COST ACTION CA20109

MODENERLANDS

Modular Energy Islands for Sustainability and Resilience

Strategic Workshop

Visions and Strategies to enhance the concept of Floating Energy Islands

Beckmannshof (Botanical garden)

Ruhr University Bochum, Germany

September 2-3, 2024

BOOK OF ABSTRACTS

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EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

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COST ACTION CA20109

MODENERLANDS

Modular Energy Islands for Sustainability and Resilience

Book of Abstracts for the Strategic Workshop

Visions and Strategies to enhance the concept of Floating Energy Islands

Organizers

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www.modenerlands.eu

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The COST Action and the Strategic Workshop

The COST Action CA20109 MODENERLANDS is dedicated to advancing the development of high-performance Energy Islands that are safe, smart, modular, cost-effective, and socially beneficial. These islands, built on offshore floating platforms, are designed to tackle the challenges associated with renewable energy, particularly wind and wave energy.

The primary goal of this Action is to foster the development of European R&D groups focused on Sustainable Energy and related technologies. The aim is to integrate Floating Energy Islands into the planning, design, and development of future renewable energy infrastructures. This Action seeks to establish pathways that promote synergies in Research, Education, and Training, supporting the development and future deployment of floating energy islands in deep-sea ocean waters, ultimately advancing sustainability in the energy sector.

The Action's technical work is organized into three Working Groups. WG1 focuses on assessing resources and evaluating the future of renewable energy in the context of climate change. WG2 is dedicated to the modularized construction of offshore floating platforms, designed to be easily expanded to meet future energy demands. This group will introduce the concept of the Modular Energy Island, which serves as a platform to optimize the collection and conversion of renewable energy sources. WG3 investigates new challenges in the design and manufacture of advanced technologies for energy storage and transmission. Additionally, this group will explore the potential of Green Hydrogen technologies for efficient energy storage and grid integration, while also considering resilience analysis and techno-economic factors.

The Strategic Workshop (SW), held at the Ruhr University Bochum, Germany, spans one and a half days. The workshop's theme is " Visions and Strategies to enhance the concept of Floating Energy Islands". The main objectives are to encourage active participation from members of the Action's three Working Groups and to invite external specialists representing various stakeholders to present their latest developments and projects related to the scientific and technical topics addressed by the Action. Additionally, the workshop offers an opportunity for students who attended previous training schools organized in the framework of the Action to showcase the work they developed during and after the training schools.

Carlos Rebelo
Action Chair
University of Coimbra, Portugal

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

Workshop Venue | Ruhr University Bochum

The Ruhr University Bochum is in the heart of Europe in the dynamic metropolitan region of the *Ruhrgebiet*. With its 21 faculties is home to about 40,000 students and driving force of social change. “Built to change” is its mission statement and mandate for the future, and as such is a driving force for the entire region. The spirit of Ruhr University Bochum is to promote talent from all over the world, tearing down disciplinary barriers, embracing diversity, keeping an open mind.

The Workshop is taking place at the *Beckmanns Hof*, a protected monument that reopened in 2012 as the International Convention Centre of the *Ruhr-Universität Bochum*. It is located next to the Botanical Garden of the RUB. The historical building was modernized and expanded and is now handicapped accessible. Meeting rooms are technically equipped with a projector and laptop. Flip charts and whiteboards are standard.

Program Overview

2nd Sept (Monday)			Location
9:00 - 9:30	**Registration**		Beckmannshof
9:30 - 9:45	Welcome by the Vice Rector of RUB	Günther Meschke	
9:45 – 10:00	Opening of the Workshop	Rüdiger Höffer	
10:00 – 10:15	Overview of COST Action and SW	Carlos Rebelo	
10:15 - 10:45	Invited Lecture IL1	Michal Kociniak	
10:45 - 11:15	Invited Lecture IL2	Erick Ulloa Jimenez	
11:15 - 11:45	Coffee-break		
11:45 – 12:15	Invited Lecture IL3	Susanne Leidescher	
12:15 - 13:45	Lunch break		Mensa
13:45 - 14:00	Overview of WG1 developments	Anina Glumac	Beckmannshof
14:00 - 15:30	Presentations by WG1 members		
15:30 – 15:45	Coffee-break		
15:45 – 16:00	Overview of WG2 developments	Abdollah Malekjafarian	Beckmannshof
16:00 – 17:30	Presentations by WG2 members		
17:30 – 19:00	Visit wind tunnel & test facilities		
19:30 – 22:00	Dinner		Campus "Q-West"
3rd Sept (Tuesday)			
9:00 - 9:30	Invited Lecture IL4	José Pascual-Fernández	Beckmannshof
9:30 – 10:00	Invited Lecture IL5	Suat Uçar	
10:00 – 10:45	Poster Session		
10:45 - 11:00	Coffee-break		
11:00 - 11:15	Overview of WG3 developments	Luana Tesch	Beckmannshof
11:15 – 12:45	Presentations by WG3 members		
12:45 – 13:00	Closure of workshop	Lambis Baniotopoulos & Rüdiger Höffer	
13:00 – 14:30	Lunch		Mensa
14:30 - 15:30	Visit to Chinese Garden		

