COST ACTION CA20109

MODENERLANDS

Modular Energy Islands for Sustainability and Resilience

Strategic Workshop

Energy Islands

Technical Challenges and Industrial Opportunities

Belval, Esch-sur-Alzette, Luxembourg | May 15-16, 2023

BOOK OF ABSTRACTS

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Modular Energy Islands for Sustainability and Resilience

Book of Abstracts for the Strategic Workshop on the

Energy Islands – Technical Challenges and Industrial Opportunities

Edited by

Carlos Rebelo, Charalampos Baniotopoulos, Hassan Hemida, Enzo Marino, Ruben Paul Borg and Anina Glumac

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COST Action CA20109 Modenerlands, supported by COST
(European Cooperation in Science and Technology)

www.modenerlands.eu

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The COST Action and the Strategic Workshop

The COST Action CA20109 MODENERLANDS is focused on advancing the concept of safe, smart, modular, cost-effective, and socially valuable high-performance Energy Islands. These islands will be based on offshore floating platforms and aim to address the challenges of renewable energy, particularly wind and wave energy.

The main objective of this Action is to merge and systematize the efforts of European Research and Development groups working on Sustainable Energy and related technologies, with a view to incorporating Floating Energy Islands into the plans, design, and development of future infrastructures of renewable energy. The Action aims to propose pathways for incorporating and promoting relevant synergies in Research, Education, and Training. These pathways will facilitate the development and future implementation of floating energy islands in oceanic deep-sea waters, thereby enhancing sustainability in the energy sector.

The Action's technical work is structured into three Working Groups. WG1 focus on assessing resources and examining the future of renewable energy in light of climate change. WG2 addresses the Modularized Construction of Offshore Floating Platforms, which can be easily extended to meet future energy needs. This working group will introduce the concept of Modular Energy Island, which acts as a platform to maximize collection and conversion of renewable energy sources.WG3 explores new challenges related to the design and manufacture of cutting-edge technologies for energy storage and transmission. This working group will also examine the potential of Green Hydrogen-related technologies for efficient energy storage and grid integration, while considering resilience analysis and techno-economic criteria.

The Strategic Workshop (SW), which takes place at the University of Luxembourg, Campus Belval, Maison des Sciences Humaines, Esch-sur-Alzette, Luxembourg, lasts for one and a half days. The theme of the workshop is "Energy Islands - Technical Challenges and Industrial Opportunities". The primary objectives of the workshop is to encourage active participation from the Action members of the three Working Groups and invite specialists from outside the Action who represent different stakeholders to present their recent developments and projects related to the scientific and technical topics addressed in the Action. Additionally, the workshop provides an opportunity for students who attended the first training school held in Chania, Crete, to present their work developed during and after the training school.

Dr Carlos Rebelo
Chair
University of Coimbra, Portugal

Dr Charalampos Baniotopoulos
Vice-Chair
Aristotle University of Thessaloniki, Greece
University of Birmingham, United Kingdom

Belval Campus of University of Luxembourg

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The Faculty of Humanities, Education and Social Sciences is located on Campus Belval, a former steel industry site in the South of Luxembourg.

Belval is not is not only housing the University of Luxembourg but is also home to numerous other research institutes and start-up companies. Eventually around 7,000 students and 3,000 people will work in this new hub for research and teaching.

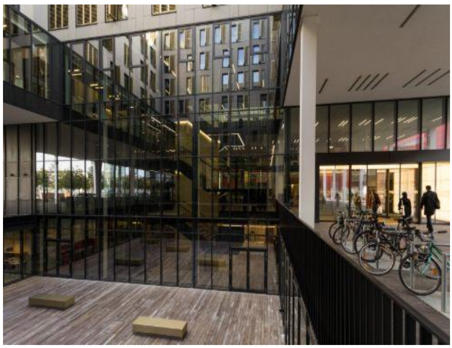
Workshop venue

The Workshop is taking place at Belval campus of University of Luxembourg in Esch-sur-Alzette. Esch-sur-Alzette is the second largest city in Luxembourg. In 2022, Esch-sur-Alzette was rewarded with the title of European Capital of Culture.

Location: Maison des Sciences Humaines (MSH)

Address: 11 Porte des Sciences, 4366 Esch-sur-Alzette

Room: Black Box.



Program Overview

Place	Belval, Esch-sur-Alzette, Luxembourg	
Venue	University of Luxembourg – Campus Belval, Maison des Sciences Humaines (MSH), Black Box	
15th May (Monday)		
8:30 - 9:00	Registration	MSH
Plenary Sessions		**Black Box (MSH)**
9:00 - 9:15	Welcome	Anina Glumac & Stephane Bordas
9:15 - 9:30	Overview of COST Action and SW	Carlos Rebelo
9:30 - 10:00	Invited Lecture	Ricardo Renedo Williams (EC)
10:00 - 10:30	Invited Lecture	Pedro Rodriguez (Lux. Inst. Science)
10:30 - 11:00	Coffee-break & POSTER Session	
11:00 - 11:30	Invited Lecture	William Otto (Space@sea)
11:30 – 12:00	Invited Lecture	Sarah Thomas (North Sea FPP)
12:00 - 13:15	Lunch break	
13:15 - 14:15	Special session Training School Chania	Presentations by TS Students
14:15 - 14:30	Overview of WG1 developments	Hassan Hemida
14:30 - 16:00	Presentations by WG1 members	
16:00 - 16:30	Coffee-break	
16:30 - 16:45	Overview of WG2 developments	M. Gkantou & A. Malekjafarian
16:45 – 18:15	Presentations by WG2 members	
20:00	Dinner at Snooze Pub	
16th May (Tuesday)		
Plenary Sessions		**Black Box (MSH)**
9:00 - 9:30	Invited Lecture	Paulo Brito (WIRE – CA20127)
9:30 – 10:00	Invited Lecture	Mohammad Shah (DNV)
10:00 – 10:30	Invited Lecture	Lúcio Rodrigues (PP Inc.)
10:30 - 10:45	Overview of WG3 developments	Ruben Paul Borg
10:45 - 11:15	Coffee-break	
11:15 – 12:45	Presentations by WG3 members	
12:45– 13:00	Closure of workshop	Charalampos Baniotopoulos, Carlos Rebelo & Anina Glumac
13:00	Lunch and Fairwell	

Detailed agenda

Invited Lectures		
15th May (Monday)		
09:30 - 10:00	Ricardo Renedo Williams	The EU's Approach to Offshore Renewables
10:00 - 10:30	Pedro Rodriguez	Energy Storage as a Key Enabling Technology for Renewable Energy Integration
11:00 - 11:30	William Otto	Energy Islands; Fixed or (partially) floating?
11:30 - 12:00	Sarah Thomas	Providing Reliable (dispatchable) Renewable Energy to Off-Grid Locations
Special session Training School Chania		
15th May (Monday)		
13:15 - 13:30	Ramon Varghese	Conceptual Design of a Floating Modular Energy Island for Energy Independency: A Case Study in Crete
13:30 - 13:45	Eray Caceoğlu	Towards novel modular energy islands – a case study of Crete, Greece
13:45 - 14:00	Marin Ivankovic	Conceptual design of a sustainable floating energy island to satisfy Crete's electricity demand
14:00 - 14:15	Bodan Velkovski	Conceptual Design of a Modular Energy Island for Crete

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Presentations by WG1 members		
15th May (Monday)		
14:30 - 14:45	Félix Nieto	Large scale energy harvesting in the context of Energy Islands: eh-Tower technology potential benefits and challenges
14:45 - 15:00	Tamara Bajc	Methodology for the application of floating photovoltaic systems on water bodies
15:00 - 15:15	Zhiyu Jiang	Recent developments in floating photovoltaic concepts
15:15 - 15:30	Fatih Karipoğlu	Ranking criteria for hybrid offshore energy systems using Fuzzy AHP
15:30 - 15:45	Leonardo Micheli	From land to water: opportunities and challenges for floating photovoltaic applications
15:45 - 16:00	António Couto	Exploring wind and solar complementarity to increase the value of the renewable energy islands concept
Presentations by WG2 members		
15th May (Monday)		
16:45 - 17:00	Stefano Lenci	Along- and cross-wind coupled nonlinear oscillations in wind turbines
17:00 - 17:15	Junlin Heng	Digital twins-enabled probabilistic deterioration assessment of floating offshore wind turbine towers under uncertainties
17:15 - 17:30	Amiya Pandit	Effectiveness of passive TMD vibration controller on the damaged spar-type floating offshore wind turbine.
17:30 - 17:45	Mariela Mendez Morales	An overview of fatigue behaviour in additively manufactured metals under cyclic loading
17:45 - 18:00	Giulio Ferri	Site-specific cost minimization of floating offshore wind turbines
18:00 - 18:15	Paul E. Thomassen	Quasi-automated fatigue lifetime design of floating energy islands

Invited Lectures		
16th May (Tuesday)		
09:00 - 09:30	Paulo Brito	Hydrogen and renewable gases production from Waste
09:30 - 10:00	Mohammad Shah	Life Cycle Assessment Topic in Energy Transmission & Distribution
10:00 - 10:30	Lucio Rodrigues	Going commercial scale based on supply chain studies and real-life floating wind projects
Presentations by WG3 members		
16th May (Tuesday)		
11:15 - 11:30	Jovan Todorovic	Power system operation challenges with an energy island integrated
11:30 - 11:45	David C. Finger	Climate-Neutral Europe: the Role of Renewable Energies in the Arctic to decarbonize Europe and enhance energy independence
11:45 - 12:00	Amir R. Nejad	On the Energy Islands and Green Corridors: Towards Green Energy Transitions
12:15 - 12:30	Snezana Cundeva	Grid integration of the renewable energy from sustainable energy islands
12:30 - 12:45	Luana Tesch	Life cycle environmental impacts of renewable offshore energies: A systematic review
12:45 – 13:00	Maria-Styliani Daraki	Passive Shunted Piezoelectric Systems for Vibration Control of Wind Turbine Towers. A feasibility study

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Invited Lectures

The EU's Approach to Offshore Renewables

Ricardo Renedo Williams
Energy policy at the European Commission

Highlights:

- Where do we come from?
- The Commission's Offshore Strategy
- EU legislative framework
- What next?

Ricardo Renedo Williams is a Policy Officer in the European Commission's Directorate-General for Energy, at the Unit for Infrastructure and Regional Cooperation, since March 2021. Ricardo is an expert on offshore renewables and grids, working on related aspects including grid planning and project support, supply chains and electricity market design. He also works on smart electricity grids. Previously, Ricardo worked at the European Network of Transmission System Operators for Electricity (ENTSO-E) as an electricity market specialist. Ricardo is an energy engineer with two master's degrees.

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Energy Storage as a Key Enabling Technology for Renewable Energy Integration

Pedro Rodriguez Cortes
Luxembourg Institute of Science and Technology

This presentation will take a bird's eye view of the evolution of power/energy systems and will justify the need to integrate energy storage systems into electricity and thermal grids. Based on these needs, some growth opportunities in the energy storage sector will be identified. Finally, the main technological trends in this field will be reviewed and some illustrative applications will be presented.

Highlights:

- Need for Energy Storage
- Growth Opportunities
- Technology Trends
- Some Applications

Prof. Pedro Rodriguez is with the Luxembourg Institute of Science and Technology, where he leads the Intelligent Clean Energy Systems (ICES) unit since 2021. He is a part-time professor at the Technical University of Catalonia, Spain and a visiting professor at Chalmers University, Sweden. He received a Honorary Doctorate by the Aalborg University, Denmark. He is an IEEE Fellow and a Distinguished Lecturer. He was awarded the 2020's Sustainable Energy Systems Technical Achievement Award by the IEEE-PELS. He is Highly Cited Researchers in Engineering and the holder of 16 licensed patents. His research interests include intelligent energy systems, distributed generation, and universal energy access.

Energy Islands; Fixed or (partially) Floating?

William Otto
Space@sea

Highlights:

- Floating islands provide modularity and therefore scalable, adaptable, flexible
- Floating islands are movable
- Research to the wind, wave and current induced dynamics of floating islands
- Mooring technologies
- (Fixed) Breakwaters

William Otto has been educated as a naval architect at the TU Delft with a specialisation in ship hydrodynamics. His main field of expertise is the dynamic behaviour of moored constructions in wind and waves. This expertise has been obtained by performing numerous model test campaigns for, among others, Oil&Gas platforms, floating wind turbines and floating PV. The experimental work has always been supplemented by numerical and mathematical models. All with the ultimate goal of obtaining a clear understanding of why constructions behave like they do.

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Providing Reliable (dispatchable) Renewable Energy to Off-Grid Locations

Sarah Thomas
Head of Technology Development
Floating Power Plant

Highlights:

- Introducing the FPP-technology and design: The unique combination of floating wind- and wave energy in one platform - complex, but better and more reliable output
- Technology maturity: Taking complex ideas from idea to reality
- The challenges of being off- or weak grid - and how new technology can solve it
- How to use hydrogen as a battery to enable usability and reliability of renewable energy
- The future for floating wind, hydrogen and P2X

Sarah Thomas, Head of Technology at Floating Power Plant, has spent the last decade designing, modelling, testing, and putting innovative renewable energy devices in the ocean.
She holds a Masters in Mathematics and a PhD in Engineering, focused on numerical models simulating forces around waves and renewable energy devices built to harness the power of the ocean.
She heads an international team of engineers and oversees cooperation with external partners (both private, public, and academic) all working together to help the global energy transition towards a more sustainable future.

Hydrogen and Renewable Gases Production from Waste

Paulo Brito
Superior School of Technology and Management of the Polytechnic Institute of Portalegre

Highlights:

- Waste availability
- Thermal gasification technologies
- Biochemical gasification technologies
- Renewable gases production projects in VALORIZA

Paulo Sérgio Duque de Brito has a degree in chemical engineering, Processes and Industry specialization, in the Technical Superior Institute; has a master's degree in "Corrosion Science and Engineering" by UMIST, Manchester University; is a PhD in Chemical Engineering, by the Superior Technical Institute in the electrochemical – on fuel cells. He has also an MBA – Master of Business and Administration. Currently, he is Full Professor of the Superior School of Technology and Management of the Polytechnic Institute of Portalegre (IPP). Is coordinator of the research centre VALORIZA – Research Centre for Endogenous Resource Valorization and the Coordinator of the Master Technologies for Environmental Valorization and Energy Production. The main areas he investigates are related with Bioenergy, waste environmental treatments, materials corrosion and energy galvanic production. He has published more than 300 works, in books, articles and conferences presentations. http://orcid.org/0000-0002-2581-4460)

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Life Cycle Assessment Topic in Energy Transmission & Distribution

Mohammad Shah
OHL Team Leader, Transmission & Distribution Technology Department at DNV

Highlights:

- Why LCA is important
- European Initiatives & Outlook
- Life Cycle Assessment of different technologies
- What would be the benefits?

Mohammad Shah is a highly experienced team lead in the Transmission and Distribution Technology Department, where he oversees the overhead line team and leads innovation and technology roadmap initiatives. With over 10 years of experience in the energy sector, he has provided consulting services for numerous international TSOs, including TenneT TSO, 50Hertz, Elia Group, Statnett, KEPCO, CLP Power, and the European Bank for Reconstruction and Development. Dr. Shah has published several journal papers on the design and optimization of energy structures.
Throughout his career, Dr. Shah has taken on numerous leadership roles, including leading renewable power plant due diligence, investment due diligence, and bankability studies in the high voltage field. He has also served as a technical consultant for regulatory-related projects on national and international large transmission projects for regulatory authorities and TSOs. As a consultant at DNV, Dr. Shah led several innovation projects, including new tower design using composite materials, smart inspection using AI and multi-spectral imaging, and extreme weather condition indexing like downburst and galloping. Dr. Shah earned a M.S. in Energy System Engineering from the Royal Institute of Technology in Stockholm and a Doctorate of Energy System from the University of Coimbra under the European Marie Curie Fellowship.

Going Commercial Scale Based on Supply Chain Studies and Real-life Floating Wind Projects

Lucio Rodrigues
Head of Procurement – Principal Power Inc.

Auction processes for commercial floating wind farms in global markets are underway a great achievement for the floating wind industry, and a first of many steps towards even bolder ambitions. Out of a floating wind farm commercial project, the platform represents a sizable part of the CAPEX, second only to the wind turbine generator (WTG). This is a major potential lever towards the optimization of the Levelized Cost of Energy (LCOE). Principle Power is preparing to serial-produce these platforms by building on 15 years of track record around the WindFloat®. We have designed, deployed, and are operating a market-leading 75 MW of capacity in Portugal and Scotland, as well as supporting the construction of another 30 MW project in France.

Working with existing and planned facilities and contractors around the world to collect feedback on the next-generation WindFloat® design, we have been laser-focused on identifying and addressing bottlenecks throughout the entire supply chain, from the design, fabrication, assembly, loadout, and installation phases. Principle Power optimized its WindFloat® design for compatibility with large wind turbines, adaptability to project specific requirements, and for standardized and modular layouts for various execution models and contract structures. During the workshop students will learn from the supply chain studies and real-life floating wind projects what are the future requirements of a truly industrialized floating offshore wind supply chain. Takeaways to achieve significant reductions in cost, flexible access to supply chains, from design, engineering to manufacturing and installation strategies.

Lúcio Rodrigues is currently serving as Head of Procurement. He has more than 20 years of engineering management experience spanning a variety of fields of expertise, including Oil & Gas, Maritime, and Renewables. Among the current responsibilities at Principle Power, he ensures that purchases of products and services are in line with the company's needs and requirements. Before he oversaw the project execution and road map of the company's industrialization, and supported customers with the installation of projects involving floating offshore wind turbines. Prior to joining Principle Power, Lucio gained international experience with a variety of responsibilities. It includes driving economic value as country manager in the Oil and Gas and renewables industry.

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Abstracts - Training School Students

Conceptual Design of a Floating Modular Energy Island for Energy Independency: A Case Study in Crete

Ika Kurniawati*, Beatriz Beaumont, Danka Kostadinovic, Ivan Sokol, Ramon Varghese, Hassan Hemida, Panagiotis Alevras, Charalampos Baniotopoulos
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Summary. This paper aims to investigate the development of a floating sustainable energy island at a conceptual design level that would enhance the energy independence of islands focusing on a case study at the island of Crete. The selection of the best location of the floating energy island is addressed through the assessment of the great potential of the wind, solar, and wave as renewable energy resources, taking into consideration criteria with regard to human activities. To this end, the concept of an innovative floating modular energy island (FMEI) that integrates different renewable energy resources is proposed; in addition, a case study that focuses on the energy independency of a big island illustrates the concept referring to the substitution of the local thermal power plants that are currently in operation in Crete by sustainable energy power.

Keywords: Floating Modular Energy Island, Renewable Energy, Potential Energy Assessment.

Introduction

Energy islands can be defined as offshore infrastructures that can integrate different technologies for offshore energy production, especially in deep waters. Their desired ability to remain afloat and to generate renewable energy makes them extraordinarily interesting solution to the energy crisis. A floating modular energy island (FMEI) is a new concept based on the idea of energy islands. The structure is portable and should be easily assembled and disassembled, while maintaining its role of harvesting renewable energies. The energy is further transmitted to the on-land grid. The concept is further enhanced by considering an efficient storage and transport of energy, for example using green hydrogen technologies.

The Mediterranean Sea around the island of Crete is characterized by deep water, that makes fixed foundation offshore energy farms difficult. Thus, Crete is a promising location for proposing a floating energy island, given its potential for renewable energy from wind, solar and waves. An example of a study to assess the wind and wave energy potential in Crete was carried out by G. Lavidas and V. Venugopal [1]. The study presents the scenarios in which offshore wind energy has the potential to become a new base for renewable energy resources in Crete, with wave energy as a substitute. It should be mentioned that the fossil fuel demand in Crete is about 800 MW total nominal power [2], generated by three thermal power plants.

It is important to mention that the FMEI concept is in line with the Sustainable Development Goals, specifically goals number 7- Affordable and Clean Energy, number 9- Industry, Innovation and Infrastructure and number 13- Climate [3]. The proposed idea of this work is highly collaborated within the objective of Modenerlands COST Action, "to merge and systematize the efforts of the European Research and Development (R&D) groups working on Sustainable Energy and the related technologies, in particular, wind and wave energy

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sources." [4]. This work presents the conceptual design of a FMEI for the Island of Crete, taking into account the energy demand, the renewable energy potentials, the electrical transmission capacity, and the geographical and social aspect. The wind and solar energy potentials in the area are assessed based on the converters available on the current market. The feasibility of the floating platform and the technologies to store and transport the energy will be conceptually discussed.

Conceptual design

The first step in designing an energy island is to identify the most suitable location for the use of solar, wind and wave energies in the vicinity of the Cretan islands. The concept of FMEI is to consider the synergy between the three renewable energy sources (RES). The regions around the island of Crete with the highest solar, wind and wave energy potential were identified. The mentioned RES potential is assessed in this study in parallel with the consideration of protected areas, exclusion zones and grid connectivity. The potential locations are further curated taking into account available resources, sea depth and distance from the coast with visibility impact. For the chosen location, the performance data of the different types of energy were calculated and converted into the same unit. Once the best location is identified, the concept of a FMEI was designed and a conversion system for each type of energy was selected.

The assessment of RES in this stage of conceptual design uses open-source database of the Global Solar Atlas [5], New European Wind Atlas (NEWA) [6] and the data provided by Copernicus Marine Service [7] for wave energy potential analysis. The most suitable location near the Cretan coast was identified, taking into account the available renewable energy, the interconnection network, marine and human activities, and the seabed depth. The conceptual design covers the formation of the floating wind turbine, photovoltaic structure, and wave energy converters into an energy island. The design is evaluated by means of its energy production which substitute the power generation by TPPs. Mooring systems and suggested technologies are discussed. The design considers other aspects such as the danger of sea wave height and social acceptance by suggesting adequate distance to decrease the visibility from the coast.

References

[1] G. Lavidas and V. Venugopal, "Energy production benefits by wind and wave energies for the autonomous system of Crete", Energies, vol. 11, no. 10, p. 2741, 2018.

[2] K. Dimitris, A. Ioannis, D. Irini, C. Dimitris, "Turning Crete into an energy independent island", 4th International Hybrid Power Systems Workshop, 2019.

[3] United Nations, "Sustainable development goals – United Nations", http://www.un.org/sustainabledevelopment/sustainable-development-goals/

[4] COST, European Cooperation in Science and Technology, "MODENERLANDS", https://modenerlands.eu/about/. [Accessed on 28/10/2022].

