Photovoltaics Specialisation – Courses syllabi

Contents

COURSE 1 - Renewable sources of energy: Photovoltaics

<table>
<tr><th colspan="2">Course Details and Description*
fill in the details for each course separately in English language</th></tr>
<tr><td>Course title in English Language
*Specify whether the title is abolished or revised</td><td>Renewable sources of energy: Photovoltaics</td></tr>
<tr><td>Course description in English language</td><td>Introduction to renewable energy sources with main emphasis on photovoltaic (PV) energy conversion.</td></tr>
<tr><td>Course content</td><td>

Introduction

Market development and historical overview of PV
Climate change and the need to move to renewable sources of energy
Solar energy in the quest to combat climate change.
Photovoltaic Technology and new trends

Light

Properties of light
Photon description
The nature of solar radiation and solar potential assessment
Representing meteorological data
Sunlight optimization collection
Shading and PV energy yield

Semiconductor physics

PN junction diodes
Diode equation
Solar Cells

PV Cell - Operation

PV cell structure
Collection probability
Spectral response
Photovoltaic effect
Operation parameters
Effect of parasitic resistance
Effect of temperature
Effect of irradiance

PV Cell - Manufacturing and Technologies

Basic PV cell design
Optical losses
Current losses
Voltage losses
PV manufacturing

</td></tr>
</table>

	○ PV cell technologies ○ New emerging technologies and trends • Photovoltaic modules and arrays ○ PV system analysis ○ Module performance ○ PV interconnection effects ○ Reasons for underperformance • Applied photovoltaic system engineering ○ PV system performance ○ PV system design and sizing ○ Energy prediction ○ PV business – manufacturing Costs • Emerging topics ○ Latest PV technologies ○ Large scale PV integration issues (duck curve) ○ Intelligent PV systems ○ Battery energy storage systems (BESS) ○ PV and battery storage system design ○ Economics, costs, lifetime analysis and recycling		
Course code		**Year/Semester**	
Level	Master ☑ PhD ☐ Other* ☐ ________________		
Course purpose and objectives	• Provide familiarization on aspects of solar energy and its utilization as a renewable source of energy. • Provide a range of principles and techniques for the analysis and description of the physical and operational aspects of solar cells. • Introduce photovoltaic systems (predominantly grid connected and stand alone) analysis. • Provide hands on experience on PV system design. • Increase awareness on PV as a potential alternative source of energy. • Provide exposure to different PV module technologies. • Provide experimental setup for better familiarization with PV systems. • Utilise software tools to design PV systems.		
Learning outcomes	• Understanding of solar cell theory and techniques that are available for analysing their operational performance of PV systems. • Understanding of the design and operation of PV systems • Develop the skills for the utilisation of state-of-the-art tools for introducing PV as part of the smart grid.		
Prerequisites	-	**Required**	Not Applicable.
Course type	Mandatory ☐ Free Elective ☐ Restricted Elective ☐		

<table>
<tr><td></td><td colspan="5">Other * ________________
*specify the course type</td></tr>
<tr><td>ECTS</td><td>6</td><td>Lectures/week</td><td>2 (1.5 hours per lecture)</td><td>Laboratories/ week</td><td></td></tr>
<tr><td>Justification of ECTS</td><td colspan="5"></td></tr>
<tr><td>Teaching methodology</td><td colspan="5">• Lectures
• Assignments
• Project work</td></tr>
<tr><td>Assessment</td><td colspan="5">Quantitative ☒ Qualitative ☐ Other* ☐ ______________

Project/Lab assignment (20%)
Midterm exam (30%)
Final exam (50%)</td></tr>
<tr><td>Language</td><td colspan="5">Greek ☐ English ☒ Other* ☐ ______________

* specify the language</td></tr>
<tr><td>Instructor’s name</td><td colspan="5"></td></tr>
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COURSE 2 - Advanced digitalised PV systems