Scientific and Technical Program

2nd Sept (Monday)		
Invited Lectures		
10:15 - 10:45	Michal Kociniak	Reinforced concrete structures in modern green power generation
10:45 - 11:15	Erick Ulloa Jimenez	Research and application of probabilistic design: Addressing icing as a natural hazard for overhead lines
11:45 - 12:15	Susanne Leidescher	Sustainability considerations for Floating Wind – status and trends
Session by WG1 members		
13:45 - 14:00	Anina Glumac	Overview of WG1 developments
14:00 - 14:15	Teresa Simões	Review of maritime spatial plans for the iberian peninsula with focus on offshore energy development
14:15 - 14:30	Felix Nieto	Aowinde: an eu interreg project for supporting the offshore wind industry of galicia and north of portugal
14:30 - 14:45	Jonas Thor Snaebjornsson	Accuracy assessment of wind velocities over the sea based on geospatial data
14:45 - 15:00	M. Pinar Menguc	Radiative Cooling: Fundamentals and Potential Applications
15:00 – 15:15	Danka Kostadinovic	Energy assessment of potential location for Energy Island in the Adriatic Sea
15:15 - 15:30	Mohadeseh Ashkarkalaei	An unsupervised damage detection method for an operating wind turbine blade under environmental and operational conditions
Sesssion by WG2 members		
15:45 - 16:00	Michaela Gkantou & Abdollah Malekjafarian	Overview of WG2 developments
16:00 - 16:15	Jannette Frandsen	Shapes of artificial energy islands with optimized von Karman vortex streets

16:15 - 16:30	Junlin Heng	Fatigue mitigation of floating offshore wind turbine structures by adaptive controlling strategies
16:30 - 16:45	Jafar Mohammady Tekantappeh	Effects of inter-module connection properties on dynamic characteristics of self-erecting modular tower
16:45 - 17:00	Ramin Ghiasisangani	Corrosion detection around mooring cables of spar-type floating offshore wind turbine using dynamic response of the structure
17:00 - 17:15	Georgios Stavroulakis	Data, models and in-between for physics informed neural networks and digital twins
17:15 - 17:30	Salvatore Capasso	Towards resilient FMEI: an SPH-based framework for extreme hydoelastic events

3rd Sept (Tuesday)		
Invited Lectures		
09:00 - 09:30	José Pascual-Fernández	Interactions (impacts and potential synergies) with small-scale fisheries and coastal tourism
09:30 - 10:00	Suat Uçar	Fundamentals of Green Hydrogen: Production, Policy, Challenges, Research & Innovation and Best Practices
Session by WG3 members		
11:00 - 11:15	Luana Tesch	Overview of WG3 developments
11:15 - 11:30	Alper Nabi Akpolat	Utilization of modular energy islands with high green hydrogen production: a p2x example
11:30 - 11:45	Bahri Prebreza	Potential of sustainable energy resources for energy islands in Kosovo
11:45 - 12:00	Dora Pontinha	Concrete-based battery
12:00 - 12:15	Erhan Kayabasi	Feasibility of synthetic fuel production from waste heat of integrated iron and steel factories with the help of a floating energy island in Black Sea
12:15 - 12:30	Maria Tsami	Key Principles for Sustainable and Resilient Modular Energy Islands
12:30 - 12:45	Mosa Rossi	Optimal management of micro-grids to increase flexibility and resilience and act as energy islands: An Italian case study

Invited Lectures

Reinforced Concrete Structures in Modern Green Power Generation

Michal Kociniak
TECHNICAL DIRECTOR TALL STRUCTURES EUROPE;
DOMINION DEUTSCHLAND GMBH, DOMINION POLSKA SP. Z O.O.