[5] Global Solar Atlas by Solargis is licensed under CC BY 4.0. https://globalsolaratlas.info/map?c=35.366656,24.700012,8

[6] New European Wind Atlas (NEWA) is licensed under CC BY 4.0. https://map.neweuropeanwindatlas.eu/

[7] Global Ocean Waves Analysis and Forecast, Copernicus Marine Service, Copernicus. https://doi.org/10.48670/moi-00017

Towards Novel Modular Energy Islands – A Case Study of Crete, Greece

Eray Caceoğlu[1]*, Marko Mancic[2], Carolina Crespo[3], Sara Uceda Gil[4], Vladimir Gjorgievski[5], Alonso Benito Sanchez[6], Ruben Paul Borg[7], Emilio Muñoz Cerón[8]

[1] MSc Student, Department of Civil Engineering, Middle East Technical University, Ankara, Turkey; [2] Faculty Member, Faculty of Mechanical Engineering, University of Niš, Niš, Serbia; [3] PhD Student, Department of Energy and Environmental Engineering, University of Lisbon, Lisbon, Portugal; [4] Naval Architect, WunderHexicon, Barcelona, Spain; [5] Assistant Professor, Faculty of Electrical Engineering and Information Technologies, Skopje, North Macedonia; [6] Senior Engineer, WunderHexicon, Marseille, France; [7] Associate Professor, Department of Construction and Property Management, University of Malta, Msida, Malta; [8] Professor, Engineering Projects Division, University of Jaén, Jaén, Spain,

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Summary. This study presents an early conceptual design of a novel floating modular energy island in Crete, Greece. The energy island consists of novel hybrid energy modules producing electricity from wind, solar photovoltaics and waves. They are also equipped with hydrogen storage facilities. The energy island is located at eastern shores of Crete. One module is estimated to produce 51 GWh/year of electricity with wind being the dominant source, therefore, with approximately 70 energy islands as the one proposed, would make Crete energy independent. The estimated cost for such intervention may rise up to 1417 M€.

Keywords: hybrid renewable energy, floating energy islands, offshore renewable energy, Crete

1. Introduction

EU has set ambitious goals for reaching climate neutrality by 2050 as defined in the European Green Deal. To achieve this, one of the approaches, already undertaken by Denmark, envisages development offshore energy islands, capable of producing energy offshore and sending it to the mainland consumers. This study presents an early conceptual design of a floating modular energy island which would be a hybrid energy power plant producing electricity from wind turbines, solar PV and wave energy converters in Crete, Greece.

2. Site Selection

The site selection to implement a modular energy island is a crucial process which should be based on evaluation of various criteria. The site selection consists of two steps: The first step is to evaluate the availability of environmental resources using open-source data. In this study, the main concerns are: average annual wind speed at 100 m height, horizontal solar irradiation and significant wave height. The second step considers the environmental protection areas, existing electricity grid system and water depth. The site should be as close as possible to the existing power lines, water depth should be minimized, and environmental protection areas must not be violated. These concerns have been mapped in

QGIS in selecting the most suitable site. Accounting for the aforementioned restrictions, the most suitable locations are placed on the eastern shores of the island. The selected site has water depth between 100-500 m and total area of 134 km^2. In addition, it is 5-15 km far from the coast.

3. Proposed Technology

The proposed novel modular energy island concept takes advantage of wind, photovoltaics and wave energy, with an on-board compartment for storing equipment and hydrogen as an energy storage medium. This combination helps minimize the cost per kW installed power and enables modularity and power rating scaling.

A single module consists of (i) 10 MW wind turbine with 122 m of hub height, which is the main energy source, (ii) solar panels of 4000 m^2 which covers the floaters with south-oriented 10 degrees slope, utility compartment with 35 degrees slope along with the tower and the nacelle, (iii) 50 wave energy converters fitted below the floater to extract energy from the foot print of the floater with moderate wave energy potential providing more stable output while avoiding breakdown caused by severe weather, and (iv) a utility pyramidal compartment designed to hold equipment and hydrogen storage, also covered by PV solar panels. The platform is tension leg type (TLP) which significantly reduces the motions and has the lower footprint at the seabed. The platform is formed of (i) truss structure using cylinders of around 4-5m diameter, (ii) 4 mooring lines and (iii) 4 main columns providing volume. Fig. 1 shows the arrangement of a module.

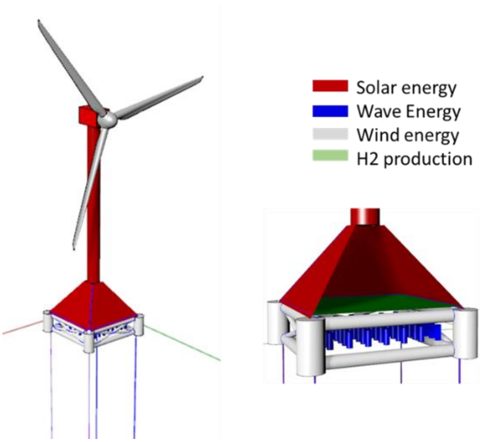

Fig. 1. Arrangement of one module

4. Power Production

According to the hourly analysis of the energy generation, in case no storage is included, a rule-of-thumb would be to size the capacity of the transformer substation such that it is proportional to the number of modules $P_t = n \cdot P_m$, where P_t is the rated power of the transformer, n is the number of modules, while P_m = 10 MW, as an approximate instantaneous peak power generation of one module. The total energy generation is estimated to be about 51 GWh/year assuming losses at widely accepted intervals. The power electronics for each energy source are located in pyramidal console of the module. As a result of the preliminary power calculations, the energy production mostly relies on wind (39.440 MWh/year). Despite producing less power, solar energy (10.330 MWh/year) is less deviant than the wind. Wave energy (1840 MWh/year) is mostly considered as a complimentary source. A total of 70 modules are planned to ensure energy independence of Crete.

5. Cost Estimation

Average cost of a PV power plant commissioned in 2019 was around 1025 €/kW [1]. Since solar has a small contribution to total installed capacity, it also does not contribute much to total costs – 0.15 M€. For wind power, the method proposed by Dicorato et al. [2] was used. Total wind power costs amount to 766 M€. For wave power, costs can be somewhat more difficult to assess. Furthermore, there is the added complication of there being as of yet no main well-established wave power technology – different projects tend to use different technologies. Nonetheless, a value of 3100 €/kW is mentioned for a generic floating wave energy plant [3]. For simplicity, this value was used. Total wave costs are thus estimated as 651 M€. Global cost of the project is estimated to be around 1417 M€.

6. Conclusion and Future Work

For the selected site, social acceptance may be a problem due to proxy to coastline. During micrositing, this distance may be increased. Also, Crete is a region with high earthquake hazard which must be accounted for in the final design to ensure that the structure will have sufficient resistance to survive a possible large earthquake. Finally, in future design iterations, storage elements, such as Li-ion of flow battery storage (to manage short term variability) or hydrogen storage (as a seasonal storage) can be considered.

7. References

[1] Lugo- Laguna, D., Arcos- Vargas, A., & Nuñez- hernandez, F. (2021). A European assessment of the solar energy cost: Key factors and optimal technology. Sustainability (Switzerland), 13(6), 1–25. https://doi.org/10.3390/su13063238

[2] Dicorato, M., Forte, G., Pisani, M., & Trovato, M. (2011). Guidelines for assessment of investment cost for offshore wind generation. Renewable Energy, 36, 2043–2051.

[3] Tetu, A., & Chozas, J. (2021). A Proposed Guidance for the Economic Assessment of Wave Energy Converters at Early Development Stages. Energies, 14, 4699. https://doi.org/10.3390/en14154699

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Conceptual design of a sustainable floating energy island to satisfy Crete's electricity demand

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Summary. The study was developed in the scope of the first Training School of the CA 20109 MODENERLANDS and aimed to propose an offshore energy island to satisfy the energy demand for the island of Crete, Greece, relying solely on renewable sources. To achieve this goal, two main sub-tasks had to be completed: determining a suitable island location and making the conceptual design of the floating structure along with a selection of technologies that allow for harvesting renewable energy sources. Finally, it was concluded that Crete's resources are so rich that the storage and export of a potential energy surplus should be thoroughly examined. Moreover, with the success of this case study, it was demonstrated that energy islands are a feasible and attainable goal for the future of hybrid renewable energy production.

Keywords: modular energy island, sustainable energy, Crete Greece

Introduction

The idea of self-sufficient islands in terms of energy has been present for over a couple of decades, primarily because of the rich resources many islands hold [1]. In 1997, the Danish Island of Samsø became a global model for sustainability by turning its electricity production to 100% renewable sources, by installing eleven onshore and ten offshore wind turbines and using local biofuel to power their vehicles. It has been broadly recognised that a significant part of the project's success is due to the active participation of the locals, who even funded the offshore wind farm construction [2]. In 2012, the Swedish energy company Hexicon proposed to install a 54 MW floating energy platform in Maltese waters. The aim was to provide Malta with an offshore wind farm incorporating solar and wave generation to decrease the country's dependency on fossil fuels [3]. This is one example of how different types of renewable energy sources could be integrated into a hybrid system.

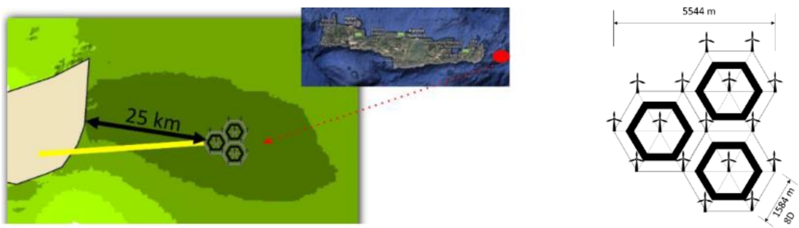
In order to start making conceptual design of Energy island it is necessary to know current energy status of Crete. Whole island of Crete annually consumes 3 TWh of energy with peak power consumption of 623 MW during summer and with minimum power consumption of 160 MW during winter. Crete currently have 1151.6 MW of installed power, 843.3 MW of which comes from non-renewable sources (steam turbines, diesel generators, gas turbines, combined cycle) and 308.3 MW comes from renewable energy sources (Hydro, solar and wind energy).

Considering the previous data for the current energy status, it is possible to condense the project into two main objectives: choosing location of the energy island according to all relevant criteria and proposing conceptual design of island that will satisfy energy demand of Crete

Conceptual Design of a Floating Energy Island: Crete

Selecting an optimal location was an iterative process in which several criteria were considered: wind, solar and wave energy potential need to be as high as possible, water depth needs to be sufficient to accommodate island, impact of proposed island on nature and human activity needs to be as low as possible and it should be designed in the way to be accepted by local community. Fig. 1 a) shows the selected optimal location 25 km east of Crete.

To meet that the annual peak demand of 623 MW, while considering installed 308.3 MW from renewable sources, the energy island would have to produce at least 314.7 MW of power. That means that island would produce more energy than necessary for the significant portion of year. Nevertheless, it is essential to highlight that two submarine cables will connect the island of Crete with the mainland soon; hence, part of the energy could be transmitted to the island if necessary. It is also possible to accommodate hydrogen energy storage facilities. Since wave energy potential was not significant when choosing the location, energy produced form waves was neglected. NREL-10 MW wind turbines were used as a reference for wind energy production mainly based on the wind turbine class selection IEC-61400 standard [4]. Since the rotor diameter of a wind turbine is 198 m, the micro-sitting of turbines proposed for the modular platform was determined using a recommended factor of this value (minimal recommended spacing is eight rotor diameters). Regarding solar panels, the characterisation of photovoltaic systems must be available for harsh offshore environmental conditions. However, this study does not focus on a specific solar panel since there is insufficient literature regarding their performance in offshore conditions. Finally, conceptual design of actual island is proposed Fig. 1 b). It accommodates 16 wind turbines (wind turbine symbols) and solar panels (black surface) covering 3.91 km2 (20% of island area). It was designed as three connected hexagonal modules to ease potential later adjustments to island power production (adding or removing modules).



(a) (b)

Fig. 1. a) Selected location of energy island, b) Conceptual design of the modular energy island

Conclusions

The best location for the proposed floating energy island has been determined at the east of Crete, where there is high energy potential from wind and solar sources and no interference with existing human activities or protected areas. Island was designed as three hexagonal modules that accommodate wind turbines in each module's nod and the centre, solar panels allocated on floating platforms and wave energy converters at the perimeter of island. This case study demonstrated that energy resources of Crete are so rich that the storage and export of a potential energy surplus should be thoroughly examined and that energy islands are a feasible and attainable goal for the future of hybrid renewable energy production.

References

[1] Kuang, Y. et al., A review of renewable energy utilization in islands, Renewable and Sustainable Energy Reviews, vol. 59. Elsevier Ltd, pp. 504–513, Jun. 01, 2016. DOI: 10.1016/j.rser.2016.01.014.

[2] Groppi, D.; Pfeifer, A.; Garcia, D. A.; Krajačić, G.; Duić, N., A review on energy storage and demand side management solutions in smart energy islands, Renewable and Sustainable Energy Reviews, vol. 135, Jan. 2021, DOI: 10.1016/j.rser.2020.110183.

[3] Rebello De Andrade, F., Hydrogen as energy backup for the Hexicon: A case study on Malta, Master Thesis, KTH Royal Institute of Technology, Stockholm, 2013.

[4] IEC, IEC 61400-1: Wind turbines-Part 1: Design requirements. International Electrotechnical Commission, 2005. [Online]. Available: www.iec.ch/searchpub

Conceptual Design of a Modular Energy Island for Crete

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The concept of energy islands represent an exciting and promising solution to scale up renewable electricity production, support easy installation of offshore generation facilities, and speed up the decarbonization process. Since more energy can be produced in the open sea area (wind is stronger and less intermittent, there is no shading, and the wave energy potential is higher), the wide adoption of energy islands seems to actualize. This paper investigates the possibility of applying the energy island concept to foster an increase in renewable energy production share of Crete island, safely shut down the fossil fuels production, and achieve island energy independence. The paper investigates the best solutions for energy island construction and inspects which renewable energy production technologies should be utilized and in which percent. A brief discussion on other important aspects, such as environmental impact and social adoption of energy islands is also provided.

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Abstracts – Working Group 1

Large Scale Energy Harvesting in the Context of Energy Islands: Eh-Tower Technology Potential Benefits and Challenges

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Summary. The eh-Tower concept for the large scale deployment of energy harvesters is described in the frame of its application associated to the Energy Island concept. Potential synergies and benefits are outlined and the main challenges being faced nowadays are briefly reviewed.

Keywords: eh-Tower, energy harvesting, Energy Island, turbulence.

Introduction. Energy harvesting is considered within this abstract as the electricity that can be generated from the mechanical energy of wind that induces the vibration of a dynamical system considering electromagnetic or piezoelectric effects [1]. This subject has attracted substantial research efforts in the last two decades, although with the focus put on powering microelectronic components. However, this technology is still immature as it faces important challenges in its transition from the lab to the real world engineering applications. According to Wang and co-workers [2], one of the challenges is the uncertainty associated with the wind characteristics in the ambient environment, but at the same time there are substantial opportunities in the improvements associated to the decrease of costs that would enable the deployment of thousands of harvesters establishing a power grid to serve for large-scale power supply. Furthermore, advances in material science and circuits should improve the power output of energy harvesters. Energy Islands, which aim at maximizing the collection and conversion of the renewable resources to efficiently transfer them to the electricity network, provide an excellent platform for the development of energy harvesting technologies at low cut-in velocities [3].

eh-Tower technology description. The eh-Tower concept consists of a conventional tower (floating or mono-pile arrangements) fitted along its height with a large number of energy harvesters. This concept might be developed in "stand alone" configuration or as an addition to standard Horizontal Axis Wind Turbines (HAWTs), as it is depicted in Fig. 1.

The wind speed range target of this technology is the relatively low velocity and high recurrence interval (between 2 and 6 m/s), which is below the cut-in or rated wind speeds of HAWTs; henceforth, with the potential to be operative over a large number of hours over the year. At early TRLs, this concept has been developed by the authors in the frame of the Interreg Atlantic Area project EMPORIA4KT in 2021.

Potential benefits and challenges. The eh-Tower concept offers features of potential interest in the frame of the Energy Island concept development. First, this technology aims at the power generation in the range of wind speeds suboptimal for HAWTs, so this would be operating with a wind resource that would not be exploited otherwise. Additionally, it would take advantage of the infrastructures and power grid already developed for the energy islands, therefore minimizing the economic cost of the technology. Another

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potential impact is in the refurbishment of obsolete HAWTs or in providing a second life to the blades of decommissioned HAWTs. One of the main challenges is the assessment of the aeroelastic performance of the harvesters under real environment flow conditions. To this end, the authors are currently working on a research project whose goal is to use numerical methods to study the aeroelastic response of the harvesters under turbulent flow, considering both linear and nonlinear dynamical systems. It should be noted that the development of accurate numerical models for the aeroelastic performance of the harvesters would enable the application of optimum design methods and digital-twin techniques that would facilitate a higher efficiency in the power generation. Furthermore, a commercial implementation would require improvements in electromagnetic technology and materials, as well as fatigue assessment and corrosion protection.

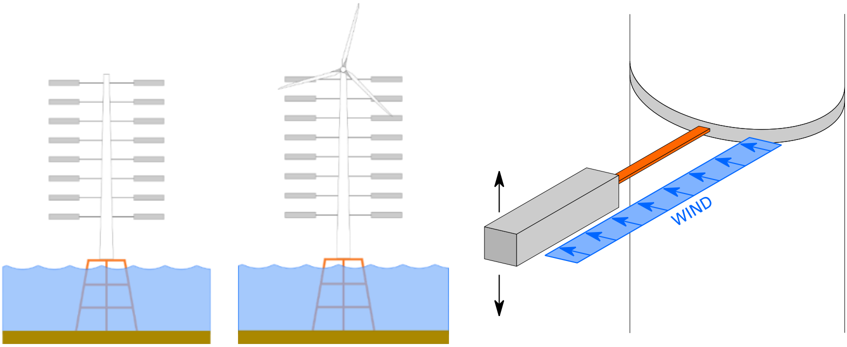

Fig. 1.Conceptual sketch of the technology. a) stand- alone deployment, b) combined with HAWT (hybridization) and c) detail of one wind-excited harvester.

Conclusions. The eh-Technology has been introduced and briefly described, considering the potential synergies within the frame of the Energy Islands concept development.

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References

[1] Zu, H., Tang, T., Yang, H., Wang, J., Song, J. and Peng, G. (2021) The state-of-the-art brief review of piezoelectric energy harvesting from flow-induced vibration. Shock and Vibration, Article ID: 8861821.

[2] Wang, J., Yurchenko, D., Hu, G., Zhao, L., Tang, L. and Yang, Y. (2021) Perspectives in flow-induced vibration energy harvesting. Applied Physics Letters 119, Article ID: 100502.

[3] Nieto, F. and Álvarez, A.J. (2022) Assessing the potential in wind-excited energy harvesters by computational methods. 1st Working Group Meeting and 2nd Management Committee Meeting. COST Action MODENERLANDS. Coimbra, Portugal; April 11-12, 2022.

Ranking Criteria for Hybrid Offshore Energy Systems Using Fuzzy AHP

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Summary. Offshore energy production systems, namely wind, solar PV and wave energies have been considered to be exploited more commonly recently. The storage or transmission of produced energy is very critical step for offshore energy systems. This study ranks the criteria which have impacts on hybrid offshore systems which include mentioned three energy systems. The main criteria selected for this study are technical challenges, environmental challenges and industrial opportunities. According to the expert's opinions, technical challenges are found as the first ranked main criteria with the highest importance of 0.386. The second rank belongs to the industrial opportunities while the lowest importance weight belongs to the environmental challenges. Met-ocean suitability which is categorized under technical challenges is calculated as a sub-criterion of the highest importance while energy production harmony is calculated as a sub-criterion of the lowest importance.

Keywords: Hybrid offshore systems, criteria weights, Fuzzy AHP.

Introduction. Offshore energy production systems, namely wind, solar PV and wave energies have been considered to be exploited more commonly recently. Among the three of the energy systems, offshore wind energy has the highest deployment with 54.9 GW as of June 2022 in the world [1]. On the other hand, offshore solar PV and wave energy systems are at their infancy. The smaller investments in prototype level are carried out to offshore solar and wave energy market. Due to global warming and climate change problem as well as the energy crisis, renewable energy systems are the only option for clean and sustainable energy sources. However, these energy systems include technical and environmental challenges along with industrial opportunities. In this study, the challenges and opportunities of hybrid offshore energy systems are investigated for their sub-criteria weights. This study also presents the importance weights and ranks of detected challenges and opportunities. These weights and ranks can give brief information to researchers for determining the gaps and critical research areas for hybrid offshore energy systems.

Methodology. In the scope of the study, challenges and opportunities criteria are determined and categorized under three main criteria. In order to calculate the weights and ranks, Fuzzy Analytic Hierarchy Process (FAHP) which is the commonly used techniques of Multi-criteria decision method (MCDM), is utilized [2]. FAHP can be carried out for the weight calculation by creating the different triangular structures in less time and effort comparing to the other similar methods [3]. To apply the FAHP, firstly the opinions from experts are collected and comparison matrixes are created. While creating the matrices, fuzzy logic numbers are used [4]. Based on the pairwise comparison method, the average importance weights are calculated. This study used the FAHP method to calculate and rank the detected main and sub-criteria weights. Five experts working in the offshore energy have participated and their opinions are analyzed in the study.

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Results. The importance weights and ranks which are results of FAHP are shown in Table 1. According to the experts' opinions, the technical challenges are found as first ranked main criteria with the highest importance of 0.386. The second rank belongs to the industrial opportunities while lowest importance weight belongs to the environmental challenges. In addition to Table 1, the weights calculation and ranking for sub-criteria of 13 are demonstrated in Table 2. According to Table 2, met-ocean suitability which is categorized under technical challenges is calculated as a sub-criterion of the highest importance while energy production harmony is calculated as a sub-criterion of the lowest importance.

Table 1. The average of importance weights and ranks of main criteria.

Main Criteria	Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5	Avg.	RANK
Technical Challenges	0,454	0,457	0,425	0,452	0,143	0,386	1
Environmental Challenges	0,454	0,226	0,425	0,223	0,143	0,294	3
Industrial Opportunities	0,093	0,318	0,151	0,325	0,713	0,320	2

Table 2. The average of importance weights and ranks of sub criteria.

Sub Criteria	Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5	Avg.	RANK
Platform design	0,042	0,078	0,082	0,149	0,086	0,087	3
Energy production harmony	0,020	0,083	0,038	0,016	0,067	0,045	13
Energy storage	0,016	0,078	0,011	0,035	0,280	0,084	4
Installation and maintenance process	0,015	0,078	0,019	0,126	0,280	0,104	2
Met-ocean suitability	0,044	0,159	0,077	0,080	0,446	0,161	1
visibility to touristic areas	0,019	0,053	0,025	0,104	0,089	0,058	8
Impact on fishing regions	0,015	0,053	0,025	0,080	0,089	0,052	10
Acoustic noise impact on marine ecosystem	0,015	0,053	0,025	0,061	0,089	0,049	12
The new R&D and manufacturer areas	0,015	0,093	0,015	0,047	0,073	0,049	11
Import of know-how and job creation	0,023	0,075	0,028	0,069	0,135	0,066	7
Improving existing infrastructure	0,031	0,077	0,028	0,077	0,168	0,076	5
Possible international cooperation	0,009	0,033	0,043	0,119	0,168	0,074	6
Energy independent and zero carbon emission targets	0,015	0,040	0,035	0,013	0,168	0,054	9

Acknowledgements. We thank to the experts who participated in our survey.