<table>
<tr><th colspan="4">Course Details and Description*
fill in the details for each course separately in English language</th></tr>
<tr><td>Course title in English Language
*Specify whether the title is abolished or revised</td><td colspan="3">Advanced digitalised PV systems</td></tr>
<tr><td>Course description in English language</td><td colspan="3">This course delves into cutting-edge digitalized technologies for photovoltaic (PV) systems. Participants will explore smart monitoring and control, Internet of Things (IoT) integration, advanced artificial intelligence (AI)-driven performance analytics, and the use of Digital Twins for operational optimization in PV systems. Key topics include fault diagnosis, reactive and proactive maintenance, solar generation forecasting, grid integration using smart devices, grid support services from PV systems and energy management in hybrid solar systems. The course also covers the revolutionary impact of Virtual Power Plants (VPP) and blockchain in energy systems, equipping students with the knowledge to drive innovation in the renewable energy sector.</td></tr>
<tr><td>Course content</td><td colspan="3">Introduction to digitalized PV systems. Smart monitoring and control in PV systems. Integration of IoT in solar power systems. Advanced AI-driven PV system performance monitoring (fault detection and diagnosis). Digital Twin technologies for PV system operations. Predictive operation and maintenance (O&M) in PV systems using digital tools. Grid Integration of PV with smart grid digital solutions. Forecasting solar generation using data-driven techniques. Smart Inverters and grid support services from PV systems. VPP and blockchain technology.</td></tr>
<tr><td>Course code</td><td></td><td>Year/Semester</td><td></td></tr>
<tr><td>Level</td><td colspan="3">Master ☒ PhD ☐ Other* ☐ ________________

* specify the level</td></tr>
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<tr><td>Course purpose and objectives</td><td colspan="5">The purpose of this course is to equip participants with the knowledge and skills required to design and optimize digitalized PV systems. By integrating advanced technologies like IoT, AI, Digital Twins, and blockchain, students will develop the expertise needed to implement advanced analytics, smart monitoring solutions and predictive O&M solutions to enhance the performance and reliability of modern solar power systems.
This course aims to:
• Provide a comprehensive understanding of digitalized PV systems and their role in advancing renewable energy technologies.
• Develop proficiency in deploying smart monitoring, control systems, and IoT devices in PV system operations.
• Enhance knowledge of advanced AI, data analytics, and Digital Twin technologies for optimizing PV system performance and reliability.
• Foster expertise in predictive maintenance strategies to minimize downtime and operational costs in PV systems.
• Promote the use of blockchain for decentralized power management.
• Prepare participants to address modern challenges in PV system operations using state-of-the-art digital tools and techniques.</td></tr>
<tr><td>Learning outcomes</td><td colspan="5">By the end of the course, students should be able to:
• Understand the fundamentals and benefits of digitalized PV systems.
• Emphasize the need for advanced analytics, smart monitoring, predictive O&M and cutting-edge solutions.
• Apply smart monitoring, control solutions, IoT-based techniques, and AI-driven analytics to optimize PV system performance and operations.
• Use data-driven techniques to forecast solar energy generation.
• Provide good understanding of digital twin concepts for PV system operations and explore the role of VPP and blockchain technology in energy systems.
• Undertake performance and failure analysis at the system level.</td></tr>
<tr><td>Prerequisites</td><td colspan="2">Knowledge of photovoltaic systems.</td><td colspan="2">Required</td><td>Not Applicable.</td></tr>
<tr><td>Course type</td><td colspan="5">Mandatory ☐ Free Elective ☐ Restricted Elective ☐

Other * ☐ ________________
*specify the course type</td></tr>
<tr><td>ECTS</td><td>8</td><td>Lectures/week</td><td>2 (1.5 hours per lecture)</td><td>Laboratories /week</td><td></td></tr>
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	Project/Lab assignment (20%) Midterm exam (30%) Final exam (50%)
Language	Greek ☐ English ☒ Other* ☐ _______________ ** specify the language*
Instructor's name	