The current times, due to climate change and the international situation, require the rapid development of alternative methods of electricity production. This is related to the widest possible participation of renewable energy in the share of power generation. New technologies require the use of new materials. Nevertheless, the use of traditional materials like steel and concrete is still in high use all the time. This article is an overview of reinforced concrete structures in renewable energy. Tall and special reinforced concrete structures play a big role all the time. Offshore, wind or solar energy facilities require the use of reinforced concrete all the time, whether for traditional foundations, load bearing or new floating structures. The large use of wind power is creating increased demand for the production of transmission cables. Also, the planned development of nuclear power involves the use of reinforced concrete to a large extent. The overall result is that reinforced concrete will continue to be a construction material for a long time to come, despite the problems associated with it, production costs or CO2 emissions. The presentation introduces reinforced concrete structures used for green energy production. Types of wind turbine foundations for the offshore market are presented. The development of the structures over time and foundation solutions for these types of structures are shown. The presentation shows both gravity based foundations and floating foundations. The methods of their construction were demonstrated. Types of onshore wind turbine foundations and the direction of their development were also presented. The offshore energy market is causing an increased demand for cables to transmit this energy to land. For this purpose it is necessary to build special reinforced concrete structures, the so-called cable towers. Examples of such structures are shown, as well as a tower made by DOMINION. Finally, reinforced concrete solar towers used in the production of energy from the sun are presented. The principle of operation and the method of locating the receiver were discussed. Examples of solutions for this type of construction and towers built by DOMINION are demonstrated.

Highlights:

- Offshore foundations
- Onshore foundations
- Concrete towers
- Solar towers

Michal Kociniak is the Technical Director of the DOMINION Division for Tall Structures in Germany and in Poland. Before, he worked as chief engineer at Dominion, and as a designer and chief structural designer in Krakow, Poland. He works for DOMINION since 13 years. He obtained his academic degree at the Krakow University of Technology in 2000. In 2022 he made his PhD at Building Research Institute in Warsaw. He has more than 20 years of experience working in tall structures, special concrete structures, chimneys, cooling towers and other industrial constructions.

Research and Application of Probabilistic Design: Addressing Icing as a Natural Hazard for Overhead Lines

Erick Ulloa Jimenez
Amprion GmbH
Dortmund, Germany

This research focuses on the challenges and solutions associated with ice loads on transmission towers. Amprion, a leading Transmission System Operator in Germany, in collaboration with Niemann Engineers and other partners, is dedicated to ensuring the reliability of overhead power lines, especially under extreme weather conditions like icing. The need to refurbish transmission towers arises due to evolving climatic conditions, increased electrical demands, and the implementation of updated standards. To address these challenges, a probabilistic approach is employed in structural calculations, ensuring accurate assessment of ice and wind loads, which is critical for maintaining the integrity and efficiency of the infrastructure.

Experimental investigations are conducted in climatic wind tunnels to study ice accretion under various conditions. These experiments contribute to refining models for calculating ice loads and validating standards like ISO 12494. Future initiatives include additional experiments on wet snow accretion and the deployment of weather stations and ice sensors to correlate experimental data with real-world conditions. These efforts are geared towards optimizing the design and maintenance of overhead lines, enhancing their resilience against natural hazards.

Highlights:

- Overhead Lines
- Ice Loads
- Probabilistic Design
- Climatic Wind Tunnel Experiments

Since 2020 Project manager structural engineering Amprion GmbH
2015-2019 Structural engineer Löschmann + Partner
2013-2015 Research assistant at the Bochum University of Applied Sciences
2012-2013 Student assistant at the Bochum University of Applied Sciences
2013-2015 Bochum University of Applied Sciences, master's degree
in Civil Engineering
2010-2013 Bochum University of Applied Sciences, bachelor's degree in civil engineering

Sustainability Considerations for Floating Wind – Status and Trends

Susanne Leidescher
Ramboll Offshore Wind
Hamburg, Germany, susanne.leidescher@ramboll.com

This lecture will explore the current state and emerging trends in sustainability for Floating Wind, focusing on how these innovative structures can contribute to global renewable energy goals while minimizing environmental impact. With case studies of pioneering projects, future prospects will be discussed, offering actionable insights for stakeholders aiming to balance energy needs with environmental and social stewardship and showcasing potential synergies for Floating Energy Islands.

Highlights:

- Environmental Impact and Mitigation Strategies
- Sustainable Design and Technology Innovations
- Economic viability and social acceptance
- Case Studies exploring regional political frameworks and future trends for shaping a sustainable project execution.