References

[1] World Forum Offshore Wind (2022) Global Offshore Wind Report HY 1 2022. Link: https://wfo-global.org/wp-content/uploads/2022/09/WFO_Global-Offshore-Wind-Report-HY1-2022.pdf

[2] Zhu K (2014) Fuzzy analytic hierarchy process. Fallacy of the popular methods. Eur J Oper Res 236:209–2017

[3] Ozturk S, Karipoglu F (2022) Investigation of the best possible methods for wind turbine blade waste management by using GIS and FAHP: Turkey case. Env Sci Pol Res 1-14

[4] Buckley JJ (1985) Fuzzy hierarchical analysis. Fuzzy Sets Syst 17:233–247

From Land to Water: Opportunities and Challenges for Floating Photovoltaic Applications

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Summary. In floating photovoltaics (FPV), modules are installed on water surfaces. This allows reducing the land competition with agriculture and avoiding some threats posed to biodiversity. Experts have also reported higher energy yields for FPV due to the cooling effect of water. At the same time, however, the water environment increases the degradation risks and the costs of FPV compared to land-based photovoltaics. This work assesses opportunities that FPV offers and the challenges it faces.

Introduction and motivation. The low power density, and the subsequent high land requirement, is one of the main challenges associated with the current and future deployment of photovoltaics (PV). Floating PV (FPV), in which modules are installed on the surface of water bodies rather than on land (Fig. 1), is one of the arising solutions to address this issue. Even if it still represents a small portion of the global PV capacity, the total installed FPV capacity has been rising exponentially since 2010 (Fig. 2).

So far, most of the literature (and of the installed capacity) is related to in-land floating systems (i.e. FPV deployed on enclosed water bodies, such as artificial lakes and reservoirs). However, the scope of MODENERLANDS is the investigation of energy islands, and therefore requires a better understanding of the opportunities and challenges that the marine environment poses to floating PV installations. This work presents an overview of these, briefly reported in following subsection, aiming to favour the engagement of the Cost Action members on this topic and the creation of joint studies and activities.

Fig. 1. Floating photovoltaic system in Korea, from [9].

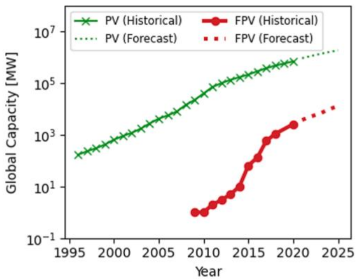

Fig. 2. Evolution and forecast of cumulative PV and floating PV (FPV) capacities worldwide [2].

FPV vs. traditional PV: advantages and disadvantages. The push toward FPV is motivated by various factors [1]. These include the need to limit the subtraction of land from agriculture, the possible integration with hydropower plants or offshore wind farms, the potential reduction in costs thanks to the easier installation and decommission processes, the reduction in water evaporation rates and the cooling effect of water, which maximizes the energy conversion efficiency of FPV modules. Indeed, the PV modules' efficiency rises inversely to the temperature: the lower the temperature, the higher the efficiency.

Among the previously listed advantages, the better thermal management has been reported so often to be considered as "intrinsic" to FPV. In reality, however, as discussed in [2], the operating temperatures of FPVs are not always lower than those of LPV, but depend on the system designs and the site characteristics. In general, horizontal FPV systems, in direct contact with water, are more likely to achieve lower temperatures and, therefore, higher electrical efficiencies than tilted systems. At the same time, however, it is often neglected that, at European latitudes, lower inclinations would lead to higher angular and reflection losses compared to optimally oriented land-based PV systems, and therefore cause higher power drops than any energy gain due to cooling [3]. This directly translates into higher costs of electricity and lower revenues, that have to be counter-balanced through reduced capital expenditures [4]. These can be achieved, for example, by sharing the grid connection infrastructure and costs with another technology, such as an offshore wind farm [8].

In addition, scarce data are still available on degradation when PV modules are mounted on water, especially for marine installations. However, while the lower temperatures might reduce thermal degradation [5], the proximity to water is expected to introduce additional risks for the systems, such as potential induced degradation, corrosion and failure of anchoring and mooring structures [6]. Marine installations will be even more likely to experience these [7]. For example, the deposition of salt on PV modules is expected to cause both reversible shading losses and longer-term corrosion.

Potential future works in MODENERLANDS. MODENERLAND opens the opportunity to create new networks and investigations on the installation of floating PV systems on the sea. For example, the hybridization of offshore wind farms and floating PV would require the optimization of their designs, in order to favour the cable pooling and maximize the capacity factor of the combined solution [8]. This can be done by investigating the intermittency of the two sources in different locations both on the Mediterranean and on the northern European seas. Wind speed and direction, irradiance and ambient temperature data are available on databases such as Copernicus, and can be used to model the performance of the two systems for this purpose.

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References

[1] World Bank Group, SERIS, and ESMAP, "Where Sun Meets Water: Floating Solar Handbook for Practitioners," Washington, DC, 2019. doi: 10.1596/32804.

[2] L. Micheli, "The temperature of floating photovoltaics: Case studies, models and recent findings," Sol. Energy, vol. 242, pp. 234–245, Aug. 2022, doi: 10.1016/j.solener.2022.06.039.

[3] L. Micheli, "Energy and economic assessment of floating photovoltaics in Spanish reservoirs: cost competitiveness and the role of temperature," Sol. Energy, vol. 227, 2021.

[4] L. Micheli, D. L. Talavera, G. Marco Tina, F. Almonacid, and E. F. Fernández, “Techno-economic potential and perspectives of floating photovoltaics in Europe,” Sol. Energy, vol. 243, 2022.

[5] M. Rosa-Clot and G. M. Tina, Levelized cost of energy (LCOE) analysis. Elsevier Inc., 2020.

[6] H. Liu, V. Krishna, J. Lun Leung, T. Reindl, and L. Zhao, “Field experience and performance analysis of floating PV technologies in the tropics,” Prog. Photovoltaics Res. Appl., vol. 26, 2018.

[7] T. Hooper, A. Armstrong, and B. Vlaswinkel, “Environmental impacts and benefits of marine floating solar,” Sol. Energy, vol. 219, no. August 2020, pp. 11–14, 2021.

[8] S. Z. M. Golroodbari et al., “Pooling the cable: A techno-economic feasibility study of integrating offshore floating photovoltaic solar technology within an offshore wind park,” Sol. Energy, 2021.

[9] S. H. Kim, S. C. Baek, K. B. Choi, and S. J. Park, “Design and installation of 500-kW floating photovoltaic structures using high-durability steel,” Energies, vol. 13, no. 18, 2020.

Recent Developments in Floating Photovoltaic Concepts

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Summary. The floating photovoltaic (FPV) technologies have been evolving in the past few years. Previous FPV applications can be found on freshwater bodies or in nearshore costal areas with relatively benign environments. Recently, research efforts have been dedicated towards developing innovative floating concepts suitable for operation in a variety of marine environments. In this talk, an overview of the technical aspects of FPV technologies is given and several novel FPV concepts are presented. A focus is laid on the material choice, structural design, modularity, connection systems, and motion performance. Finally, cost aspects of FPV technologies will be discussed.

References

Dai, J., Zhang, C., Lim, H.V., Ang, K.K., Qian, X., Wong, J.L.H., Tan, S.T. and Wang, C.L., 2020. Design and construction of floating modular photovoltaic system for water reservoirs. Energy, 191, p.116549.

Liu, H., V. Krishna, J. Lun Leung, T. Reindl and L. Zhao (2018). Field experience and performance analysis of floating PV technologies in the tropics. Progress in Photovoltaics: Research and Applications 26(12): 957-967.

Oliveira-Pinto, S. and Stokkermans, J., 2020. Assessment of the potential of different floating solar technologies–overview and analysis of different case studies. Energy conversion and Management, 211, p.112747.

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Exploring wind and solar complementarity to increase the value of the renewable energy islands concept

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Summary. Enhancing the capabilities of energy islands requires introducing new design paradigms, such as exploring wind and photovoltaic solar power complementarity to minimize the levels of flexibility required to deal with the variability of these technologies and provide a stable combined generation. This work addresses wind-solar complementarity in three deep-offshore regions in Portugal. Results highlight the reduction in the level of curtailment and reduction of low generation events when local complementarity is explored.

Introduction The renewable energy island concept offers a promising solution for meeting the growing demand for electricity while reducing the environmental impact of power generation. With continued research and development, the potential of renewable energy islands can be fully realized in the future. Renewable energy sources such as solar photovoltaic and wind power (usually designated as variable renewable energy sources – vRES) are crucial for the functioning of a renewable energy island. To support the development of these islands, a proper planning of the installation of these renewable technologies is necessary, including the identification of locations without restrictions for installation that, at the same time, present relevant energy indicators for exploring these technologies. However, considering the high initial cost, to increase the value of infrastructure associated with these islands, it is necessary to include new paradigms in their planning.

Local complementarity of vRES can allow for strategically planning the utilization of these energy sources, taking advantage of the inherent characteristics of each technology's primary resource. In fact, several authors argue that exploring complementarity can minimize i) the negative impacts of their individual variability and ii) the system's flexibility requirements, while allowing for more efficient use of land as the installed capacity and energy production per square meter of land use/floating system increase, and making the power system more resilient to extreme weather events [1]. On other hand, it is common to "overplanting" [2] power plants, i.e., the installed nominal capacity is above the permitted (nominal) power to increase the capacity factor.

In this work, different aspects of the integration of wind and solar technology are analysed in order to understand and maximize the complementarity between these technologies to increase their value within energy islands concept. Specifically, it applies common metrics for identify the vRES complementarity using three deep-offshore locations in Portugal, identified after applying a planning methodology that takes into consideration i) restrictions on the installation of vRES technology and ii) wind power potential. Considering the development of floating solar technology, through individual or integrated applications on the wind tower support structure or in the island developed, the optimal orientation and inclination are analysed to identify potential benefits. Different scenarios of overplanting are also considered using: i) wind, or ii) solar PV aiming to identify the potential for additional energy generation and the levels of energy curtailment for each location.

Methodology. The main steps of the methodology are presented in Fig. 1. The first step involves identifying locations where the technology can be installed using planning tools in a geographic information system. After identifying the most suitable locations for vRES installation, data with hourly resolution is obtained. In the case of solar PV technology, data is obtained for different azimuth and inclination angles. Due to limitations in obtaining solar PV generation series in offshore environments, the decision was made to identify the closest point on the coast for each point used. Finally, in step 3, complementarity analysis is carried out considering the most common metric in this type of work - Pearson correlation. The integration of solar PV technology is analysed considering an overplant solution that considers different azimuth and inclination angles of the panels. This inclusion solution is compared with a solution where only wind technology is considered.

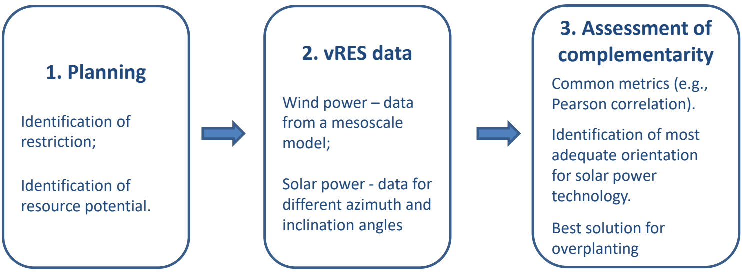

Fig. 1. Overview of the main steps of the methodology implemented.

Results. The indicators obtained in this work demonstrate the importance of complementarity between wind and solar PV energy. For the three locations analysed, due to their typical generation profiles (Fig. 2a), the results suggest that a diversified portfolio with more than one technology presents similar capacity factors when compared with the use of a single technology, with a lower level of energy curtailment, Fig. 2b). According to Fig. 2c), the levels of energy curtailment for different slope and azimuth orientations of solar panels are significantly different.

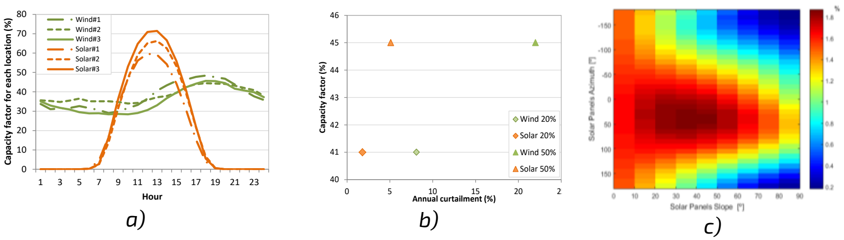

Fig. 2. a) Wind and solar daily profiles for the three locations analysed. Annual curtailment of the total energy produced for offshore location #1 in the North of Portugal using different: b) mix of wind and solar technology - 20% and 50% of the initial installed capacity, and c) solar panel orientations – optimal orientation and azimuth 34° and 5°, respectively.

Conclusions. The results obtained in this work show the importance and the existence of the complementarity between wind and solar PV in the regions analysed. Exploring only one technology can lead to a high level of curtailment if overplanting is considered. Despite some simplifications assumed, results show that complementarity between wind and solar PV energy needs to be explored in the concept of an energy island.

References

[1] J. Jurasz, F. A. Canales, A. Kies, M. Guezgouz, and A. Beluco, "A review on the complementarity of renewable energy sources: Concept, metrics, application and future research directions," Sol. Energy, vol. 195, no. December 2019, pp. 703–724, 2020

[2] C. Wolter, H. Klinge Jacobsen, L. Zeni, G. Rogdakis, and N. A. Cutululis, "Overplanting in offshore wind power plants in different regulatory regimes," Wiley Interdiscip. Rev. Energy Environ., vol. 9, no. 3, pp. 1–16, 2020..

Potential of Wind Energy in Bosnia And Herzegovina

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Summary. It is globally recognized that the use of renewable energy is of great importance for achieving sustainable development. Nevertheless, considering the reduction of fossil fuel reserves, as well as the environmental impact of using fossil fuels, research into usable renewable energy sources is becoming increasingly important for long-term development (G. Mortensen, L. Landberg, I. Troen, E.L. Petersen, 1993). In Bosnia and Herzegovina, one can find geographical diversity of great importance for the development of wind parks. Bosnia and Herzegovina has natural and geographical potential for the development of wind energy, and some estimates speak of a minimum of 1,000 MW of commercially usable wind power plants (Tešid Miroslav, Elvir Zlomušica i Sabina Sijačid, Elvir Zlomušica i Sabina Sijačid, 2009). Looking at the legislation and energy trends in the European Union, there is a need in Bosnia and Herzegovina for a stronger step forward in the construction and increase of the capacity of renewable energy sources that are integrated into the electric power system (World Wind Energy Association: World Wind Energy Report 2009, 2010). Although wind power plants are not traditional technologies in Bosnia and Herzegovina, they currently have the greatest potential and are certainly the most acceptable on the market (http://www.bh-news.com/index.php/component/ba/). International, especially European experience indicates that project financing models are mainly used in the research of wind potential, project development, construction and use of wind farms. In this paper, we will show locations in Bosnia and Herzegovina with the highest wind potential, and the way in which wind strength is measured using SODAR and LIDAR. We will explain the principle of operation of large and small (home) wind turbines, as well as the advantages and disadvantages of wind turbines, and provide a conclusion, with the aim of examining the possibility of producing electricity from renewable energy sources,primarily wind energy in Bosnia and Herzegovina (http://www.bh-news.com/index.php/component/ba/. Wind energy potential is currently being measured at 11 strategically located locations throughout Bosnia and Herzegovina using state-of-the-art equipment for wind parks.(Aleksandar Tadid1, Milica Vujadinovid,2011)

Keywords: wind power plants, geographical position, development, Bosnia and Herzegovina

Introduction. The sector of renewable energy sources has been given the task of providing reliable power supply for industry, trade and society as a whole. The motivation is not only to replace the dwindling source of fossil fuels, but also to achieve cleaner air and to meet the goals for net zero carbon emissions in globally different time horizons. Both solar and onshore wind energy are limited by geographic factors. In addition, wind energy is generated by airflow, which in turn is influenced by a number of factors, including prevailing climate, weather conditions, underlying surface conditions, topography, and geomorphology,(Wolfgang Platzer,2003). These factors lead to the randomness, intermittentness and uncontrollability of wind power (Nourani Esfetang and Kazemzadeh, 2018). If wind turbines for the production of wind energy are installed in Bosnia and Herzegovina, as the most

developed in the field of renewable energy sources (OIE), it could take the leading position, if the appropriate assumptions are made, which is confirmed by the intensity of interest in the construction of wind power plants. Some of the potential investors have been measuring and researching wind energy since 2004/2005 at several locations in Bosnia and Herzegovina, and certain requests for permits, consents and connections to the grid have already been sent to the relevant institutions. (Pedersen, E.; Waye, K.P 2007). The aim of this paper was to present a specific methodology for documenting windmills, to create a graphic representation using computer graphics, as well as to expand the importance of wind potential in Bosnia and Herzegovina.

Methods. This research developed a specific methodology for documenting and displaying the geographic areas where such unique constructions may be found. The techniques used are part of the field of engineering graphics and cartography (Fyhri, A.; Aasvang, G.M 2010). The use of digital photogrammetry is for the purpose of study. Measurements made only using a measuring mast or tower may be classified as banking, and serve in the subsequent phases of the project as a reference for obtaining full or partial financing of the project. A document classified as bankable is also an expertise for wind conditions. This includes the compilation of measurement data from all sensors, the effect and other analyses, such as: relief analysis, measurement uncertainty analysis, air density analysis, wind force distribution analysis, wind turbine set productivity analysis and more (Mc Cullagh, P.; Nelder, J.A,1989). The expertise includes data that enables the assessment of investments in terms of wind, the choice of turbines, Weitbull's distribution and wind roses in Bosnia and Herzegovina. This information may support decision-making in projects of the results of our research for Bosnia and Herzegovina.(Vjetroelektrane.com, http:// www. Vjetroelektrane .com/ energija -vjetra-u-energetici/, (23.03.2015.)

Research results. Wind energy, as a sustainable source of energy, has been considered the fastest growing branch of industry in the world in the last ten years. With its strategic documents, the EU initiated the processes of adopting action plans at the national, regional and local levels in order to use all the potential for energy efficient savings. Wind as a source of energy overtook coal and became the second largest energy capacity in the EU, according to the Eurostat report (CROENERGO.EU, http://www.croenergo.eu/Energija-vjetra-u-2014-godini-porasla-za-cak-44!-25760.aspx/(21.03.20 15.). Bosnia and Herzegovina is recognized as a country with significant energy resources, both conventional and renewable. In the strategy for the development of electric energy until 2030, wind energy occupies a significant place. The basic strategic goal of Bosnia and Herzegovina is the harmonization of legislation, which is a complex task that implies extensive and essential changes and a comprehensive reform of the energy sector. In order to be effective, legal regulation, that is, energy policy, must satisfy three basic criteria: financial, ecological and safety. (Klæboe, R.; Amundsen, A.H.; Madshus, C.; Norén-Cosgriff, K.M,2016)

Conclusion. If the characteristics of wind in Bosnia and Herzegovina are observed, we may conclude that our country has a good wind potential. This does not mean that the entire area of Bosnia and Herzegovina is extremely suitable for the construction of wind power plants. Measurements of certain characteristics of the wind, using LIDAR, SODAR and anemographs, (speed, direction, frequency), have shown that one area is more suitable for the use of wind energy than the rest of

Bosnia and Herzegovina (Artar, S. Tolun, 2016). The goal was to obtain the main technical parameters of the windmill, including the obtained power and momentum. These results will be discussed according to Betz's theory. In this paper, we present solutions such as graphic and cartographic representation by integrating computer design, geodetic processing, photogrammetry, cartography and computer graphics.

References

G. Mortensen, L. Landberg, I. Troen, E.L. Petersen: Wind Atlas Analysis and Application Program (WASP), Riso National Laboratory, Roskilde, Denmark, 1993 and updates.

World Wind Energy Association: World Wind Energy Report 2009, 2010. Zlomušica, S. Zalihid, M. Behmen, M. Čampara, Izračunavanje koeficijenta hrapavosti na kompleksnim terenima, 13. simpozij termičara Srbije i Crne Gore, pod sloganom Energetika-Efikasnost - Ekologija, Sokobanja 16-19. Oktobar2007.

http://www.bh-news.com/index.php/component/ba/Aleksandar Tadid1, Milica Vujadinovid: Wind potential and wind power development strategy in Bosnia and herzegovina Infoteh-Jahorina Vol. 10, Ref. F-30, p. 1034-1038, March 2011.

Tešid Miroslav, Elvir Zlomušica i Sabina Sijačid, Elvir Zlomušica i Sabina Sijačid:ENERGY 3, energija, ekologija, ekonomija" doo Mostar",IZGRADNJA VJETROELEKTRANE PODVELEŽJE, Mostar 2010. Wolfgang Platzer: A Guide To IAIK's ECC Library, IAIK, University of Technology Graz, June 2003, http://jce.iaik.ac.at

Pedersen, E.; Waye, K.P: Wind turbine noise, annoyance and self-reported health and well-being in different living environments. Occup. Environ. Med. 2007, 64, 480–486.

Pedersen, E.; Larsman, P. The impact of visual factors on noise annoyance among people living in the vicinity of wind turbines. J. Environ. Psychol. 2008, 28, 379–389.

Fyhri, A.; Aasvang, G.M: Noise, sleep and poor health: Modeling the relationship between road traffic noise and cardiovascular problems. Sci. Total Environ. 2010, 408, 4935–4942.

Klaeboe, R.; Turunen-Rise, I.H.; Harvik, L.; Madshus, C.: Vibration in dwellings from road and rail traffic—Part II: Exposure-effect relationships based on ordinal logit and logistic regression models. Appl. Acoust. 2003, 64, 89–109.

Mc Cullagh, P.; Nelder, J.A. Generalized Linear Models.: Monographs on Statistics and Applied Probability, 2nd ed.; Chapman and Hall: London, UK, 1989; p. 37.

Klæboe, R.; Amundsen, A.H.; Madshus, C.; Norén-Cosgriff, K.M: Turunen-Rindel, I. Human reaction to vibrations from blasting activity—Norwegian exposure–effect relationships. Appl. Acoust. 2016, 111, 49–57.

Klæboe, R. Ordinal.info Oslo: Institute of Transport Economics, 2016. Available online: http://ordinal.info (accessed on 22 July 2016).

Miedema, H.M.E. Position Paper on Dose Response Relationships between Transportation Noise and Annoyance; Office for Official Publications of the European Communities: Luxembourg City, Luxembourg, 2002.

Artar, S. Tolun: Wind energy potential of G€okçeada Island in Turkey, Renew. Sustain. Energy Rev. 12 (2008) 839-851.

CROENERGO.EU,http://www.croenergo.eu/Energija-vjetra-u-2014-godini-porasla-za-cak44!25760.aspx/, (21.03.2015.).

Vjetroelektrane.com, http://www.vjetroelektrane.com/energija-vjetra-u-energetici/, (23.03.2015.)