COURSE 3 - Hybrid Photovoltaic and Battery Energy Storage Systems

<table>
<tr><th colspan="2">Course Details and Description*
fill in the details for each course separately in English language</th></tr>
<tr><td>Course title in English Language
*Specify whether the title is abolished or revised</td><td>Hybrid Photovoltaic and Battery Energy Storage Systems</td></tr>
<tr><td>Course description in English language</td><td>This course provides an in-depth understanding of the operations of hybrid photovoltaic (PV) and battery energy storage systems (BESS). It covers the applied principles of solar energy, battery technologies, system design, integration, and optimization for residential, commercial, and industrial applications. Emphasis is placed on real-world applications, emerging technologies, and sustainability.</td></tr>
<tr><td>Course content</td><td>1. Introduction to Hybrid Energy Systems
o Overview of renewable energy systems
o Role of PV and BESS in hybrid systems
o Advantages and challenges
2. Photovoltaic Systems
o Variability and intermittency of PV systems
o Challenges and forecasting needs for the energy sector
o System components and design
3. Battery Energy Storage Systems
o Battery types and chemistries (e.g., Li-ion, lead-acid, flow batteries)
o Battery sizing, charging, and discharging characteristics
o Safety, maintenance, and lifecycle considerations
4. Hybrid PV-BESS System Design and Integration
o System architecture and configurations (on-grid and off-grid)
o Power electronics and inverters
o Control strategies and energy management
5. System Modeling and Simulation
o Introduction to simulation tools
o Performance analysis and optimization
6. Economic and Environmental Considerations
o Cost-benefit analysis
o Carbon footprint reduction
o Incentives and policies</td></tr>
</table>

	7. **Case Studies and Emerging Trends** ○ Real-world applications of PV-BESS systems ○ Advances in battery technologies and PV modules ○ Future prospects and innovations		
Course code		**Year/Semester**	
Level	Master ■ PhD ☐ Other* ☐ _______________ ** specify the level*		
Course purpose and objectives	The purpose of this course is to provide participants with the knowledge and skills required to understand the basic operations design, and practical implementation principles of hybrid energy systems combining photovoltaic (PV) solar technology and battery energy storage systems (BESS). The course focuses on the integration of PV and BESS to optimize energy efficiency for residential, commercial, and industrial applications, and emphasizes sustainability and the role of hybrid systems in reducing carbon footprints. This course aims to: • Provide a comprehensive understanding of hybrid PV-plus-storage systems and their role in advancing sustainable energy solutions. • Develop proficiency in designing, integrating, and optimizing hybrid PV and BESS for residential, commercial, and industrial applications. • Enhance knowledge of emerging battery technologies, system configurations, and energy management strategies to maximize efficiency and reliability. • Foster expertise in real-world applications, including load management, grid support, and off-grid solutions, utilizing hybrid PV and BESS. • Prepare participants to address modern challenges in energy storage and solar energy integration using innovative practices. • Promote an understanding of sustainability principles and their application in reducing environmental impacts.		
Learning outcomes	By the end of this course, students will be able to: • Understand the fundamental principles of photovoltaic systems and battery energy storage technologies. • Analyze and design hybrid PV-BESS systems for various applications. • Evaluate the performance and efficiency of hybrid energy systems. • Discuss economic, environmental, and regulatory considerations related to hybrid energy systems. • Apply software tools to size and design PV-BESS systems.		
Prerequisites	Knowledge of photovoltaic and battery systems.	**Required**	Not Applicable.

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Other * ☐ ________________
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<tr><td>Assessment</td><td colspan="5">Quantitative ■ Qualitative ☐ Other* ☐ ______________
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Midterm exam (30%)
Final exam (50%)</td></tr>
<tr><td>Language</td><td colspan="5">Greek ☐ English ■ Other* ☐ ______________
* specify the language</td></tr>
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COURSE 4 - Novel Applications and Technologies of PV

