamics, material science and related topics to develop physical and mathematical models of analyzed technical issues in order to solve them using advanced IT tools, crytically analyze and evaluate the solution, verify it experimentally and present information.
EOZ2A_U02	Is able to use knowledge to plan and conduct research on energy processes using various methods, including experimental ones, is able to use available software and create own computer codes for the purpose of analysis of the solution, is able to perform a critical analysis of results and prepare a synthetic compilation presenting the results of conducted research in terms of economic and environmental analysis.
EOZ2A_U03	Is able to formulate hypotheses related to the functioning and effectiveness of renewable energy systems, perform verification analysis, apply optimization methods and solve practical technical and economic problems.
EOZ2A_U04	Is able to create mathematical models of technical issues to solve them, can asses the functioning of energy systems and prepare a forecast and plan for their development at different levels of management.
EOZ2A_U05	Is able to carry out critical, from the technical, economic, environmental and social point of view - analysis of the functioning of any element of the energy system and develop a project of improvement in the construction and operation of renewable and classic energy equipment and installations.
EOZ2A_U06	Is able to develop a complete project involving machinery, equipment and energy installations, including also relevant automation, control, monitoring and process visualisation systems using a wide range of modern technical, IT and data transmission tools.
EOZ2A_U07	Is able also to assess the impact of energy systems on the global functioning of civilization, including society, natural environment, economic and social development and related issues, is able to present own point of view to a wide range of audiences, also using a foreign language and presentations illustrating advanced technical and non-technical problems in the field of energy.
EOZ2A_U08	Is able to lead a team dedicated to solving energy-related technical problems using a variety of technical and IT tools and resources.
EOZ2A_U09	Is able to plan self-learning using various forms of information acquisition, including professional publications (also in a foreign language) and to conduct self-learning by criticall analysis of the information acquired.
EOZ2A_W01	Knows and understands the phenomena described in the basic sciences, methods of their thermodynamic description and modelling in connection with the use of materials in the power industry.
EOZ2A_W02	Knows and understands basic and advanced processes occurring during the operation and functioning of machines, networks and power and electrical systems that use renewable energy sources, the importance of automation and control of their operation, the importance of proper design and selection, forecasting and planning of their development and the impact of energy technologies on the environment.
EOZ2A_W03	Knows and understands development trends in fields related to renewable energy, such as processing of energy resources, co-generation, environmental protection technologies and modern information and optimization methods that broaden the application horizon of RES.
EOZ2A_W04	Knows and understands dilemmas related to the development of RES: ensuring energy security, environmental protection and sustainable energy development as well as rational utilization of energy and use of energy resources.
EOZ2A_W05	Knows and understands the norms and legal regulations applied in the power industry, the concepts in the field of industrial property protection, copyrights and patent information, the basis of economics and management in renewable energy and environmental protection.

Code	Content
EOZ2A_W06	Knows and understands the general principles for developing individual entrepreneurship, including: principles of business plan development and business management, economics and management in the energy sector and environmental protection.