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A Modelling Study to Demonstrate the Impact and Benefit of an Energy Island on the Black Sea

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Summary. Today, the energy deficit is seen as a major problem that needs to be overcome for developing and developed countries. Moreover, the harms of fossil fuels are as much a problem as the energy deficit. The establishment of renewable energy power plants on the sea is very important in order to use the high potential wind, hydrogen and solar energy sources on the sea. Energy islands, where renewable power plants are clustered on the sea, is one of the best candidates to prevent high carbon emissions from fossil fuels and reduce the energy deficit. The disadvantages of land-based renewable energy sources can be listed as the restriction of agricultural lands, environmental pollution and migration routes of animals. Since energy islands are built on the sea, ocean, lakes and large rivers, they come to the fore especially in regions where terrestrial areas are used heavily. Since 71% of the earth is covered with water, it can be claimed that the number of areas to be used in energy production with energy islands is also high. Thanks to the recently installed offshore wind turbines, it has paved the way for energy islands. In this way, solar energy systems that will be integrated into wind turbines can also be made floating and benefit from energy production. Offshore wind turbines are cited as the first target for sustainable energy infrastructure. Due to the high cost of energy, it is aimed to minimize the energy deficit by using more efficient islands in less space.

In this study, the advantages of energy islands are briefly mentioned in a proposed model. In addition to the offshore wind turbines to be used here, it is planned to make the solar energy systems floating. In this way, hybrid energy systems will be established. Solar energy systems integrated into wind turbines will provide with more and sustainable energy. During the summer periods when the wind speed decreases, the solar radiation increases and the energy balance is maintained. In solar energy systems, with underwater power cables, the energy is transferred to the inverters and then the AC electricity obtained from the wind turbine and solar panels' inverter is transferred to the onshore network distribution transformer thanks to the interconnected system. In addition, due to the natural cooling effect of water, the floating solar energy system works more efficiently and contributes to reducing the evaporation of water in the area. For the conversion of wind speed to energy in the energy island, a 5 MW floating wind turbine was used as a generator with the doubly-fed induction generator (DFIG)-based developed and simulated power electronics systems. As a control system, it has been observed that the direct torque control (DTC) system in the rotor side converter gives better results compared to the direct power control (DPC). Thanks to the simulation results, energy islands were studied, real values and simulation values were compared and a preliminary study was obtained. The main goal in this proposed study is to show that energy production can be realized with higher efficiency, reducing energy deficit and without benefiting from fossil fuels, thanks to energy islands. In future studies, it can be suggested that the energy island be developed as a touristic area, fishing center and an energy storage center aiming to charge electric and hybrid ships in the energy islands.

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Investigation of Possible Methods for Mitigating Structural Motions of Floating Offshore Wind Turbines

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Summary. Offshore wind energy has gained more reputation and importance because of the high energy potential and less turbulence effect. As offshore wind installations increase, the technology has to be improved constantly. Technical uncertainties must carefully be studied and solutions must be engineered in order to bring investment costs down. Even if some of the engineering solutions developed for fixed offshore wind turbines can be used for floating offshore wind turbines (FOWT), there are a lot of FOWT specific problems that are needed to be addressed such as ensuring the stability under harsh sea conditions, difficult installation and maintenance, unavoidable long energy transmission lines that bring energy losses. To maintain an uninterrupted operation, providing a basic level of motion stability is an essential point. The stability of a FOWT is guaranteed by designers by modeling the 6 DoF motion of the entire structure under the dominant forcing sources, such as waves, wind thrust, buoyancy and mooring, with possible coupling between them. Testing many what-if scenarios then follows this modeling. Particularly, a designer tries to test the dynamics of a FOWT under extreme conditions so to make sure it will always operate safely. The present study covers the mitigation of FOWT motions which is one of the critical structural motions. With this regard, the consequences of motions are reviewed and common techniques to alleviate them are. This study can give general information to researchers for comparing the motion mitigation methods for floating offshore wind turbines.

Keywords: floating offshore wind turbines, structural motions, control systems.

Introduction. Floating offshore wind turbines (FOWT) have operated under the presence of strong wind, wave and seismic loads, and as a result, structural motions are induced on it which has always negative consequences [1]. These motions cause a decrease in structural life. Some of the techniques used to alleviate motions are i)using a mass damper in the nacelle or the blades, ii) employing a liquid damper, iii) applying a blade pitch control and/or generator torque control [2-4]. These approaches can be employed as passive, active, semi-active or hybrid ways [3]. Passive control methods are received comparatively more attention due to their simplicity and rugged nature.

Methods. Some of the commonly used passive techniques are listed below. These methods are categorized into different types according to the number of mass dampers used and their installation location.

1. Tuned Mass Damper (TMD): It consists of a mass that is connected to the main structure by a spring and a dashpot [2]. Under wind-wave-seismic loads, wind turbines demonstrate the motions of a lot of parts like the tower, blade, nacelle, etc. Therefore, the use of a single mass damper is not effective especially in high-vibration risky regions [5]. Mult-TMDs are suitable for multi-mode control while single TMD is effective for suppressing a single vibration mode [4]. The multi-mass dampers are more robust and well-functioning than the single types. Because of the severe forces induced by wind and wave, one of the challenges is pitch motion for floating wind systems. This motion may result in large displacements at the top of the tower and tips of blades, finally these deformations can lead to considerable bending moments and shear forces [3]. Adding the extra weights using the multi-TMD also helps to control the platform pitch motions in floating offshore wind turbines [4]. Numerical results showed that TMD could mitigate effectively the pitch motion of platform under the combined actions of wind and wave [4, 6].

2. Tuned Liquid Column Damper (TLCD) and Tuned Liquid Damper (TLD): They are commonly adopted for mitigating the structural motions of wind turbines. TLCD is composed of a U-shaped container that is partially filled with a certain level of liquid [3]. The shape of the column can be changed to provide better energy dissipation.

TLD is widely used to control tower motions. TLD consists of a tank partially filled with liquid for reducing the main structural motions [7]. Although it is more superior in the aspects of low initial cost, virtually free of maintenance and ease of frequency tuning [5].

Results. In the scope of the present study, the most commonly used techniques are given for mitigating the motion of floating offshore wind turbines. This section summarizes the specifications of the listed techniques for comparison among each other. All of them are controlled as passive control which does not need an external power source. It is known that structural motions mitigate the floating platform [5]. While TMD is used nacelle, TLCD and TLD can be used in the nacelle, tower, or foundation parts. Since TMD must be used with multi-dampers for more effective use, this is required the control algorithms for communication between them. It can be seen as a negative effect for floating offshore turbines located far away from the shore. Even though TLD is easy to design/run and cheaper, the challenge of TLD is that the irregular liquid slope deforming due to water sloshing in the tank makes it not easy to accurately estimate the motion of water [2]. Therefore, the design of TLD brings difficulties. The use of TLCD is shown as more suitable for floating offshore wind turbines because of the damping of the orifice plate and the gravitational restoring force from the liquid [3]. Also, the geometrics and liquid types can be changed to obtain better performance under different scenarios of floating offshore wind turbines. All methods are required detailed information and calculations for harsher and non-uniform sea conditions. As a result, TLCD can be a more suitable method while TMD is the oldest and most well-known idea among the mentioned three methods.

As a further study, it is planned that the listed structural motion mitigation methods will be implemented in the experimental setup which investigates the wind-wave loads on a floating offshore wind platform in the Hydraulic Laboratory, Izmir Institute of Technology.

References

[1] Zuo, Haoran, Kaiming Bi, and Hong Hao. "A state-of-the-art review on the vibration mitigation of wind turbines." Renewable and Sustainable Energy Reviews 121 (2020): 109710.

[2] Murtagh PJ, Ghosh A, Basu B, Broderick BM. Passive control of wind turbine vibrations including blade/tower interaction and rotationally sampled turbulence. Wind Energy 2008;11:305–17.

[3] Lackner MA, Rotea MA. Passive structural control of offshore wind turbines. Wind Energy 2011;14:373–88.

[4] Hussan M, Rahman MS, Sharmin F, Kim D, Do J. Multiple tuned mass damper for multi-mode vibration reduction of offshore wind turbine under seismic excitation. Ocean Eng 2018;160:449–60.

[5] Zuo H, Bi K, Hao H. Mitigation of tower and out-of-plane blade vibrations of offshore monopile wind turbines by using multiple tuned mass dampers. Struct Infrastruct Eng 2019;15:269–84.

[6] Fitzgerald B, Staino A, Basu B. Wavelet-based individual blade pitch control for vibration control of wind turbine blades. Struct Control Health Monit 2019;26(1): e2284.

[7] Tao W, Basu B, Reliability analysis of active tendon-controlled wind turbines by a computationally efficient wavelet-based probability density evolution method. Struct Control Health Monit 2018;25(3):2078.

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Renewable Energy Resource Assessment in the Black Sea Region—A Review

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Summary. A review of the current state of the art resource assessment of renewable energy in the Black Sea region was conducted to identify gaps in research and application. Publications were identified and categorized by the type of renewable energy resource covered and the applied resource assessment methods. Most of the publications considered renewable energy systems and conducted a selected type of resource assessment. Several different aspects were covered to assess resource use. Other publications focused on similar aspects including supply risks and technology-specific aspects in the resource assessment of renewable energy systems.

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References

Onea, F.; Manolache, A.I.; Ganea, D. Assessment of the Black Sea High-Altitude Wind Energy. J. Mar. Sci. Eng. 2022, 10, 1463. https://doi.org/10.3390/jmse10101463

Kucukali, S., Dinckal, C. Wind energy resource assessment of Izmit in the West Black Sea Coastal Region of Turkey. Renewable and Sustainable Energy Reviews, 2014, 30, https://doi.org/10.1016/j.rser.2013.11.018

Kustova, I., Egenhofer, C. How Black Sea offshore wind power can deliver a green deal for this EU region. CEPS Report, 2020, 25 p. Available: www.ceps.eu

Argin, M. et al. Exploring the offshore wind energy potential of Turkey based on multicriteria site selection, Energy Strategy Reviews, 2019, Vol. 23, pp. 33-46.

Jansen, M. et al. Offshore wind competitiveness in mature markets without subsidy. Nature energy, 2020, Vol. 5, pp. 614-622, https://doi.org/10.1038/s41560-020-0661-2

Topham, E., McMillan D. Sustainable decommissioning of an offshore wind farm, Renewable Energy, 2017, Vol. 102(B), pp. 470-480.

Rusu L, Ganea D, Mereuta E. A joint evaluation of wave and wind energy resources in the Black Sea based on 20-year hindcast information. Energy Exploration & Exploitation. 2018;36(2):335-351. doi:10.1177/0144598717736389

Bingölbali, B., Majidi, A. G., Adem Akpınar, A. Inter- and intra-annual wave energy resource assessment in the south-western Black Sea coast. Renewable Energy, 2021, Vol. 169, 809-819 https://doi.org/10.1016/j.renene.2021.01.057

Tanase, V. M., Chiotoroiu, B. C., Vatu, N. Wave energy along the Romanian Southern Black Sea coast. Journal of Physics: Conference Series, 1122 (2018) 012029, doi:10.1088/1742-6596/1122/1/012029

Yeşilyurt, M. K., Öner, I. V., Ömeroğlu, G., Yilmaz, E. C. A scrutiny study on wave energy potential and policy in Turkey. Periodicals of Engineering and Natural Sciences, 2017, 5(3), 286-297, doi: 10.21533/pen.v5i3.108

Guillou, N., Lavidas, G., Chapalain, G. Wave Energy Resource Assessment for Exploitation—A Review. J. Mar. Sci. Eng. 2020, 8, 705; doi:10.3390/jmse809070

Abstracts – Working Group 2

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Along- and Cross- Wind Coupled Nonlinear Oscillations in Wind Turbines

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Summary. The work is aimed at studying the 1:1 internal nonlinear resonance occurring in wind turbines due to the circular cross-section of the tower. After obtaining the equation of motion, the multiple time scale method is used to obtain an approximate analytical solution. It is shown that coupled motion can be activated above certain critical thresholds.

Governing equations and internal resonance. Defining x(t) as the position of the centroid of the nacelle along the wind, y(t) its position orthogonal to the wind and α(t) the rotation around the vertical axis of the wind tower, the nonlinear equations of motion of the simplified 3-dof model are, in dimensionless form:

$$\ddot{x} - (\dot{\alpha}^2 \cos\alpha + \ddot{\alpha}\ \sin\alpha) + 2c_x\dot{x} + x + k_3 x(x^2 + y^2) = f(t),$$

$$\ddot{y} - (\dot{\alpha}^2 \sin\alpha - \ddot{\alpha}\ \cos\alpha) + 2c_y\dot{y} + y + k_3 y(x^2 + y^2) = 0,$$

$$(1 + I_p)\ddot{\alpha} - (\ddot{x}\sin\alpha - \ddot{y}\ \cos\alpha) + 2c_\alpha\dot{\alpha} + k_\alpha\alpha = -f(t)\ \sin\alpha, \quad (1)$$

where ***f(t)*** is the force due to the wind and to the buoy oscillations (for floating off-shore wind turbines), $\boldsymbol{I_p}$ the (dimensionless) moment of inertia of the nacelle and blades with respect to the axis of the tower, $\boldsymbol{k_\alpha}$ the linear stiffnesses of the nacelle rotation, $\boldsymbol{k_3}$ the nonlinear stiffness, due to the slenderness of the tower, and $\boldsymbol{c_x}$, $\boldsymbol{c_y}$ and $\boldsymbol{c_\alpha}$ are the damping coefficients. See [4] for more details on the derivation of the (1). Note that the nonlinearities are both in the stiffness and inertia.

The linear undamped unforced version on (1) is:

$$\ddot{x} + x = 0, \qquad \ddot{y} + \ddot{\alpha} + y = 0, \qquad (1 + I_p)\ddot{\alpha} + \ddot{y} + k_\alpha\alpha = 0, \qquad (2)$$

from which we see that the along-wind linear dynamics is decoupled from the transversal and rotational dynamics. The natural frequencies are $\boldsymbol{\omega_1=1}$ (along-wind) and

$$\omega_{2,3} = \sqrt{\frac{1+I_p+k_\alpha \pm \sqrt{(1+I_p)^2 - k_\alpha(2I_p-2-k_\alpha)}}{2\,I_p}}, \qquad (3)$$

For very large value of the rotational stiffness $\boldsymbol{k_\alpha}$ (which is the common case when the rotation is restrained) we have

$$\omega_2 = 1 - \frac{1}{2\,k_\alpha} + \frac{\frac{3}{8} - \frac{I_p}{2}}{k_\alpha^2} + \cdots, \qquad \omega_3 = \frac{\sqrt{k_\alpha}}{\sqrt{I_p}} + \frac{1}{2\sqrt{I_p}\sqrt{k_\alpha}} + \frac{1}{8}\,\frac{4I_p - 1}{\sqrt{I_p}\,k_\alpha^{3/2}} + \cdots, \qquad (4)$$

so that for large values of $\boldsymbol{k}_\alpha$ we have $\omega_1 \cong \omega_2$ and a 1:1 internal resonance occurs. The third natural frequency ω_3, on the other hand, is very large.

Nonlinear dynamics and coupled solutions. From (1) we see that there is the monomodal, along-wind, solution x(t)≠0 and y(t)= α(t)=0, where x(t) satisfies the classical Duffing equation $\ddot{x} + 2c_x\dot{x} + x + k_3x^3 = f(t)$.

To see if coupled along- and cross-wind solutions exist, the multiple time scale method is applied to (1), assuming that the excitation is periodic in time $f(t) = \cos(\omega t)$. It is found that coupled solutions appear for large amplitudes, and branches from the monomodal solution of (5), as it is shown in Fig. 1 (see the black curve).

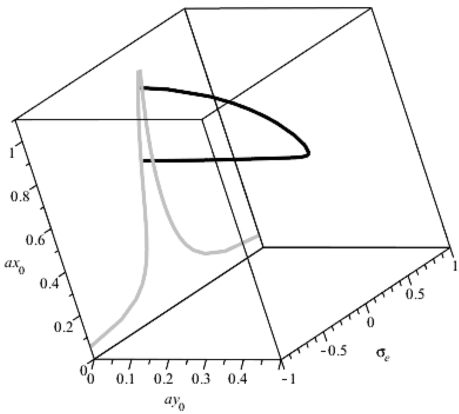

Fig. 1. The along-wind (ax_0) and cross-wind (ay_0) amplitudes as a function of the detuning parameter $\sigma_e = \omega - 1$. $I_p = 0.1$, $k_\alpha = 100$, $k_3 = 1$, $F = 0.1$ and $c_x = c_y = c_\alpha = 0.05$. The monomodal solution ($ay_0 = 0$) is in grey, the coupled one in black.

References

[1] Clementi F., Lenci S., Rega G., 2020, 1:1 internal resonance in a two d.o.f. complete system: a comprehensive analysis and its possible exploitation for design, Meccanica, 55, 1309-1332.

[2] Jiang B., Hui Y., Yang Q., Hua X., 2022, Nonlinear dynamic analysis of parked large wind turbine blade considering harmonic inertial excitation using continuum mathematical model, Thin-Walled Structures, 181, 110128.

[3] Yuan G., Wang Y., 2021, Internal, primary and combination resonances of a wind turbine blade with coupled flapwise and edgewise motions, Journal of Sound and Vibration, 514, 116439.

[4] Lenci S., 2023, in preparation.

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Digital Twins-Enabled Probabilistic Deterioration Assessment of Floating Offshore Wind Turbine Towers Under Uncertainties

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Summary. The novel concept of modular energy islands comes with novels challenges, i.e., the coupled corrosion fatigue (CF) deterioration of floating wind turbine towers (FOWTTs). This work proposes a digital twins-based assessment approach to elucidate the CF feature of FOWTTs under uncertainties, by integrating both the site loads, material data, deterioration model and numerical simulation. The output highlights the notable C-F issue in FOWTTs, and offers basis for condition-based management.

Introduction. The emerging climate challenges and energy crisis have imposed urgent and heavy demands for a green and sustainable world with renewable and reliable energy supplies. The concept of modular energy island (MEI) [1] has been proposed to fully exploit the abundant natural powers at deep-water oceans, including wind, tidal, solar and other energies. The novel application also leads to novel engineering challenges. Especially, the massive high-strength bolts in ring-flange connections of wind turbine towers become highly prone to deterioration under coupling effect of dynamic loads-induced fatigue and marine corrosion, i.e., corrosion-fatigue (CF) [2]. The work aims to offer novel insights into the C-F deterioration of bolts in floating wind turbine towers (FOWTTs) on the MEI, by integrating the material test data, site-specific condition, probabilistic CF (PCF) model and multi-physics simulation

Methodology. The wind-wave data measured from the Mexico Gulf [3] are incorporated into the multi-physics simulation tool OpenFAST [4] to derive fatigue stress spectra in bolts, see Fig. 1. The spectra and climate conditions are processed by a PCF model [5], by which the deterioration evolution is estimated.

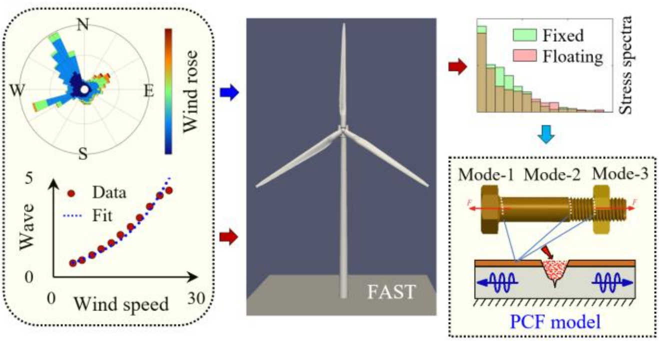

Fig. 1. Procedures for the probabilistic assessment of deterioration states using site data.

Results. Fig. 2 shows the evolution of fatigue crack growth, and the failure mode of the most critical bolt at the bottom flange. The model-3 (first engaged threads) demonstrates a high priority while the other two modes also have considerable contributions to the failure of bolts.

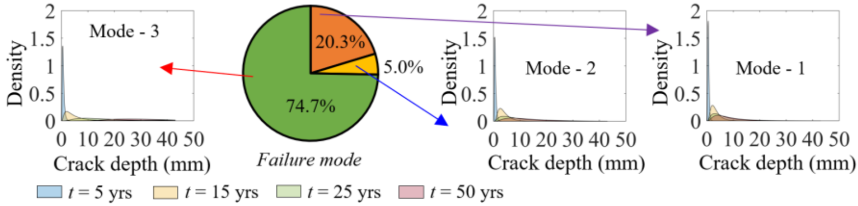

Fig. 2. Fatigue crack depth growth and failure modes of the most critical bolt in ring-flanges.

Fig. 3 shows the deterioration evolution of the above crucial bolts. The result suggests a premature failure risk (at 22 years) of bolts at the given marine condition under the target reliability of 1.7.

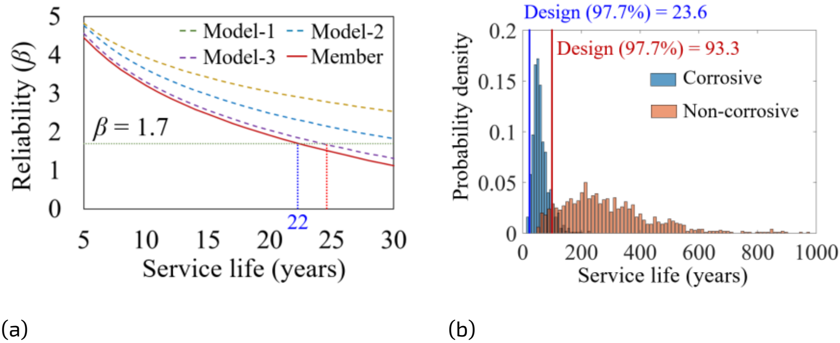

Fig. 3. Deterioration evolution of the most critical bolt: (a) Reliability; (b) Life distribution.

Conclusions.
(1) The high-strength bolt in ring-flanges of FOWTTs shows 3 major failure mode under CF, while the first engaged thread has the highest possibility. In both modes, the distribution of crack depth levels off and accumulates at the size threshold (i.e., 46.8 mm) with the service life.

(2) The strong marine corrosion risks premature failure of bolts since it fails to meet the design reliability index of 1.7. Particular efforts are suggested for bolts in FOWTTs.

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References

[1] Rebelo, C. & Baniotopoulos, C. (2022). Modular Energy Islands for Sustainability and Resilience Proceedings CESARE'22, 6-9 May, 2022, Irbid.

[2] Adedipe, O., Brennan, F., & Kolios, A. (2016). Review of corrosion fatigue in offshore structures: Present status and challenges in the offshore wind sector. Renewable and Sustainable Energy Reviews, 61, 141-154.