<table>
<tr><th colspan="4">Course Details and Description*
fill in the details for each course separately in English language</th></tr>
<tr><td>Course title in English Language
Specify whether the title is abolished or revised</td><td colspan="3">Novel Applications and Technologies of PV</td></tr>
<tr><td>Course description in English language</td><td colspan="3">This course explores groundbreaking advancements and applications in photovoltaic (PV) technology. Topics include cutting-edge materials like perovskites, organic and nano-technologies, and innovative PV module designs such as bifacial. This course also investigates the integration of PV systems for off-grid, rural, and urban contexts, including smart cities and infrastructure. Participants will also examine specialized applications such as Building-Integrated Photovoltaics (BIPV), Agri-Photovoltaics, floating PV systems, and PV roadways (PV noise barriers). Additionally, the course addresses solar-plus-storage systems and PV-powered electric vehicle (EV) charging stations, equipping students with the skills to apply the PV technology in diverse and emerging fields.</td></tr>
<tr><td>Course content</td><td colspan="3">Advanced materials for Solar Cells: From Silicon to organic and nano-technologies. Emerging PV technologies: Bifacial c-Si, Thin-Film, and Perovskites. PV for off-grid and rural electrification projects. PV in Smart Cities: Integration and management for urban areas. Building-Integrated Photovoltaics (BIPV): Design and applications. Agri-Photovoltaics (Agri-PV): Integrating PV with agriculture. Floating PV: Applications and Innovations. PV roadways and noise barrier infrastructure. PV-powered electric vehicle charging stations. Hybrid PV Systems (PV plus storage and other renewables).</td></tr>
<tr><td>Course code</td><td></td><td>Year/Semester</td><td></td></tr>
<tr><td>Level</td><td colspan="3">Master ■ PhD ☐ Other* ☐ ______________

* *specify the level*</td></tr>
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Course purpose and objectives	The purpose of this course is to provide participants with a comprehensive understanding of novel PV applications and technologies. By exploring advanced materials, emerging designs, and innovative applications, the course aims to equip students with the skills and knowledge to implement PV solutions in diverse and future-oriented contexts, from rural electrification to urban integration and hybrid systems. This course aims to: • Introduce participants to advanced materials, PV module technologies and designs. • Explore emerging PV technologies such as bifacial, thin-film, and perovskite solar cells and understand their potential and limitations. • Provide insights into novel PV applications, including off-grid and rural electrification, urban energy management, and smart city integration. • Highlight the design and functional advantages of BIPV. • Examine specialized applications like Agri-Photovoltaics (Agri-PV), floating PV, and PV roadways to showcase the versatility of PV systems. • Develop an understanding of hybrid PV systems that incorporate energy storage systems and other renewable energy sources for enhanced reliability. • Foster knowledge of PV-powered infrastructure, including electric vehicle charging stations and noise barrier integration. • Equip participants with the skills to apply innovative PV solutions for sustainable development in diverse sectors.		
Learning outcomes	By the end of this course, participants will be able to: • Understand advanced materials for solar cells, including silicon alternatives, organic compounds, and nano-technologies. • Analyze the potential of emerging PV technologies, such as bifacial, thin-film, and perovskite solar cells. • Design PV solutions for off-grid and rural electrification projects. • Explore PV integration and management in urban settings, including smart cities. • Design and evaluate BIPV for architectural and functional applications. • Assess the role of Agri-Photovoltaics (Agri-PV) in combining solar energy with agricultural productivity. • Investigate floating PV systems. • Examine the potential of PV-powered infrastructure, including roadways and noise barriers. • Develop solutions for PV-powered electric vehicle charging stations. • Integrate hybrid PV systems with energy storage systems and other renewable technologies for optimized performance.		
Prerequisites	Knowledge of photovoltaics.	**Required**	Not Applicable.
Course type	Mandatory ☐ Free Elective ☐ Restricted Elective ☐ Other * ☐ ________________		

	**specify the course type*				
ECTS	8	**Lectures/week**	2 (1.5 hours per lecture)	**Laboratories/ week**	
Justification of ECTS					
Teaching methodology	• Lectures • Assignments • Project work				
Assessment	Quantitative ☑ Qualitative ☐ Other* ☐ ______________ Project/Lab assignment (20%) Midterm exam (30%) Final exam (50%)				
Language	Greek ☐ English ☑ Other* ☐ ______________ ** specify the language*				
Instructor's name					