[3] National Data Buoy Center (NDBC), 2022. https://www.ndbc.noaa.gov/obs.shtml

[4] National Renewable Energy Laboratory (NREL), 2022. OpenFAST – an open-source wind turbine simulation tool. https://github.com/openfast

[5] Heng, J., Zhang, J., Dong, Y., et al. Corrosion fatigue prognosis of ring flange connections in floating offshore wind turbine towers considering multi-modes failure. (in preparation)

Effectiveness of Passive TMD Vibration Controller on the Damaged Spar-Type Floating Offshore Wind Turbine

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Summary. The objective of the present study is to investigate the effectiveness of passive vibration controller, namely, tuned mass damper (TMD) in minimizing the excess vibration caused in a damaged spar-type floating offshore wind turbine (FOWT) subjected to combined wind-wave loading. NREL 5MW OC3 Hywind spar type FOWT is considered as the benchmark model for the numerical investigation. The damage such as corrosion in the mooring lines submerged under the water are modelled in openFAST. The dynamic response of the benchmark and damaged FOWT under moderate sea states is evaluate. It is observed that corroded mooring cables have significant effect on the platform motion. To reduce the excess oscillation, a passive TMD is attached to the nacelle of the FOWT. The results obtained demonstrates that implementation of TMD has considerable effect on the stability of the structure.

Keywords: Spar-OWT; TMD; Damage; Tower; Vibration Control

Introduction. In view of the increase in demand for the clean green energy to minimize the greenhouse gas emissions leads to remarkable growth in the wind energy sector. Wind turbines harvest the readily available wind to meet the energy needs. But several challenges like the limited onshore space, noise and visual pollution are the challenges that restricts their development. To this end, offshore wind turbines are considerably adopted for producing the significant amount of green energy. But installation of the floating offshore wind turbines (FOWT) in deep ocean under the harsh environmental conditions is a major challenge for their stability. The wind-wave action over the period damages different components of the FOWT. This not only develop the fatigue but also causes excessive vibrations due to stochastic nature of wind-wave. Vibration control in FOWTs has been a great matter of concern for the efficient power production. Hence, this has been a very active area of research. Si et al. [1], Dinh and Basu [2] Yang et al. [3], Jahangiri and Sun [4] examine the passive type TMD in control the tower and blade vibration in FOWTs. Queija et al. [5] reviewed the different control strategies implemented in the FOWTs and discussed about their advantages and drawbacks for the industry implementation. However, there is no immediate study available in literature that evaluates the efficiency of passive TMD for a damaged FOWTs. So, the focus of this investigation is to evaluate the behaviour of FOWT with corroded mooring lines attached with a TMD at nacelle.

Methodology. The 5MW turbine properties are adopted from the [6]. But the corrosion in the mooring cables affects the properties such as reduction in diameter and axial stiffness. In this case, the diameter of the three mooring cables is reduced to 50% and stiffness to 75% to simulate the worst-case scenario under moderate sea state and reference wind speed of 12 m/s. Wave height of 5.49m and time period of 11.3 s is selected to generate the wind field in Turbsim around the wind and turbine. But the effect of current is not in the scope of this investigation. Three individual TMD (x,y,z) is implemented at the nacelle.

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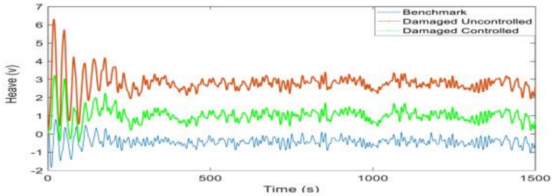
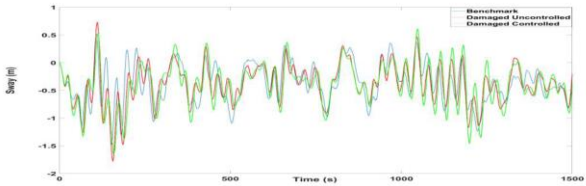
Results



(a)



(b)

Fig. 1 Temporal variation of (a) Heave (b) Sway response of FOWT.

The simulation for the proposed method is carried out for 1500 s and the time history of the heave and sway motion is shown in Fig. 1. It is clearly noticed that TMD significantly supress the platform heave motion when fixed to the damaged FOWT from the Fig 1 (a).

Conclusion. The results obtained from the numerical investigation suggests that inclusion of passive TMD can have significant effect on stabilising the platform heave motion.

References

[1] Y. Si, H.R. Karimi, H. Gao, Modelling and optimization of a passive structural control design for a spar-type floating wind turbine, Engineering structures, 69 (2014) 168-182.

[2] V.N. Dinh, B. Basu, Passive control of floating offshore wind turbine nacelle and spar vibrations by multiple tuned mass dampers, Structural Control and Health Monitoring, 22 (2015) 152-176.

[3] J. Yang, E. He, Y. Hu, Dynamic modeling and vibration suppression for an offshore wind turbine with a tuned mass damper in floating platform, Applied Ocean Research, 83 (2019) 21-29.

[4] V. Jahangiri, C. Sun, Three-dimensional vibration control of offshore floating wind turbines using multiple tuned mass dampers, Ocean Engineering, 206 (2020) 107196.

[5] J. López-Queija, E. Robles, J. Jugo, S. Alonso-Quesada, Review of control technologies for floating offshore wind turbines, Renewable and Sustainable Energy Reviews, 167 (2022) 112787.

[6] J. Jonkman, Definition of the Floating System for Phase IV of OC3, in, National Renewable Energy Lab.(NREL), Golden, CO (United States), 2010.

An Overview of Fatigue Behaviour in Additively Manufactured Metals Under Cyclic Loading

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Summary. In recent years, the appeal of modular construction has grown substantially, and the energy industry is no exception. However, modularity results in a greater number of complex joints, for which new fabrication methods must be investigated to ease the use of modular structures. Although its fatigue behaviour has only been loosely studied, additive manufacturing (AM) may be one of these new methods. This paper provides an overview of the current research state of cyclic material properties for AM metals.

Keywords: additive manufacturing, WAAM, fatigue, LCF

Introduction. Structures for energy production are evolving towards systems with lighter components that simplify manufacturing, transportation, and erection processes, such as modular towers, jackets, and sustainable offshore platforms (i.e., man-made islands for hybrid renewable energy generation). Nevertheless, modular construction has an increased number of joints than conventional construction methods, many of which have a higher geometric complexity. This issue opens the opportunity for developing innovative approaches that provide solutions from a practical and scientific point of view.

One example of a versatile and innovative method is Metal Additive Manufacturing (AM). Some applications of AM have been introduced to the energy market, improving the design and fabrication of generators and blades [1], [2]. Nevertheless, the study of AM materials' fatigue life is still in its early stages. Promising results have been found in the latest research, matching or even surpassing the behaviour of conventional hot-rolled or forged steels, but the studies are still not enough to state firm conclusions; more about this topic will be discussed later.

Wired Arc Additive Manufacturing (WAAM) belongs to the Direct Energy Deposition (DED) fabrication technique. This process is suitable for large components because it does not require an enclosed atmosphere and is relatively fast and inexpensive. The method consists of melting the source material to accumulate layers. The source material can be either a metallic powder flow or a metallic wire melted through laser or electron beams. Nevertheless, WAAM technology is not fully developed yet, and one of the main challenges is characterising its mechanical properties and fatigue behaviour [3].

Mechanical properties and fatigue of WAAM materials. In many energy generation structures, like wind towers, cyclic loads due to wind, operation and waves can lead to over one billion load cycles. Hence the importance of studying the cyclic behaviour of WAAM materials that could potentially be used in components for such structures. A review of the latest research on the topic was performed as a starting point.

In general, every investigation characterised the material using tensile tests, low cycle fatigue (LCF) experiments and post-fracture examination with Scanning Electron Microscopy (SEM). Still, few researchers included high cycle fatigue (HCF) or fatigue crack growth tests in their experimental campaigns. Nevertheless, some conclusions are transversal throughout the literature: i) WAAM materials have an anisotropic nature that depends on the printing direction, ii) compared with the wrought hot-rolled material, these AM materials have similar or improved mechanical properties, iii) it is suggested that the fatigue life improves for high strain amplitudes but deteriorates for low strain amplitudes compared to traditional metals and design guidelines and iv) cracks may initiate prematurely but it is harder to propagate in the material [4]–[6].

Conclusions and future work. The literature review completed revealed that the cyclic behaviour of WAAM materials is still highly undeveloped, and most of the research is still focused on the static material properties of the metals produced. However, understanding this phenomenon is absolutely necessary if AM is going to be used in energy production structures that are usually under the effect of millions of loading cycles.

To fill the gap abovementioned, an experimental campaign has been planned to assess the fatigue life of WAAM carbon steel. The campaign is divided into two main stages, the first dedicated primarily to the study of LCF, the second to the study of HCF, and the third to fatigue crack propagation. The LCF experimental campaign's main objectives are to study the cyclic elastoplastic behaviour and develop constitutive models that can later be integrated with the finite element method to predict fatigue life. Likewise, the cyclic curves, stress-life, strain-life and energy-life relations will also be determined, and the fracture surfaces will be analysed to identify the main failure mechanisms.

Acknowledgements. National funds financed this work through FCT - Foundation for Science and Technology, under grant agreement 2022.11645.BD attributed to the first author.

References

[1] A. Hayes, L. Sethuraman, K. Dykes, and L. J. Fingersh, "Structural Optimisation of a Direct-Drive Wind Turbine Generator Inspired by Additive Manufacturing," 2018, vol. 26, pp. 740–752. doi: 10.1016/j.promfg.2018.07.084.

[2] B. Post, B. Richardson, P. Lloyd, L. Love, S. Nolet, and J. Hannan, "Additive Manufacturing of Wind Turbine Molds," 2017. [Online]. Available: http://www.osti.gov/scitech/

[3] T. Tankova and L. S. da Silva, "Robotics and Additive Manufacturing in the Construction Industry," Current Robotics Reports, vol. 1, no. 1, pp. 13–18, Mar. 2020, doi: 10.1007/s43154-020-00003-8.

[4] A. Ermakova, J. Razavi, F. Berto, and A. Mehmanparast, "Uniaxial and multiaxial fatigue behaviour of wire arc additively manufactured ER70S-6 low carbon steel components," Int J Fatigue, vol. 166, Jan. 2023, doi: 10.1016/j.ijfatigue.2022.107283.

[5] Y. Li et al., "Low cycle fatigue behavior of wire arc additive manufactured and solution annealed 308 L stainless steel," Addit Manuf, vol. 52, Apr. 2022, doi: 10.1016/j.addma.2022.102688.

[6] S. Mu, Y. Li, D. Song, B. Xu, and X. Chen, "Low Cycle Fatigue Behavior and Failure Mechanism of Wire Arc Additive Manufacturing 16MND5 Bainitic Steel," J Mater Eng Perform, vol. 30, no. 7, pp. 4911–4924, Jul. 2021, doi: 10.1007/s11665-021-05554-1.

Site-Specific Cost Minimization of Floating Offshore Wind Turbines

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Summary. This contribution presents a site-specific optimization aimed at finding the most economic platform and moorings configurations of 10MW FOWT installed in the Mediterranean Sea. Simulations demonstrate that the there is room for a significant cost reduction compared with upscaled designs with a controlled increase of the loads on the turbine tower. These results open interesting perspectives for the reduction of the Levelized Cost of Energy (LCOE) in sites characterized low wind resource.

Keywords: Floating offshore wind, optimization, semisubmersible platform.

Introduction. Floating Offshore Wind Turbines (FOWTs) are ground-breaking systems capable of extracting wind energy from stronger and less turbulent winds characterizing areas where fixed-bottom solutions are technically and economically unsuitable. For such systems, the design of the substructure becomes crucial in determining the whole system dynamics as well as the overall cost of the installation. This contribution presents an optimization procedure aimed at minimizing the substructure costs of a 10MW semisubmersible FOWT exposed to the actual metocean conditions of the selected installation site. The optimization is performed considering design variables related to platform and mooring lines. Constraints on the structural response of the system under 50-year return period loads, as well as feasibility constraints on the maximum admissible platform displacements, mooring lines geometry, and anchor loads are considered. Results shows that the optimized solution drastically reduces the substructure costs, with a controlled increase of the turbine stresses with respect to a more conventional design based on an upscaled approach.

Methodology. The optimization procedure is carried out employing a 7-DoF frequency domain model of the FOWT. The tool, detailed described in [1] and [2], is capable to consider the joint action of wind and wave loads and to account for the contributions of first and second order hydrodynamics, mooring lines and wind turbine. The same design variables and constraints employed in [1] and [2] are adopted. Additionally, a constraint on the maximum tower-base bending moment, M_{MAX}^{TWB}, under an extreme event at the installation site (off the Tuscany coast, see Fig. 1) is adopted in order to limit the increase of the loads on the turbine tower. Concerning the objective cost function, only manufacturing cost, i.e., the raw cost of the materials and the fabrication cost of the substructure are considered [2].

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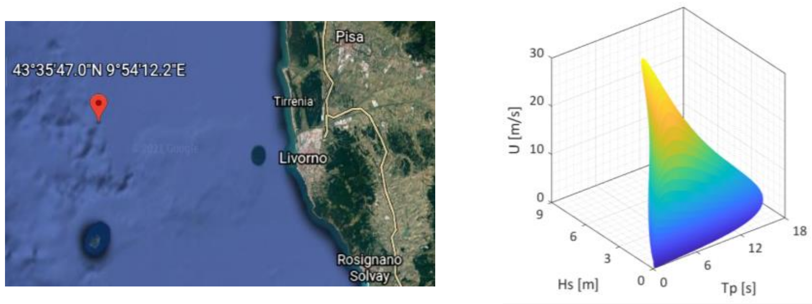
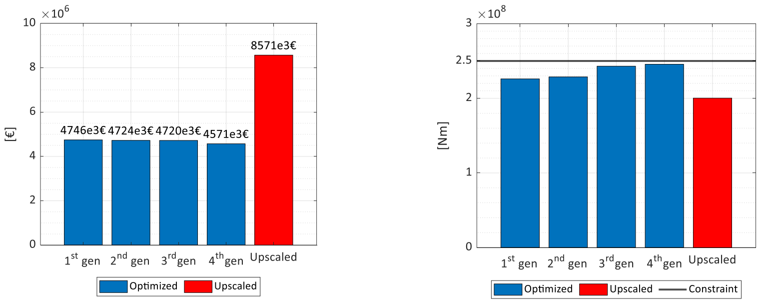


(a) (b)

Fig. 1. Location of the installation site (a) and 50-year return period environmental contour surface (b).

Results. Results are presented in Fig. 2 and Table 1. As it is possible to notice, the optimal solution presents a significant reduction of the manufacturing cost of the substructure, with a controlled increase of the loads on the wind turbine tower in comparison with an upscaled solution. This is achieved by lowering the column diameter and maximizing the platform radius (see Table 1).



(a) (b)

Fig. 2 Evolution of the manufacturing cost (a) and the maximum tower-base bending moment during the optimization.

Table 1: Comparison between optimized and upscale systems.

Variables	**Optimized**	**Upscaled**	**Variation [%]**
d [m]	14.00	16.97	-17.50
r [m]	36.00	40.83	-11.83
drf [m]	24.50	28.23	-13.21
x_{anch} [m]	710.0	837.6	-15.23
L [m]	720.0	821.0	-12.52
Cost [€]	4.571E+06	8.571E+06	-46.67
$M_{MAX}{}^{TWB}$ [Nm]	2.456E+08	2.003E+08	22.62

Conclusions. An optimization procedure based on a coupled frequency domain analysis model is adopted to find the substructure of a 10MW FOWT which most effectively reduces the substructure cost without an uncontrolled increase of the loads on the turbine tower. The optimized solution features a reduction of the manufacturing cost of about the 47% with respect to an upscaled solution. Given the flexibility of the frequency domain simulation model, future works will be focused on different platform concepts and on multi-objective optimizations including fatigue loads in order to identify better trade-off solutions between cost and structural performances.

References

[1] G. Ferri, E. Marino, N. Bruschi, and C. Borri, "Platform and mooring system optimization of a 10 MW semisubmersible offshore wind turbine," Renew. Energy, vol. 182, pp. 1152–1170, 2022, doi: 10.1016/j.renene.2021.10.060.

[2] G. Ferri and E. Marino, "Site-specific optimizations of a 10 MW floating offshore wind turbine for the Mediterranean Sea," Renew. Energy, vol. 202, no. November 2022, pp. 921–941, 2023, doi: 10.1016/j.renene.2022.11.116.

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Quasi-Automated Fatigue Lifetime Design of Floating Energy Islands

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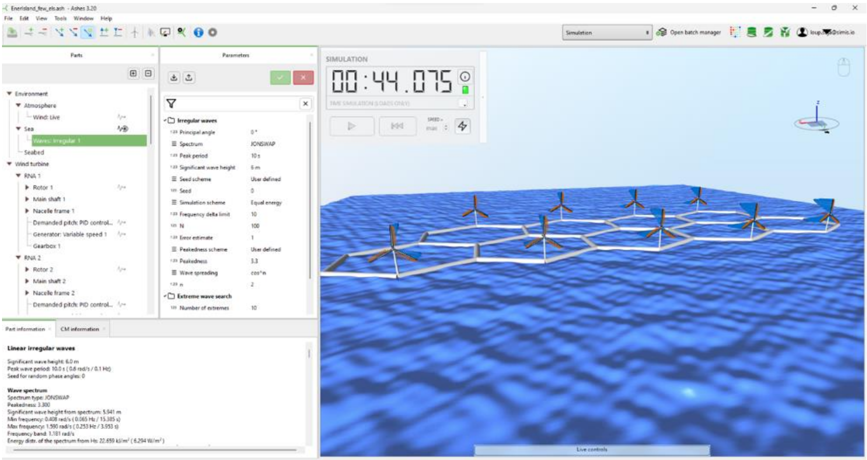
Summary. Fatigue lifetime will often be a decisive design parameter for floating offshore structures in general and floating renewable energy islands (FREIs) in particular, due to the dynamic nature of wind and waves as well as the operation of wind turbines. Due to wind turbines, new and/or revised engineering methodology as well as software are necessary for safe and economical operation. Appropriate procedures for fatigue design are investigated, benchmarked and suggested using the software Ashes.

Keywords: floating energy island, integrated simulation, wind turbine simulation



Introduction. Floating structures have been in successful operation for decades, especially in the offshore oil and gas industry. Likewise, methodology and simulation software have been successfully developed and used.

However, for floating renewable energy production neither methodology nor simulation software from the establish oil and gas industry applies directly to floating renewable energy concepts.

For oil and gas installation the waves and current are typically the paramount environmental loading compared to wind. For a floating renewable energy island (FREI), the wind climate and loading are not only of similar importance as the waves and current, but also – of course – in most cases essential for the energy production. This makes a FREI much more complicated and cumbersome when it comes to design, analysis and simulation (DAS). Additionally, wind energy production using rotors makes the operation heavily influential on the loading and thus the design, analysis and simulation. DAS is not only more complicated and extensive – it also must include additional parts, compared to oil and gas, such as the control systems. Thus, conventional engineering methods from oil and gas are often less or not at all applicable for a FREI.

Fatigue is expected to be the most time consuming and complicated part of DAS of a FREI and is the focus here.

Methodology. The fatigue design typically consists of the following principal parts:

1. Establish from 10s to 10 000s of load cases (LCs) for time simulations from simplified algorithms, metocean conditions, or a combination thereof.

2. Run all load cases and collect stress ranges for the chosen collection of structural joints.

3. Calculate fatigue life for all chosen joints using SN curves and generate a fatigue report.

The simulation software Ashes will be used to (partly) automate all three principal parts of the fatigue design. Thus, we can investigate to what degree fatigue design is realistic in different phases of a FREI project, particularly early phase of a research project.

The computational resources available will typically be the limiting factor for the number of LCs and joints that can be included in the fatigue design, and thus the accuracy of the estimated fatigue lifetime.

Results. Tables/graphs presenting:

• The computational resources and wall-clock time required to simulate increasing number of load cases.

• Comparison and the degree of convergence for different numbers of LCs and different algorithms for automatically choosing/defining LCs.

Conclusion. Demonstrate that “industrial strength” fatigue analysis is realistic even in most research contexts if the software used is integrated (metocean statistics, loading, structural mechanics, fatigue simulation). Present recommended methodologies for:

• Fatigue design of a FREI, particularly how load cases should be chosen based on diminishing rate of return and converging fatigue life by increasing number of LCs.

• Different degrees of maturity of a FREI (typically less load cases and higher uncertainty of fatigue life is appropriate in an early phase).

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Modern Lands

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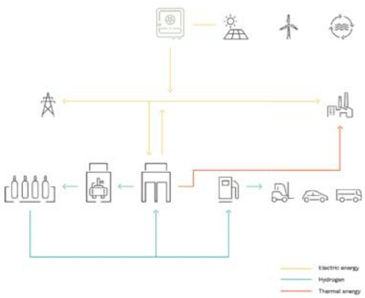
Summary. Presentation of a case study of Green energy application in respect to wider use in Energy Islands. The idea of storage of electrical energy on an island is crucial for becomming autark and self sustained. One way to accomodate storage beyond battery capacity ist the transformation into green hydreogen from solar energy. Besides technical chalanges ther is a need to transfer existing laboratory konwledge into practial application and use scenarious. The Poster will present a system solution for producing, storing, distributing and reconverting hydrogen. It is based on a modual system and can be applied and adjusted on Island applications.



Green hydrogen. Green hydrogen is produced from solar energy (alternatively wind energy or hydropower) Compressor where the hydrogen is brought to the appropriate pressure level.

Seasonal storage. So that surplus hydrogen can be readily stored by means of electrolysis – and for longer periods of time

Reconvention + elektrolyseur. If required, the green hydrogen is converted back into electricity and heat by means of a fuel cell.

Reuelling of H2 vehicles. Use of heat. e.g. for low-temperature heating

A Modal-Based Approach for Damage Detection of Mooring Lines of a Floating Wind Structure

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Summary. Floating offshore structures are normally installed in relatively deep water where fixed-based structures cannot be installed. Therefore, accessing their foundations and substructures for the purpose of visual inspection and sensor installation is hardly possible. Therefore, developing novel SHM approaches which reply on the measurements collected on the floating platform is highly important. In this study, a modal-based approach is proposed for condition monitoring of mooring lines of a floating structure which is a spar-type Floating Offshore Wind Turbine (FOWT). In this approach the responses measured at the tower and the floating platform is employed for monitoring of mooring lines.

Numerical modelling. The OpenFAST (v3.0.0) software is used in this study for numerical modelling of the FOWT. In this study, the 5MW Offshore Code Comparison Collaborative (OC3) Hywind model is employed for the numerical simulations. The simplified mooring arrangement for the OC3-Hywind system contains three slack catenary lines, connected to fairleads at the platform and anchors fixed to the seabed. The mooring lines are orientated at 120 degrees to each other. Three load cases (LCs) are selected while modelling the damage scenarios, with the aim of investigating the dynamic response of the damaged structure. LC1, LC2 and LC3 represent Mild waves [1], Moderate waves [2] and Severe waves [3], respectively. All three load cases are applied to the healthy and damaged structures, to identify modal properties in each case and establish a relationship between loading and dynamic response. The damage scenarios are: Scenario A- Corrosion of the mooring lines (A1: 10%, A2: 30% and A3: 50%), Scenario B- Damage at a single mooring line (B1: 10%, B2: 30% and B3: 50%), Scenario and C- Marine growth on the mooring lines.

Results. The modal parameters of the structure are extracted using the acceleration responses. In particular, the translational accelerations recorded along the tower are used. Changes in such properties may then be used for diagnosing the damages. For each of the four frequencies measured, a corresponding mode shape is also recorded. These mode shapes are in complex form, where only the real components are plotted in Fig. 1. All mode shapes are composed of seven values, each coming from a measurement point, which are normalised by dividing them by the largest absolute value recorded in each set. Similarly, the tower height is also normalised, with the first measurement point being plotted at 0 on the x-axis and the last measurement point, located at the highest point on the tower, being plotted at 1. For all load cases, the mode shapes corresponding to each damage scenario are plotted for comparison.

It is shown that the first and second tower bending modes in the fore-aft direction observed very little change in mode shape because of damage in the mooring lines. However, the mode shape corresponding to the rigid body platform surge saw significant changes between the healthy and damaged structure. This means that unlike natural frequency, the mode shape corresponding to the rigid body mode of the platform is sensitive to damage.

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When considering damage of a single mooring line only, as was done in Scenarios B1-B3, a linear relationship can be seen between damage extent and changes in mode shapes.

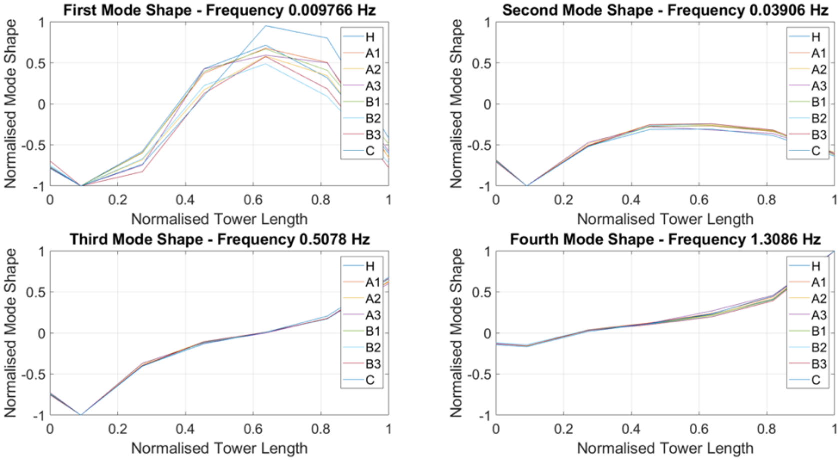

Fig. 1. Normalised Mode Shapes for the first four modes – LC1.

Conclusions. This study indicates that mode shape values may have the potential to be used to both identify damage of a single mooring line and diagnose its severity in the future. It has been shown that the presence of damage and its severity may be identified using the signal processing technique presented, but further calibration work would be necessary to be able to distinguish different damage types from one another.

References

[1] Akella A, Saini R, Sharma MP. Social, economical and environmental impacts of renewable energy systems. Renewable Energy. 2009;34:390-6.

[2] Butterfield S, Musial W, Jonkman J, Sclavounos P. Engineering challenges for floating offshore wind turbines. National Renewable Energy Lab.(NREL), Golden, CO (United States); 2007.

[3] Chung M, Kim S, Lee K, Shin DH. Detection of damaged mooring line based on deep neural networks. Ocean Engineering. 2020;209:107522.

Fault Detection in Wave Energy Converters Using Machine Learning Techniques for Predictive Maintenance

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Summary. Wave energy converters (WEC) have the potential to provide a secure and abundant method of renewable energy production. A preliminary methodology is proposed for developing a generic tool for real-time health monitoring and fault detection in WEC systems using MATLAB and WEC-Sim, with a focus on the application of machine learning (ML) techniques for predictive maintenance. The findings aim to demonstrate the feasibility of ML for predictive maintenance when applied to WEC systems.

Introduction. Wave power is more reliable than solar and wind due to substantially greater energy density (2-3 kW/m² compared to 0.1-0.2 kW/m² and 0.4-0.6 kW/m², respectively [1]), combined with the ability to generate up to 90% of the time (in comparison to 20-30% for solar and wind) [2], the potential for power generation from ocean waves is immense. Combining precise computational modelling with on-site data (both historic and real-time) allows for complex, site- and system- specific digital representation of WEC systems, that allows not only for better predictive maintenance capabilities, but also for generation of more accurate inputs for WEC design, testing and development. Improvements in ML technologies present unique opportunities to optimise maintenance strategies, with traditional reactive interventions being replaced with predictive methods by avoiding breakdowns instead of reacting to them [3].

The aim of this preliminary research is to establish a working methodology for fault implementation, feature identification, fault detection and eventually component level remaining useful life (RUL) prediction in WEC systems.

Methodology. The workflow for the development of a ML tool capable of improving the reliability and survivability of WEC systems is as follows:

1) Model Definition: For early-stage development, the Reference Model 3 (RM3) type Point Absorber [4] is considered due to both the simplicity of the system and as it is widely documented.

2) Data Acquisition: Due to lack of availability of real-world data, a simple CAD geometry, developed in SolidWorks, is coupled with a Simulink model to represent the RM3 and synthetic data is produced using models and simulations generated using WEC-Sim [5].

3) Data Pre-processing: The raw data is pre-processed using MATLAB [6] and Excel [7]. This process aims to generate "clean" data and is crucial to ensure that the feature identification produces worthwhile markers for the ML model development.

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4) Feature Identification: Areas and components prone to failure are analysed for anomalies, faults and trends which will be used for health identification, using MATLAB's predictive maintenance toolbox alongside more traditional ML techniques (i.e., signal processing). Initially, a mooring line fault is introduced to the chosen WEC system by way of stiffness reduction. This stage aims to identify measurable conditions suitable for failure markers.

5) Train Model: A replicable ML algorithm will be generated and trained within MATLAB to detect condition indicators for chosen areas/components of the WEC system. MATLAB's predictive maintenance toolbox is used to build and train a model based on markers identified in the previous step, in order to make accurate predictions for the remaining useful life of the systems and/or components/areas of focus. This should be an iterative process.

6) Deploy & Integrate: The developed ML model is tested, retrained and improved at this step. Successful implementation on a single type of WEC using synthetic data allows for modification towards both a general WEC predictive maintenance tool and a tool capable of handling design specific variations (i.e., application to different types of WEC system and potentially alternate comparative offshore structures (i.e., floating wind)). The developed ML model will be validated using a case study that employs real world data which in turn will complete the model's development process.

Results. Synthetic data has been generated both for healthy and faulty scenarios. Before analysis, the data has undergone pre-processing to extract time and frequency domain features through specialised MATLAB applications. The accuracy of these extracted features is evaluated using traditional techniques. These features will be utilised to explore the effectiveness of popular ML techniques and their ability to predict RUL of selected components.

Conclusions. The extracted data appears to be well-suited for feature extraction. The quantity and quality of the extracted features are optimal for the development of an ML algorithm that can accurately detect faults and predict RUL.

References

[1] S. Ding, D. Han, and Y. Zan, "The Application of Wave Energy Converter in Hybrid Energy System," Open Mech. Eng. J., vol. 8, pp. 936–940, 2014.

[2] B. Drew, A. R. Plummer, and M. N. Sahinkaya, "A review of wave energy converter technology:," Proc. IMechE Vol. 223 Part A J. Power Energy, pp. 887–902, Aug. 2009, doi: 10.1243/09576509JPE782.

[3] CORPOWER OCEAN AB, "WaveBoost: Advanced PTO for enhanced reliability and performance of Wave Energy Converters," Sweden, 2019.

[4] V. S. Neary et al., "Methodology for Design and Economic Analysis of Marine Energy Conversion (MEC) Technologies," Sandia Natl. Lab., no. March, p. 261, 2014, doi: 10.13140/RG.2.2.10201.95846.

[5] Y.-H. Yu, K. Ruehl, N. Tom, and J. Van Rij, "Review of WEC-Sim Development and Applications." Accessed: Jan. 05, 2022. [Online]. Available: https://wec-sim.github.io/WEC-Sim/.

[6] The MathWorks Inc., "MATLAB® Primer 2021b," 2021.

[7] M. Corporation, "Microsoft Excel." 2016. [Online]. Available: https://www.microsoft.com/en-us/microsoft-365/excel

Types of Offshore Structures as Floating Platforms

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Summary. The aim of this paper is to know about the Floating Platforms- as basic functional behaviour, which is one of the types of offshore structures (from the table 1.8, p.25, (1)). The types of Floating Platforms are 1. Semi submersibles, 2. Submersibles, 3. Drillships/Barges, 4. Ships, with the material of construction as steel, concrete, hybrid. Through from these 4 types, semi submersibles and submersibles will be defined to understand the foundation system of Floating Platforms first. The foundation system is very important to keep the Floating Platform more stable and also more functional due to the FPSO (floating production, storage and offloading unit)(2) features.

Keywords: Semi submersibles, Submersibles, FPOS, offshore structures

Introduction. Floating structures call to find more usage every time to work in deeper oceans, and they ask for a more economical situation in cost. The combination of the use of floating platforms for the subsea issues, are called "Floating Production System". Today, Floating Platforms with jack-ups are being developed in the form of semisubmersibles, submersibles, and drillships/ barges(p.39, (1)).

The methodology is to look for these two types from the written literature and through the built examples in the internet. The design of the foundation system is very important due to the heavy waves.

Semi submersible is an offshore platform which may rest on the seabed or float, by having a large underwater structure as buoyancy tanks or a tower. Semi submersibles can work in water to a depth as 1000m. By anchors and dynamic positioning, i.e. thrust from propellers or water jets on all sides, they may be moored(p.390, (3)).

Submersible is a submarine. It carries one or more persons. It is designed to work in deep water that divers can not work. It could be used till 420m in 1972(p.437, (3)).

During the presentation, there will be built examples to be shown how these floating platforms are good for wind turbines

As a conclusion, we may refer that the semi submersible and submersible platforms are very effective floating platforms by having the most economical and effective foundation system.

References

[1] Reddy, D. V., (1999) OFFSHORE STRUCTURES Volume 1, Krieger Publishing Company, Malabar, Florida,
[2] Rorbakken, K., (April 1998, No.16) "Full steam ahead", Kvaerner oil&gas magazine, p.34
[3]Scott, John S., (1991) The Penguin Dictionary of Civil Engineering, 4th edition, Penguin Books, England

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Abstracts – Working Group 3

Power System Operation Challenges with an Energy Island Integrated

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Summary. Ambitious plans of some EU countries for intensive marine renewable energy deployment are imposing needs for "energy hubs" which could act as point of common coupling (PCC). These "energy hubs" – "energy islands", should gather electricity from offshore renewables and distribute it onshore. A control of vast marine renewables could be convenient with energy island concept but raises up operation and power system stability challenges for power system operators to integrate such energy bulk from marine renewables.

Keywords: energy island, renewables integration.

Introduction. Energy needs and onshore location scarcity have resulted in increasing number of marine renewable energy projects (offshore wind farms, floating PV, wave energy converters) as future energy harvesting projects. The wind turbine technology is being improved, constantly, and wind turbines are bigger in both size and installed power. First offshore wind farm was erected in 1991 with eleven wind turbines with 450 kW nominal power of single turbine. Nowadays, wind farms reach 1.3 GW of installed power and the 15 MW wind turbine is expected in 2023.

Large amount of intermittent offshore production has to be transmitted to onshore grid. Such scenario might have serious power system stability obstacles so power system operators might need adapted approach control of power system.

Large offshore renewables deployed in wide offshore area might need offshore point of common coupling (PCC) in order to have better energy transmission control from offshore to onshore power grid. This necessity initiates idea of creation of an energy island, either natural or artificial, as an energy hub for large amount of energy generated from these offshore power facilities.

Methodology. First offshore wind farm platforms with power transformers, compensators, power breakers and other power equipment, have been hints for the first artificial energy islands. Ambitious plans for intensive marine renewables deployment are imposing needs for development of artificial energy island concept instead wind farm platforms. Such first ambitious plan has Danish Energy Agency to establish two energy islands. One artificial in the North Sea and one in natural island in the Baltic Sea. The islands serve as hubs - or green power plants - that gather electricity from the surrounding offshore wind farms and distribute it to the electricity grid in Denmark as well as directly to other countries. This allows electricity from an area with vast wind resources to be more easily routed to areas that need it the most, while also ensuring that the energy generated from the turbines is utilized as efficiently as possible in terms of demand for electricity [1].

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As described in [2], a technical solution of interconnection system solution of an energy island and onshore power grid depends on distance, installed power and voltage level, mostly.

For a stability's sake, high voltage direct current (HVDC) against high voltage alternating current (HVAC) solution of interconnecting lines could be better solution, since at each end of HVDC transmission/interconnection line a power converter is necessary. These power converters enable non-synchronized grid operation at each transmission line. Such solution could increase investment costs but each project is independent and some initial investment costs could be economic reasonable in long terms.

Results. Introducing an energy island concept improves power system control possibilities. Transmission System Operators (TSOs) might be delighted to have developed concept of energy island as "energy hub" which could act as energy crossroad and PCC of intermittent renewable production, likely. It might be that control of vast variable production and interconnection power transmission could be convenient with energy hub with storage and energy transform facilities. Consequently, dislocated marine renewables, far from a shore, could be operated from relative vicinity (from energy islands) or indirectly by controlling an "energy hub" itself.

Conclusions. The energy island concept raises up new challenges for power system engineers in both construction and operational manner. It gives more opportunities for integration and operation of renewables, but imposes new power system stability challenges to integrate such energy bulk from an energy island into onshore power system by means of submarine cables.

References

[1]https://ens.dk/en/our-responsibilities/wind-power/energy-islands/denmarks-energy-islands, accessed in December 2022.

[2] N. B. Negra, J.Todorovic, and T. Ackermann, "Loss evaluation of HVAC and HVDC transmission solutions for large offshore wind farms" in, Volume 76, Issue 11, July 2006, Pages 916–927, ELSEVIER Electric Power System Research, Science Direct.

Climate-Neutral Europe: The Role of Renewable Energies in the Arctic to decarbonize Europe and enhance energy independence

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Summary. The European Union consumes about 60 Exajoule (16.6 Peta Wh) of primary energy per year. In the past years, about 10% of this energy originated from natural gas (CH4). The dramatic developments in Ukraine and the accentuating climate crisis call for an eminent replacement of imported Russian natural gas with climate-neutral alternatives. Consumption reduction, enhanced energy efficiency, electrification, and industrial symbiosis should be prioritized. Being part of the European Economic Area, Iceland annually produces almost 20 TWh of green renewable electricity, using domestic hydropower and geothermal sources. About 80% of Icelandic electricity is exported in the form of energy-intensive products, namely aluminum and silicon. Due to the use of renewable energies, the exported Icelandic products disclose a very low carbon footprint. In regard to EU energy security and climate change targets, the Icelandic example may be used as a demonstration case for other energy products, namely hydrogen and power to X products. It may also be applied to other Arctic regions, namely Greenland, which is also part of the overseas countries and territories of the EU. In this presentation, we will demonstrate the following: i) how to assess the hydropower potential of remote Artic areas (Finger, 2018), ii) how excess hydropower can be used for green hydrogen production and subsequently to converted to carbon-neutral CH4 (Cabalzar et al. 2021), iii) compare the life cycle analysis results of hydrogen produced in Iceland and mainland Europe (Vilbergsson et al. 2023) and iv) show the potential of Greenland to become a key player in decarbonizing the EU. While the first three topics have been well described and published (see references below), the potential of renewable energy production in Greenland is currently being investigated by the University of Greenland. One single fjord could yield an electricity production of over 2 GW and an annual yield of around 5 TWh. While exploiting such natural resources should consider local environmental, social, and economic aspects, the production of climate-neutral energy in the arctic can be an essential part of decarbonizing Europe – and be an alternative to other fossil-based foreign energy sources.

References

Finger D. (2018) The value of satellite retrieved snow cover images to assess water resources and the theoretical hydropower potential in ungauged mountain catchments, Jökull, 68, 47-66. doi.org/10.33799/jokull.2018.68.047

Cabalzar U., Blumer L., Fluri R., Zhang X., Bauer C., Finger D., Bach C., Frank E., Bordenet B., and C. Stahel (2021) Projekt IMPEGA - Import von strombasiertem Gas, Aqua & Gas 6, 40-45, Schweizerischer Verein des Gas- und Wasserfaches

Vilbergsson K., Dillman K., Emami N., Ásbjörnsson E., Heinonen J., and D.C. Finger (in press) Can remote green hydrogen production play a key role in decarbonizing Europe in the future? A cradle-to-gate LCA of hydrogen production in Austria, Belgium, and Iceland, International Journal of Hydrogen Energy, in press

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On the Energy Islands and Green Corridors: Towards Green Energy Transitions

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Summary. Implementation and development of both energy islands and green corridors can greatly contribute towards green energy transition in Europe and worldwide. Energy islands can act as strategic infrastructures for the green corridors. A road map can offer rich facets of learning about energy islands and green corridors.

Keywords: energy islands; green corridors; road map; green energy.

Introduction. Energy islands are seen to play an important role in the energy system of Europe as they will contribute to scale up renewable energy from offshore wind energy and solar, renewable hydrogen production, and ammonia. In addition to the decarbonization of energy system, the energy islands can act as electricity distribution hubs, can be interconnected and assure connectivity to different end uses and contribute to the improvement of energy flows among the European countries [1], [2] .

Green corridors are defined as maritime routes targeting zero emissions between two or more ports. The aim is to support the establishment of at least 6 green corridors by 2025 and to further increase their number by 2030. Green corridors can give an impulse to the clean maritime fuels, the alternative propulsion systems, and the zero-emission vessels. Nevertheless, the green corridors require governmental and private support and the European and worldwide availability of supportive infrastructures [3].

The main aim of this present research study is to investigate the potential role of energy islands as infrastructures of importance for the establishment and development of green corridors and supporting the green energy transitions.

Research Methodology and Results. In this study, as a research approach, insights were drawn from the analysis of academical studies and industrial projects and reports, and blended with the findings from a wide array of stakeholders for the energy islands and the green corridors.

Various case studies of energy islands and green corridors were also analysed and discussed.

In terms of results - the key lessons, challenges, incentives, barriers and practices/best practices with reference to development of energy islands and green corridors will be discussed. Moreover, a road map for the energy islands as enablers of green corridors which integrates various facets of learning about development of energy islands and green corridors will be pursued further in this research study.

Conclusions. Energy islands have the potential to act as strategic infrastructures among the key enablers for the green corridors. Energy islands and green corridors can have an important contribution towards green energy transition.

An integrated road map for energy islands and green corridors can contribute towards sound feasibility studies by managing risk and increasing stakeholders confidence, and facilitating to reach to the decarbonization targets and timelines. This road map incorporates various learning facets and requires continuous updates over the time.

Acknowledgements. COST Action CA20109 Modular Energy Islands for sustainability and resilience is acknowledged.

References

[1] DNV. 2022. Energy transition - Are offshore energy islands the future of hydrogen and e-fuel production? av at https://www.dnv.com/energy-transition/offshore-energy-islands.html, accessed at 15 Dec.2022

[2] WindEurope. 2022. Energy islands coming to Europe's seas, accessed at 21 Dec.2022 av. at:

https://windeurope.org/newsroom/news/energy-islands-coming-to europes-seas/

[3] Government of UK, Department of Transport. 2022 Policy paper -COP 26: Clydebank Declaration for green shipping corridors, accessed at 26 Dec.2022, av. at:

https://www.gov.uk/government/publications/cop-26-clydebank-declaration-for-green-shippingcorridors/cop-26-clydebank-declaration-for-green-shipping-corridors.

Grid Integration of the Renewable Energy from Sustainable Energy Islands

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Summary. Modular floating sustainable energy islands (SEI) are considered as innovative solutions enabling a sizeable offshore renewable energy expansion. The concept of energy islands covers the definition of an existing island, the construction of an artificial island, or an island based on a floating platform serving as a hub for electricity generation from combination of different surrounding renewable energy sources, such as offshore wind, sea current, wave and solar energy.

SEI can create better connections between the renewable energy generated offshore and the existing onshore energy system. The electricity generated within the SEI can be partly used onsite by converting it to different types of energy storage products (Power-to-X technologies). The remaining surplus generated electricity will be exported directly to the mainland and will have to be integrated in the existing onshore grid.

Existing electricity grids need to be upgraded and made more flexible to integrate increased renewable energy share while keeping quality and security of supply. There are various grid constrains associated with renewable energy grid integration such as power output variability, control of power converters, hosting capacity, power quality issues, bidirectional power flow between the converter and the grid, optimal storage requirements etc. To enhance the grid integration of renewable electricity generated on the SEI it is necessary to explore extensively all of these issues.

Our past research has addressed some of these issues from multiple viewpoints. From the electricity grid viewpoint, we have studied the hosting capacity of power grids for distributed generation without energy storage and with electric vehicles (EVs) that charge without specific coordination. To enable larger shares of renewable energy, we have also explored the possibility of using EVs to regulate the frequency in microgrids and the possibility of using residential energy storage to reduce the impacts of buildings with PV on the distribution grid [1]. From the viewpoint of energy consumers, we have explored methods of energy sharing in energy communities, which ensure that all energy community members benefit from the energy sharing [2, 3].

Our current research is in line to the MODENERLAND WG3 programme. The hosting capacity of specific onshore power grids will be studied. Another research activity will be to explore different methods of energy sharing in energy communities consisted of local electricity generation and flexible consumers. When the members of an energy community have flexible end-use appliances and loads, such as EVs, they can also provide different ancillary services to the distribution grid, through coordinated smart charging of the electric vehicles.

A business model will be proposed in order to determine the factors that govern the profitability of the community model that has the ability for smart charging of EV.

Keywords: Hosting capacity, Energy communities, Electric vehicles, Smart charging

References

[1] Gjorgievski, Vladimir, and Snezana Cundeva. "The effects of residential battery storage on grid impact indicators." In 2019 IEEE Milan PowerTech, pp. 1-6. IEEE, 2019.

[2] Gjorgievski, Vladimir Z., Snezana Cundeva, and George E. Georghiou. "Social arrangements, technical designs and impacts of energy communities: A review." Renewable Energy 169 (2021): 1138-1156.

[3] Vladimir Gjorgievski, Bodan Velkovski, Snezana Cundeva, Quantification of the Shared Energy in Energy Communities, 2022 IEEE PES Innovative Smart Grid Technologies Conference Europe (ISGT-Europe), Novi Sad, October 2022

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Life Cycle Environmental Impacts of Renewable Offshore Energies: A Systematic Review

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Summary. Nowadays, the optimized usage of coastal and ocean areas to produce energy is auspicious. Due to the many possibilities and combinations of a multi-usage offshore platform, the Life Cycle Assessment (LCA) can be an ideal tool to address their environmental impact. Therefore, this study aims to perform a systematic review to gather information on performed LCA on offshore renewable energy production and storage worldwide.

Introduction. Providing sustainable development to a rising world population and electricity demand is one of the twenty-first century's big dilemmas [1]. One solution that is becoming popular nowadays is using coastal and ocean areas to produce energy. However, due to the highly competitive usage of these areas, there is a need to integrate several usages in offshore structures, creating the concept of a multi-usage offshore platform [2]. Furthermore, due to the many possibilities and combinations of types of structure, energy production, and storage, the Life Cycle Assessment (LCA) can be an essential tool to assess these energy systems' environmental burden and optimal output [2].

Even though the concept of energy islands is new, it has been a few decades since models of energy islands have been present. However, due to its complexity, it is more common to find studies, prototypes, and offshore energy farms with only one type of renewable energy. For example, in 2021, the European Union (EU) had 14.6 GW installed offshore wind capacity and 249.2 MW in projects using ocean energy [3], [4]. Although various LCA studies have been undertaken for current or prospective offshore wind farms, other types of renewable energies are still emerging technologies, so fewer LCA studies are available [2].

In this context, this study aims to perform a systematic review to gather information about the performed life cycle analysis on offshore renewable energy production and storage worldwide. Addressing the environmental impact of the vast possibilities of technologies and applications will give a better insight into the implications of this unique structure in the early design stage.

Methods. The purpose of this study is to perform a systematic review to account for the environmental impact of offshore renewable energies using LCA. Therefore, the methodology will be based on the PRISMA 2020 statement (Fig. 1)[5]. The primary source will be the Web of Science database, and the review will be categorize in three: multi-use offshore platforms, energy production, and energy storage. The energy production will be further divided into wind, photovoltaic, wave, and other. The energy storage will have two subcategories: hydrogen and batteries.

The search will be refined by considering only publications published in English and scientific journals, and the search terms will be applied to titles, abstracts, and keywords.

In addition, several search strings, including acronyms, will be tested in different combinations of terms and Boolean operators. Finally, the most relevant information from the selected papers will be extracted, and the results will be described into two categories: General information and LCA-related data.

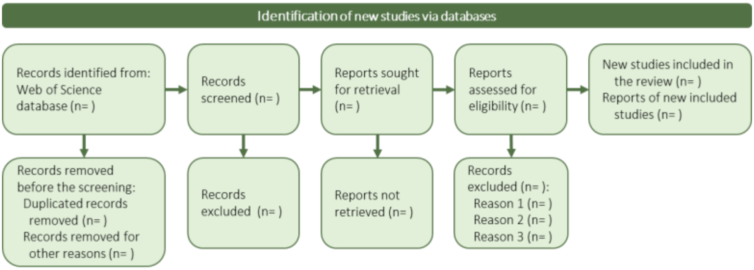

Fig. 1. PRISMA 2020 flow diagram template for this systematic review [5]

The search will be refined by considering only publications published in English and scientific journals, and the search terms will be applied to titles, abstracts, and keywords. In addition, several search strings, including acronyms, will be tested in different combinations of terms and Boolean operators. Finally, the most relevant information from the selected papers will be extracted, and the results will be described into two categories: General information and LCA-related data.

Conclusions. Because it is a novel subject and energy island models have significantly different configurations, the comparison of their eco-efficiency is challenging. Nevertheless, the LCA methodology has been vastly used to assess the environmental impact of projects and can provide a holistic view of the effects of this offshore structure on its surroundings. Moreover, since there are still very few studies correlating LCA to the energy islands specifically, the compilation of information from this study can provide the base for performing these environmental evaluations on prototypes.

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References

[1] United Nations Department of Economic and Social Affairs, Population Division, World population prospects 2022: summary of results. New York: United Nations, 2022. [Online]. Available: https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/wpp2022_summary_of_results.pdf

[2] N. Elginoz and B. Bas, “Life Cycle Assessment of a multi-use offshore platform: Combining wind and wave energy production,” Ocean Engineering, vol. 145, pp. 430–443, Nov. 2017, doi: 10.1016/j.oceaneng.2017.09.005.

[3] EurObserv'ER, “Ocean energy barometer,” European Commission, 2022. [Online]. Available: https://www.eurobserv-er.org/category/all-ocean-energy-barometers/

[4] European Commission, “Offshore renewable energy,” Belgium, 2022. [Online]. Available: https://energy.ec.europa.eu/topics/renewable-energy/offshore-renewable-energy_en

[5] M. J. Page et al., “The PRISMA 2020 statement: an updated guideline for reporting systematic reviews,” BMJ, p. n71, Mar. 2021, doi: 10.1136/bmj.n71.

Passive Shunted Piezoelectric Systems for Vibration Control of Wind Turbine Towers - A feasibility study

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Summary. According to bibliography there are numerous offshore and onshore wind turbines which have some significant problems due to aging. Problems related to harmful vibrations which must be reduced are considered here. In this work, a new type of control vibration for wind turbines based on piezoelectricity and shunt circuits is proposed. It is a method of passive vibration control, which improves the tower performance under multiple environmental loads, including wind, and seismic excitations. To design the shunted piezoelectric system, a simplified wind turbine finite element model is created and an eigenfrequency analysis is performed. In particular, this project highlights the benefits of installing structural damping systems in reducing the vibrational load of towers and therefore increasing their structural reliability and resilience to extreme events.

Keywords: wind turbine tower; piezoelectrics; shunt circuits; vibration control; feasibility analysis

Introduction. To mitigate the impact of the external environmental conditions, mainly vibrations, several control strategies have been tested in commercial wind turbines. In this work, a new proposal for the vibration control of wind turbines towers based on the piezoelectric effect is presented, [1], [2].

In particular a shunted piezoelectric system is considered. Provided that piezoelectric patches are attached at a suitably chosen position of the vibrating structure, kinetic energy is transformed into electric energy through the piezoelectric effect, and it is dissipated into a suitably designed electric network. Therefore, the passive vibration suppression is achieved, following the concept of tuned mass dampers in a modern, multiphysics setting [3],[4],[5]. Optimization is used for the choice of the parameters of the electric shunted circuit. Shunted vibration absorbers have been proposed and tested for relatively flexible, small structures and devices and have been applied in many industrial systems, for instance, for vibration suppression of wind turbine blades, in [6].

The applicability of the shunted vibration suppression technique for the vibrations of the pylon poses two challenges. First the structure is massive and vibrates in lower frequencies. Second the expected size of piezoelectric transducers and of the electric circuit are expected to be high, possibly beyond the current technological abilities.

Methodology. A simplified cantilever beam model of an onshore wind turbine tower has been used. The host beam is made of steel and one piezoceramic of type PIC151 is placed 1.82 m horizontal and 1.14 m vertical away from the fixed end, [1]. The material and geometric properties of the structure are taken from reference [1], for comparison.

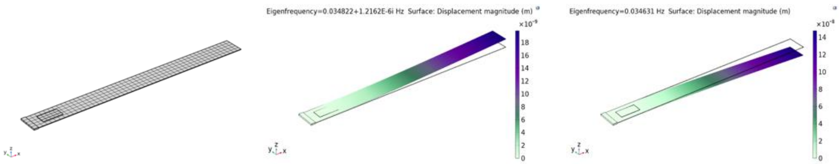
For the electric model, the boundary conditions have been defined in finite element model. A shunt damping system is proposed to reduce the vibrations of the turbine tower. The shunt damping parameters are optimizing using an optimization technique, i.e., particle swarm algorithm, genetic algorithm.

Results. In the next table are given the frequencies, which are obtained from the finite element model, for the first four flexural modes of the beam.

Table 1. Natural frequencies from finite element computation (FE).

	Open Circuit	**Short Circuit**	
Mode N.	Value	Value	Unit
1st freq.	0.034822	0.034631	Hz
2nd freq.	0.21252	0.21182	Hz
3rd freq.	0.58504	0.5842	Hz
4th freq.	1.1361	1.1358	Hz

Additionally, in Fig. 1 are shown the finite element model of the structure and the first eigenmodes in open and short circuit terms.



(a) (b) (c)

Fig. 1. Mesh modelling and first natural modes of the structure. (a) finite-element mesh (b) open-circuit eigenmodes (c) short-circuit eigenmodes.

Conclusions. In this work, the use of piezoelectric devices for the reduction of vibrations in wind turbines has been analysed. The simplified model of the turbine with coupled piezoelectric devices has been implemented with finite element software. A parametric analysis has been performed to provided the effectiveness of the proposed vibration suppression method and conclude the feasibility analysis.

References

[1] M. Á. López-Romero and M. Santos Peñas, "A Positive Position Feedback controller for vibration control of wind turbines," Energy Reports, vol. 9, pp. 1342–1353, Dec. 2023, doi: 10.1016/j.egyr.2022.12.047.

[2] G. Malliotakis, P. Alevras, and C. Baniotopoulos, "Recent Advances in Vibration Control Methods for Wind Turbine Towers," Energies, vol. 14, no. 22, p. 7536, Nov. 2021, doi: 10.3390/en14227536.

[3] André Preumont, Vibration control of active structures. New York, NY: Springer Berlin Heidelberg, 2018.

[4] K. Marakakis, G. K. Tairidis, P. Koutsianitis, and G. E. Stavroulakis, "Shunt Piezoelectric Systems for Noise and Vibration Control: A Review," Front. Built Environ., vol. 5, p. 64, May 2019, doi: 10.3389/fbuil.2019.00064.

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Funded by the European Union

[5] P. I. Koutsianitis, G. K. Tairidis, G. A. Drosopoulos, and G. E. Stavroulakis, "Conventional and star-shaped auxetic materials for the creation of band gaps," Arch Appl Mech, vol. 89, no. 12, pp. 2545–2562, Dec. 2019, doi: 10.1007/s00419-019-01594-1.

[6] H. Biglari and V. Fakhari, "Edgewise vibration reduction of small size wind turbine blades using shunt damping," Journal of Vibration and Control, vol. 26, no. 3–4, pp. 186–199, Feb. 2020, doi: 10.1177/1077546319877706.

Resilience Assessment of Transit-Transfer-Stations (TTS) Exposed to Multiple Hazards

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Summary. Transport infrastructure and transit transfer stations (TTS), such as ports and airports, are pylons of global economy and underpin social equity, serving as essential nodes within transport networks and aiding connections between different transport modes. Hazards, e.g. flooding, scour and sea level rise, affect assets of TTS leading to physical damage to the infrastructures and loss of functionality. Development of techniques for the assessment of risks and vulnerability of TTS under hazard events, performance due to increased stressors due to climate change and achieving a bounce back after hazard events aids in efficient infrastructure management. A transition from risk/loss and restoration models into quantifiable resilience despite the challenges in quantifying vulnerability and resilience worsened by the complex nature of climate change quantification. Nevertheless, today there is a complete lack of established resilience frameworks based on which the operators and owners of TTS can make informed decisions. To address this capability gap, this research aims to develop a detailed framework for enabling the assessment and quantification of TTS resilience under multiple hazards considering structural/physical interactions and correlated functional/operational interdependencies. The interaction and interdependency in this case is between assets within the same TTS and not an entire network i.e. treating the TTS as a critical node within the network. The proposed framework is based on a representative TTS which was selected on the basis of well-thought criteria, to set a TTS-benchmark for future resilience assessments. This benchmark is modelled with a three-dimensional finite element combined bridge – building model showing physical interactions of the asset's components and underlying soils. A step for developing fragility curves for combined systems within a TTS exposed to multiple hazards and also considering increasing environmental stressors due to climate change. A framework and tools for quantitative risk and resilience assessment of a TTS (in this case a port) exposed to multiple hazards will be developed as a useful tool for infrastructure owners and managers. This research envisages enabling accurate resilience assessment for TTS to be readily applied by TTS operators and owners and ultimately facilitate investment prioritisation and optimisation in future to combat the impact of climate change in the built environment.

Aerogel Materials in Composite Electrodes for Energy Storage Devices

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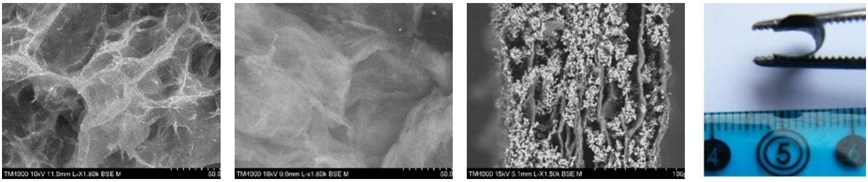
Summary. In a view of the recent interest to development of high-performance energy storage devices, supercapacitors (SCs) are the most promising candidates in comparison to batteries and fuel cells due to relatively simple structure and inherent electrochemical properties. Prepared and analysed here composite electrodes used aerogel materials that can increase the energy and power density and elongate the cycle life of the energy storage devices.

Keywords: energy storage; supercapacitors; electrodes; graphene.

The need for clean and sustainable energy sources to meet the exponentially rising energy demands of the world has compelled scientists to look for new power generation strategies. Solar cell, wind energy as well as thermoelectric energy conversion have the advantage to harvest widely distributed waste heat and are also proved as an alternative route to convert solar/thermal energy into electric power economically. At the same time the renewal of interest to fundamental mechanisms of energy storage in supercapacitors (SCs) and batteries was boosted by the progress in development of novel materials for nanostructured electrodes. SCs can be charged faster than batteries, leading to a very high power density, and do not lose their storage capabilities over time. The main shortcoming of SCs is their low energy density. Preliminary design criteria and cell specifications are following: flexible, low weight and cheap. Reduced graphene oxide (rGO) has attracted significant attention in recent years due to its extraordinary physical and chemical properties. rGO has high electrical conductivity but its capacitance is often limited by sticking of layers and some additives should be incorporated into rGO to prevent it. Combination of rGO with different additives such as transition metal oxides, polymers, etc. can result in perspective electrode materials.

In the current work structural properties, electric, electrochemical characteristics of rGO-based electrodes are studied. Stable graphene oxide (GO) solution was prepared by Hummer-based method and corresponding aerogel by freeze-drying process with the following heat treatment at 180 °C in vacuum oven (Fig. 1a) or at 700 C by rapid thermal annealing (RTA) (Fig. 1b). Obtained rGO aerogel was mixed with carbon nanotubes (CNT) and polyvinylidene fluoride (PVDF) as 80:10:10 and screen-printed onto carbon cloth (Fig. 1c). Symmetric supercapacitors were fabricated from two equal flexible electrodes (Fig. 1d) and tested in Na2SO4 electrolyte.

Strong capacitive behavior was observed for all prepared SCs based on cycling voltammogramms, galvanostatic charge-discharge (GCD) tests and impedance spectroscopy. Calculated specific capacitance of SCs made on rGO aerogel annealed at 180 °C was higher than that obtained for SCs with aerogel treated at 700 °C.



(a) (b) (c) (d)

Fig.. 1. SEM images of rGO aerogels annealed at 180 □C (a) and at 700 □C (b). Cross-section of composite electrode on carbon cloth based on rGO aerogels annealed at 180 □C (c). Flexibility of the prepared supercapacitor (d).

Calculated power density of SC made on rGO aerogel annealed at 180° with CNT and PVDF increase from 61.7 - 602 W kg-1 and a consequent decrease of corresponding energy density from 4.2 to 2.7 Wh kg-1 when the current density is increased from 0.1 to 1 A g-1. In addition, during the long-term durability test the energy density of tested SC decreased from 4.2 to 2.7 Wh kg-1 while the power density lowered from 61.7 to 53.1 W kg-1. Moreover, post-mortal analyses by X-ray photoelectron spectroscopy of SC made on rGO aerogel annealed at 180 °C with CNT and PVDF did not show significant changes in electrode structures and SC works stable more than 140 hours or 10 000 GCD cycles.

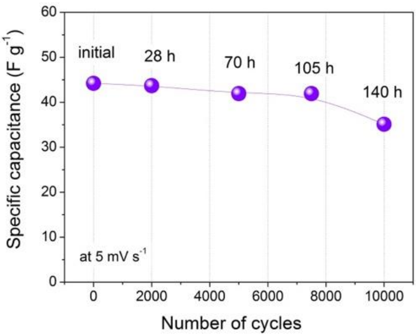


Fig. 2. Specific capacitance of SC made on rGO aerogel annealed at 180 ° with CNT and PVDF after long cycling measurements.

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Power-To-X: Challenges and Perspectives of a Large-Scale Hydrogen Economy

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Summary. Hydrogen is a promising energy vector that may enable countries to meet their ambitious decarbonization goals. The hydrogen economy could be the answer to the electricity storage crisis introduced by fluctuating electricity from renewable energy. This research compares four different Power-to-X hydrogen transportation scenarios for Germany using multi-criteria decision-making (MCDM) tools: a) Power-to-ammonia, b) methanol, b) gas, and c) liquid hydrogen (LH2). Ammonia is found to be the best solution.

Keywords: Power-to-X, Hydrogen storage, Large-scale hydrogen transportation, Power-to-ammonia.

Introduction. Hydrogen can be transported either in liquid, gas or chemically converted to other substances easier to handle. Any of the liquid forms are more attractive than gas storage solution for long-distance transportation due to its high liquid density or less reactivity of the newly formed chemical compound. The liquid hydrogen (LH2) chain consists of the generation of hydrogen, liquefaction, transportation, storage, and regasification before usage or distribution. At ambient pressure, the liquefaction temperature of H2 is -253 °C [1]; therefore, the liquefaction process is associated with very high energy consumption. It is also considered the conversion of hydrogen to ammonia or methanol right after the production of hydrogen through electrolysis.

Methodology. This research compares using multi criteria decision making (MCDM) tools, four different scenarios for green hydrogen storage without geographical limitations from different criteria points of view. Different criteria are put into perspective for the four alternatives. The MCDM assigns a value of 0 to the base case for all the compared parameters. The base case is assigned to the Power-to-gas. The weighting factors have been selected for each parameter and are calculated according to the Analytic Hierarchy Process (AHP), subjective to the criteria developed by the authors based on their expertise. The value of 3 is given to significantly better parameters than gas hydrogen (base case), and the value of -3 means substantially worse than gas hydrogen. The value 0 means it is equal compared to the base case.

Results. Fig. 1 presents the decision matrix heatmap. The temperature and pressure of storage conditions should be evaluated separately. At environmental temperature, methanol and gas hydrogen can be stored, while at environmental pressure, LH2 and methanol. Therefore, methanol is the technically easiest substance to store. From the specific energy use point of view, the best one is the base case followed by ammonia. The worst one is LH2 since its production requires larger energy use. The levelized cost of production is similar for methanol and ammonia, slightly higher for the latter, while LH2 is the costliest one. However, the one with the lowest LCO is green hydrogen gas since all four

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options require green hydrogen production. Note that methanol is liquid at atmospheric pressure and temperature; therefore, the infrastructure cost to store methanol is low, especially compared to LH2, which requires cryogenic temperatures. Since the four alternatives are considered green solutions, emissions are almost zero for the four technologies under correct process conditions [2]. From a technology readiness level (TRL) viewpoint, the Power-to-ammonia option is the one more developed since ammonia is produced based on the Haber-Bosch process, while methanol via hydrogenation is still being improved. Transportation via truck is more frequent for ammonia, followed by methanol, and finally LH2 cryogenic truck. Ammonia is the best solution from a volumetric hydrogen density point of view with 108 kgH2/m3, while gas hydrogen is the worst with only 14 kgH2/m3 [1]. Finally, from the safety point of view, the explosion limits in the air are considered, and the best option is methanol, while the worst one is hydrogen. Ammonia is the most toxic substance among alternatives. Before the weighting factor was chosen, methanol was the best option of the four alternatives. However, after the weighting factors were assigned, the ammonia solution had the highest score compared to methanol.

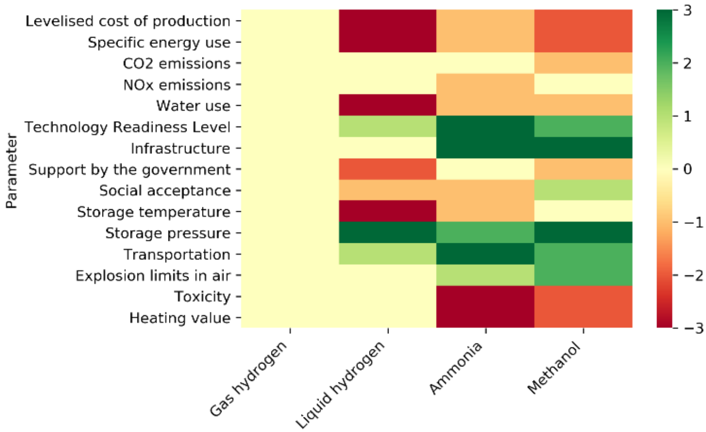

Fig. 1. Decision matrix comparative heatmap of: hydrogen gas, LH2, ammonia, and methanol [1]

Conclusions. According to the parameters evaluated in the comparison, the PtX technology that works best for the study case is Power-to-ammonia. The least advantageous would be Power-to-LH2. The reader should be warned that each country should be individually analyzed.

References

[1] J. Incer-Valverde, L. J. Patiño-Arévalo, G. Tsatsaronis and T. Morosuk, "Hydrogen-driven Power-to-X: State of the art and multicriteria evaluation of a study case," Energy Conversion and Management, vol. 266, p. 115814, 2022.

[2] G. Brändle, M. Schönfisch and S. Schulte, "Estimating long-term global supply costs for low-carbon hydrogen," Applied Energy, vol. 302, p. 117481, 2021.

Energy Performance Evaluation for a Floating Photovoltaic System Located on the Reservoir of a Hydro Power Plant under the Mediterranean Climate Conditions during a Sunny Day and a Cloudy Day

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Summary. This study is performed by utilizing experimental data from a field test located in a region having Mediterranean Climate Conditions. It is a newly installed FPVS with an installed capacity of 0.5 MWp DC. The unit is the world's biggest of its configuration referred to the installed capacity and its diameter. Results include the energy yield, final yield, performance ratio, capacity factor, and system efficiency. They refer to a daily period during sunny and cloudy days and offer a clear view regarding the system operation.

Keywords: FPV system, floating membrane, final yield, performance ratio.

Introduction. This work is focused on experimental analysis of a floating photovoltaic system employed on the water reservoir of a hydro power plant with an installed capacity of 72 MW. The trial unit is the biggest of its kind with an installed capacity of 500 kWp and a floater diameter of Φ=68.8 m.

Methodology. It is based on:

- the measured values of irradiance on the photovoltaic array plane for the selected days (clear and cloudy);
- the energy yield;
- the final yield;
- the performance ratio;
- the capacity factor, and
- the system efficiency.

Fig. 1. The utilized FPV unit on the reservoir surface of the Banja hydro power plant.

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Results

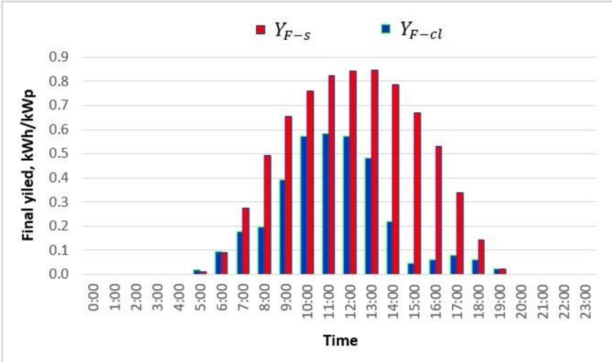

Fig. Hourly values for the final yield

Conclusions. For the considered sunny and cloudy days, it is noticed that the daily final yields are 7.289 kWh/(kWp·day) and 3.572 kWh/(kWp·day), respectively. The daily performance ratio is 86.9% (sunny day) and 89.8% (cloudy day). Also, the daily system efficiency in the selected days are 17.4% and 17.9%, respectively.

Acknowledgements. The author acknowledges the availability of Statkraft Albania by offering the necessary information about the FPV unit installed in the water reservoir of Banja Hydro Power Plant.

References.

[1] Maraj A., Kertusha Xh., Lushjnari A., "Energy performance evaluation for a Floating Photovoltaic System located on the reservoir of a hydro power plant under the Mediterranean climate conditions", SDEWES Conference 2021, Dubrovnik, Croatia.

[2] Kjedstadt T., Lindholm D., Marstein E., Selj J., Cooling of floating photovoltaics and the importance of water temperature, Solar Energy, Vol. 218, pp. 544-551, 2021.

[3] Rosa-Clot M., Tina G.M., Nizetic S., Floating photovoltaic plants and wastewater basins: an Australian project, Energy Procedia, Vol. 134, pp. 664-674, 2017.

[4] Cazzaniga R., Cicu M., Rosa-Clot M., Rosa-Clot P., Tina G.M., Ventura C., Floating photovoltaic plants: performance analysis and design solutions, Renewable and Sustainable Energy Reviews, Vol. 81, pp. 1730-1741, 2018.

Techno-Economical Analysis of Photovoltaic Power Generation: A Case Study of Sedef Island in Istanbul

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Summary. While the total installed power of electricity in Turkey was around 27.3 GW as of 2000, it has reached the level of 103.3 GW at the end of October 2022. With the increase in this energy demand, the tendency towards renewable energy is increasing day by day. Once the share of renewable energy in Turkey's total installed power was 43.3% in 2015, it has approached 54.1% in 2022. More than 500 islands and islets in Turkish territorial waters should be evaluated in terms of renewable energy potential. The nine islands located in the northeastern part of the Marmara Sea and on the Anatolian side of Istanbul are called as Prince Islands. Five of these nine islands are inhabited. As seen in Fig. 1, the Sedef Island has a total area of 1.43 km2 and has 114 detached households. In this study, the technical and economic analysis of the photovoltaic system that will meet the energy needs of these households is performed.

All of analysis will be performed with the help of PV*SOL software that is one of the leading solar software in the industry with the detailed configuration and shade analysis for photovoltaic systems. Since the building structures on the island are similar to each other, the analyzes will be carried out on one household and will also be a reference to other households on the island.


Fig. 1. Sedef Island

In addition to all these, Istanbul is a risky region in terms of earthquakes. It is predicted that if the North Anatolian Fault, which passes through the Marmara Sea, and becomes active, it may cause a very severe earthquake. According to the studies carried out by Turkey Disaster and Management Authority (AFAD), it has been reported that there will be an average of 7 hours of power outage in an earthquake greater than 7 on the Richter scale to occur in Istanbul. The renewable energy production potential of the islands in Istanbul and their support to the general grid are important for the continuity of energy.

We may lose many lives that we could have saved as our access to sustainable energy is cut off in disasters. Thus, we need to have constant access to sustainable energy in every situation. In this scenario, the establishment plan of sustainable energy is crucial in this matter. A renewable-based-distributed generation center as an energy island that produces its own energy would be a promising solution for humanity.

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Keywords: Energy Island, Photovoltaic, Techno-Economical Analysis, Renewable Energy

References

https://www5.tbmm.gov.tr/develop/owa/komisyon_tutanaklari.goruntule?pTutanakId=2632

https://www.tskb.com.tr/uploads/file/enerji-gorunumu-final.pdf

https://www.valentin-software.com/wp-content/uploads/legacy-downloads/handbuecher/en/manual-pvsol-en.pdf

Akpolat, A.N.; Dursun, E.; Kuzucuoğlu, A.E.; Yang, Y.; Blaabjerg, F.; Baba, A.F. Performance Analysis of a Grid-Connected Rooftop Solar Photovoltaic System. Electronics 2019, 8, 905. https://doi.org/10.3390/electronics8080905

Increased Day-to-Day Concentrating Solar Power Performance by Combined Solar Tower and Parabolic Trough Plants

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Concentrating solar power is an important technological option to gradually increase the share of energy produced by renewable energy sources. Central power towers and parabolic trough collectors, are currently the most mature solar thermal technologies globally installed. While the former technology requires less land area to produce the same power output, the latter operates at lower temperatures thereby requiring less demanding materials.

We investigated, by dynamic modeling, the potential of both technologies in the same plant configuration. This configuration results in a higher maximum capacity factor of 18% at 925 W/m direct normal irradiance compared to a standalone plant based on parabolic trough technology. This is achieved by the complementary seasonal action of the technologies, the tower in winter, while the parabolic collector in summer. In this way, the advantages of both concentrating technologies can be utilized and aid towards wider utilization of solar energy.

Analysis of the demand for electricity and heat storage

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Summary. This presentation refers the dependencies and possibilities of energy storage equipment use in an integrated power supply system (with electrical and thermal energy). The analysis will be made in terms of quality, quantity, location and technological advancement.

Keywords: energy storage, electrical energy, thermal storage

Instructions. Sustainability and resilience of the integrated modern supply system need stabilizing elements for maintain balance between energy production and consumption. Several electricity generation processes produce heat in a more or less intentional way. In most cases whole or part of heat is wasted. The possibility of electricity and heat storage and use in the future can significantly improve the efficiency of the whole generation system.

Methodology. Different storage technologies have now reached different stages of development. It is important to distinguish pilot and demonstration applications from those that can be used on a larger or commercial scale. Fig. 1 shows the technological advancement level of the selected storage technologies for electricity and heat storage use electrical, electro-chemical, mechanical, thermal, and chemical principles as well capital requirement including technology risk. Each of the technologies has its limitations of storage time, charging and discharging dynamics, storage capacity life time, infrastructure and exploitation cost, etc., that need to be considered and analyzed.

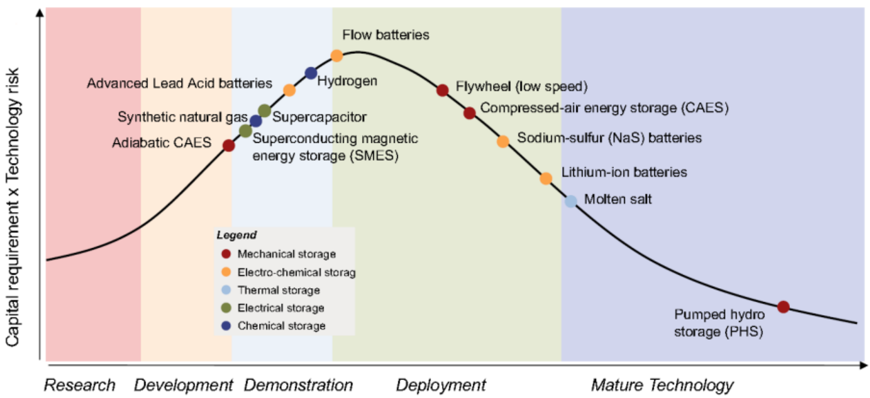

Fig. 1. Advancement of selected energy storage technologies [1].

Result

The basic criterion for the selection of the energy storage equipment are operating parameters, the most common cases including the type of storage energy are summarized in table 1. The next step is to find the best solution for given parameters, what will be presented.

Table 1. Demand for energy storage depending on the purpose (based on [2])

Concl.		Concl.		Concl.	
Seasonal storage	electric, thermal	500 ÷ 2 000	days, mounts	1 ÷ 5 per year	1 day
Arbitration	electric	100 ÷ 2 000	8 ÷ 24 h	0.25 ÷ 1 per day	> 1 h
Frequency adjustment	electric	1 ÷ 2 000	1 ÷ 15 min	20 ÷ 40 per day	1 min
Follow up stay	electric, thermal	1 ÷ 2 000	15 min ÷ 1 day	1 ÷ 29 per day	< 15min
Voltage support	electric	1 ÷ 40	1 s ÷ 1 min	10 ÷ 100 per day	ms ÷ s
Start	electric	0.1 ÷ 400	1 ÷ 4 h	< 1 per day	< 1 h
Network relief	electric, thermal	10 ÷ 500	2 ÷ 4 h	0.14 ÷ 1.25 per day	> 1 h
Deferment of investment	electric, thermal	1 ÷ 500	2 ÷ 5 h	0.75 ÷ 1.25 per day	> 1 h
Peak reduction	electric, thermal	0.001 ÷ 1	minutes, hours	1 ÷ 29 per day	< 15min
Offline (off-grid)	electric, thermal	0.001 ÷ 0.01	3 ÷ 5 h	0.75 ÷ 1.5 per day	< 1 h
Integration of renewable sources (RES)	electric, thermal	1 ÷ 400	1 min up to several hours	0.5 ÷ 2 per day	< 15 min
Waste heat	thermal	1 ÷ 10	1 h ÷ 1 day	1 ÷ 20 per day	< 10 min
Cogeneration	thermal	1 ÷ 5	minutes, hours	1 ÷ 10 per day	< 15 min
Hidden reserve	electric	10 ÷ 2 000	15 min ÷ 2 h	0.5 ÷ 2 per day	< 15 min

Conclusions. At present, most energy storage facilities focus on electricity storage, ignoring heat, which in most cases is waste, the use of system and household heat storage facilities can positively affect the improvement of generation efficiency, especially renewable energy installations.

References

[1] Kearney A., Electricity Storage Gaining Momentum, Energy Transition Institute, 2018
[2] IEA, Energy Technology Perspectives, International Energy Agency, Paris, 2014

Deployment Potential of Large-Scale PV Systems for Multiapartment Buildings

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Summary. Deployment of large-scale PV systems for multiapartment buildings for producing, self-consuming and sharing renewable energy can help improve building energy efficiency, support the use of renewable energy, and at the same time can reduce energy consumption and supply tariffs, as well as increase EU's independence from fossil fuel supplying countries. It was found out that a large-scale rooftop PV system placed on a typical multiapartment building can fully cover consumed electricity annually.

Keywords: large scale PV, multiapartment buildings, self-consumption

Introduction. About 50% of residential buildings in the European Union were built before the introduction of energy efficiency regulations [1]. According to the recommendations of the Energy Performance of Buildings Directive [2], it is necessary to increase the use of renewable energy in buildings. Analysing EU data about building stock about 49 % are multiapartment dwellings [3]. The residential sector is the second largest electricity consumption sector after the industrial sector, the share of which in 2020 was around 30% of the total electricity consumption of the European Union [4]. In accordance with EU Solar Energy Strategy European Solar Rooftops Initiative [5] and by some estimates [6], rooftop photovoltaics can provide almost 25% of the EU's electricity consumption.

Methodology. PolySun computer simulation software was selected for the study. Using the software, the architectural project corresponding to the real configuration of the roofs was modelled, considering all engineering and technical systems that were installed on the roofs of typical projects of residential buildings. The overall research methodology is based on statistical data analysis of household hourly data on electricity consumption, roof technical inspection, dynamic simulation of PV array production.

Results. Total electricity consumption by the multiapartment building of 60 apartments and common use external electricity and common use internal premises lightening for the selected building is shown in Fig. 1. About 10 % of the total apartment building electricity consumption was used for common use.

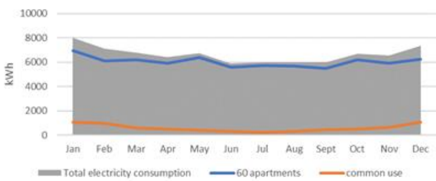

Fig. 1. Total multiapartment building electricity consumption per year.

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Simulations were performed for two building models: Model I: obstructions were considered when selecting the PV layout (Fig. 2a) and Model II: obstructions were not considered (full coverage of the roof covering) (Fig. 2b). See Table 1 for the simulation results.

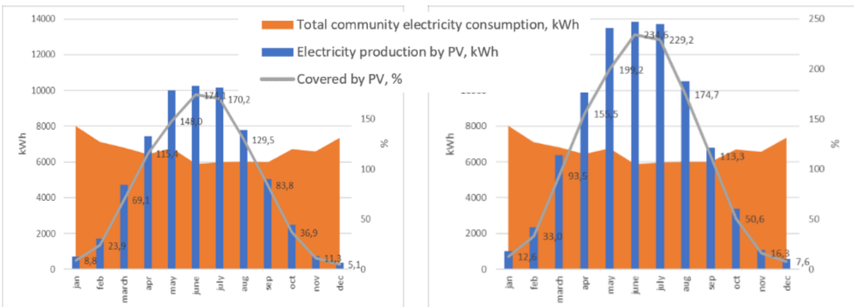
(a) (b)

Fig. 2. PV layout for building model.

Table 1. Simulation results.

	Building Model I	Building Model II
System Size, kWp	75.6	100.8
PV Modules, pcs.	216	288
Annual energy generation, kWh	61,393	83,072

Analyzing the hours of electricity load per year, it can be concluded that in the summer period the both building models PV systems can fully provide the necessary consumption and the surplus is transferred to the network.



(a) (b)

Fig. 3. Electricity consumption and production profile: a) Model I; b) Model II.

Conclusions. Using PolySun computer simulation software, a building models was created, and the proposed large-scale PV-based power system was simulated. For Model I it has shown good results around 77% of the electricity consumed by the building can be covered by self-produced electricity using the NET system. From April to August, there is surplus of electricity 14,573 kWh. In case of Model II PV system can fully cover the building electricity consumption. From April to September, there is surplus of electricity 31,237 kWh. Surplus electricity can be stored in grid and used in accordance with the NET metering or billing system rules.

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References

[1] Pajek, L.; Jevrić, M.; Ćipranić, I.; Košir, M. A Multi-Aspect Approach to Energy Retrofitting under Global Warming: A Case of a Multi-Apartment Building in Montenegro. J. Build. Eng. 2023, 63, 105462, doi:10.1016/J.JOBE.2022.105462.

[2] EUR-Lex - 02010L0031-20210101 - EN - EUR-Lex Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02010L0031-20210101 (accessed on 15 February 2023).

[3] EU Buildings Factsheets | Energy Available online: https://ec.europa.eu/energy/eu-buildings-factsheets_en (accessed on 15 February 2023).

[4] Tzeiranaki, T.; Bertoldi, S.; Castellazzi, P.; Gonzalez Torres, L.; Clementi, M.; Paci, E. Energy Consumption and Energy Efficiency Trends in the EU, 2000-2020., doi:10.2760/727548.

[5] European Commission EU Solar Energy Strategy; Belgium, 2022; p. 23;.

[6] Bódis, K.; Kougias, I.; Jäger-Waldau, A.; Taylor, N.; Szabó, S. A High-Resolution Geospatial Assessment of the Rooftop Solar Photovoltaic Potential in the European Union. Renew. Sustain. Energy Rev. 2019, 114, doi:10.1016/j.rser.2019.109309.

Wind Turbine and PV Solar Systems Integration in the Power System – Case Study of their Stability in Different Operating Regimes

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Summary. The integration of renewable energy sources, among others, constitutes a challenge in energy stability and security, considering the trend and needs for energy as well as the growing demands for energy consumption. According to many data and statistics, power systems are often faced with energy imbalance and the threat of operating limits of basic parameters, such as; frequency, voltages, and currents. The topography of the network, the construction of appropriate models, the histogram of environmental parameters, and the correct predetermination of climatic conditions constitute a good basis for creating the conditions for the most efficient and least disturbing integration of wind turbines and photovoltaics. The study includes a model built in an energy node and the integration of renewable sources, such as solar and wind.

Keywords: Solar and wind power, power system, stability and security, frequency and voltage.

Introduction. Flexibility in power systems has been defined as the ability of the power generators to react to unexpected changes in load or during system component failures. Taking into consideration the increasing penetration levels of power generation from variable and hardly predictable sources such as wind and solar energy, are become a concept that needs to be redefined and analysed [1].

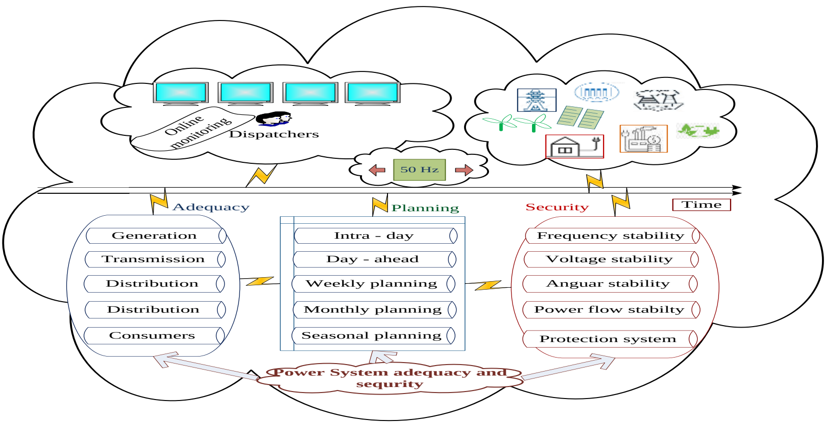

Fig. 1. The adequacy and security of the power system components.

Security of energy supply and security risks include the incapacity of an electricity infrastructure system to meet growing load demand [2]. When the new energy loses its output due to energy shutdown or stall, the frequency of the power system will be reduced, especially when the penetration level of new energy is high, which will directly affect the frequency stability of the system [3]. Factors often used to qualify the security of supply include resource availability, import dependency, supplier reliability, diversity in energy resources, and transmission infrastructure [4].

Methodology. Modeling includes of an energy node, integration of solar and wind resources, electric substation, solar parks (9 MW) and a wind park (20 MW), and synchronous generators (65 MVA) are the modeling elements. The methodology applied is based on the simulation of wind generators and photovoltaics in different operating regimes such as failures, unexpected outages, and overloaded branches.

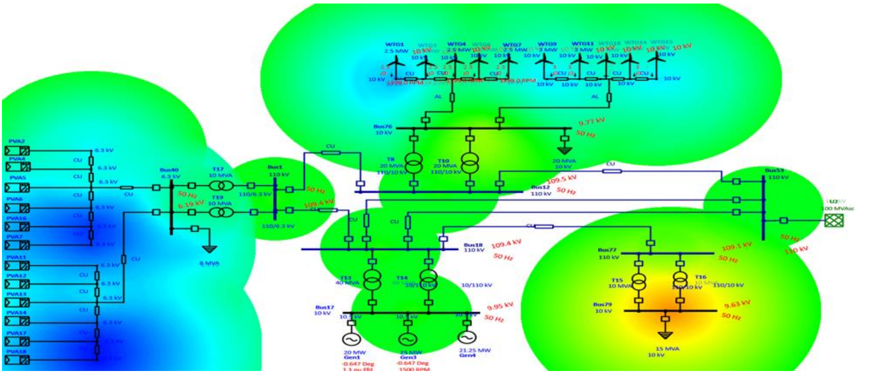

Fig. 2. The modeling of the PV and wind turbine integration in the electric substation.

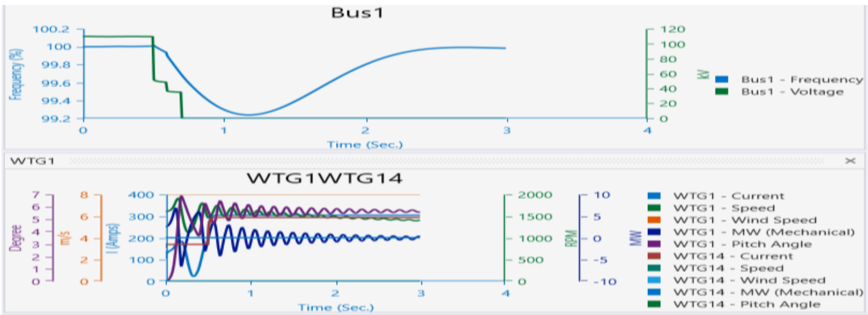

Fig. 3. The simulation of The PV and wind turbine, impact of their parameters on stability.

Results. Knowing the behavior of the main parameters, such as frequency, voltages, currents, short circuits, voltage angle, pitch angle, active and reactive power flow, wind speed in different regimes, as well as PV operation in different configurations gained by this study are very significant in their stability and safety and the operation of the power system as a whole [Fig.3].

Conclusions. The security and stability of renewable resources during operation in different conditions and regimes play a significant role in the continuity and reliability of the operation of the power system in general. The results show that the knowledge of the behaviour of the main parameters of wind and solar parks constitutes a primary condition in terms of their safety margin operation and stability. Diversity renewables, hybrid combination, and continuous monitoring of wind and PV parks is one of the tasks for increasing their reliability of integration.

References

[1] Impram, S., Nese, S., & ORAL, B., (2020). Challenges of renewable energy penetration on power system flexibility: A survey. Energy Strategy Reviwes, vol.31.

[2] Samantha Ölz, Ralph Sims and Nicolai Kirchner, "Internal Energy Agency", OECD/IEA, April 2007.

[3] Maihemuti, Saniye & Wang, Weiqing & Wu, Jiahui & Wang, Haiyun. (2022). New energy power system operation security evaluation based on the SWOT analysis. Scientific Reports. 12. 10.1038/s41598-022-16444-4.

[4] Johansson, Bengt. (2013). Security aspects of future renewable energy systems–A short overview. Energy. 61. 598–605. 10.1016/j.energy.2013.09.023.

Advanced Electron Microscopy of Materials for Power Generation

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Summary. Sanicro 25 is austenitic stainless steel developed by Sandvik for high-temperature applications.

It has excellent creep properties, as well as resistance to corrosion and oxidation and high resistance to stress corrosion cracking. It is commonly used in applications such as heat exchangers, boilers, and superheaters in the chemical and power generation industries.

The study aimed to conduct a detailed microstructural characterization of a Sanicro 25 steel sample that was heat treated in the air at a temperature of 700°C for 25,000 hours. The examined sample has a complex microstructure due to: i) oxidation for 25,000 hours, which resulted in changes observed mainly close to the surface; ii) microstructural changes close to the surface and within the bulk material due to long-term high-temperature exposure.

For the characterization of the evolution of the sample's microstructure, the following experimental methods and techniques were used: 1) thermodynamical simulation of the phase composition for the sample after standard heat treatment (as-received sample) and the sample heat treated for 25,000 hours at 700°C. Results of chemical microanalysis using TEM-EDS were used as input data for the Thermocalc package to estimate the equilibrium phase composition within the area close to the surface of the oxidized sample and further from the surface within the bulk material. 2) Following the thermodynamical calculation, microstructural characterization was performed using state-of-the-art electron microscopy methods. The use of advanced transmission electron microscopy (TEM), including Cs-corrected TEM, allowed performed microstructural research at the atomic level. To identify and characterize the complex phase structure of the specimen, the selected area electron diffraction (SAED) technique was used in combination with TEM-EDS.

Keywords: Power generation materials, microstructure, electron microscopy

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