As the Sustainability Representative in Wind at Ramboll, Susanne Leidescher coordinates global efforts to integrate sustainability into wind energy projects, with a particular emphasis on advancing sustainable design principles for decarbonization, biodiversity enhancement, circularity and social acceptance.

Susanne brings over 12 years of professional experience, with a strong focus on project management, sustainability, energy consulting, and offshore wind. She has played a key role in various phases and scopes of offshore wind projects, from initial proposals to full-scale implementation.

Interactions (Impacts and Potential Synergies) with Small-Scale Fisheries and Coastal Tourism

José J. Pascual-Fernández
COST Action RethinkBlue (Rethinking the Blue Economy: Socio-Ecological Impacts and Opportunities)
San Cristóbal de La Laguna (Tenerife), Spain, jpascual@ull.edu.es

Blue Economy promotes the multidimensional use of marine resources, with Offshore Renewable Energy projects being a prime example. However, these projects must consider coastal communities' traditional uses and dependencies, necessitating a thorough understanding of their impacts. Environmental impact assessments are commonly emphasised, but social impacts on human populations are often neglected. Assessing these impacts is a complex, transdisciplinary task that involves analysing economic, social, and cultural variables alongside technical factors. This is particularly important when the effects on local communities are poorly understood. Identifying synergies in these new developments is challenging, requiring additional long-term knowledge.

There is a concern that capital-intensive developments might marginalise traditional, smaller-scale users, like fishers, causing hidden losses and conflicts. Tourism-related stakeholders are more often considered, though their interactions differ significantly.

This presentation will summarise the existing research on the interactions between Offshore Renewable Energy projects and fisheries or tourism-related communities. It will also discuss the gaps in that knowledge and ways to advance our understanding of these issues to ensure that new developments are inclusive and considerate of all stakeholders involved.

Highlights:

- Offshore Renewable Energy projects must account for coastal communities' traditional uses and dependencies to prevent negative social impacts and detect potential synergies.
- This presentation will summarise the existing research on the interactions between Offshore Renewable Energy projects and coastal communities, the gaps in that knowledge and the potential ways forward.

Professor of Social Anthropology at University of La Laguna, completed his doctoral thesis in 1989 focusing on Canary Islands fishing communities. He is the Director of the University Institute of Social Research and Tourism. Notable publications include the edited volume Small-Scale Fisheries in Europe: Status, Resilience and Governance. Cham: Springer (25 European countries, 2020). With over 2300 citations, he has led or participated in more than forty research projects since 2008, and he actively contributes to various advisory committees and working groups on fisheries and marine science, including the lead of WG of Fisheries Governance & Emergent Activities at COST Rethinkblue.

Fundamentals of Green Hydrogen: Production, Policy, Challenges, Research & Innovation and Best Practices

Suat Uçar
Tigris Development Agency, Türkiye

This lecture will explore in depth the fundamentals of green hydrogen, covering key topics from production to policy, challenges, research, innovation and best practices. This comprehensive lecture aims to provide participants with a solid understanding of green hydrogen and its important role in the sustainable energy transition.

By this lecture, participants will be well equipped to navigate the complex landscape of green hydrogen, understand policy frameworks, contribute to research and innovation initiatives, and implement best practices in their respective fields.

Highlights:

- Introduction to Green Hydrogen
- European Policy on Green Hydrogen
- Research and Innovation Funds in EU on Green Hydrogen
- Future Outlook & Challenges
- Best Practices on Combining of Renewable Generation Sources (solar/wind/hydro) and Storage Technologies with Green Hydrogen

Suat Uçar graduated from Istanbul's Yıldız Technical University, Department of Electrical Engineering, in 2004. He has 20 years' experience in control and automation systems, energy regulation, renewable energy, energy efficient systems, project management and monitoring. Since 2011, he has been working at the Tigris Development Agency and he is now the Head of the Monitoring and Evaluation (M&E) Department. In addition to this role, he has worked as an energy expert and served as investment advisor to SMEs on renewable projects in different departments of the Agency for more than 10 years. During his time in the private sector, he implemented and managed industrial energy efficiency projects in the automotive and food sectors.

In recent years, he has been working on green hydrogen, renewable energy systems and energy storage within the framework of the global transition to clean energy. In addition, he has been contributing to some research studies on these topics and working on COST Actions.

Abstracts – Working Group 1

Review of Maritime Spatial Plans for the Iberian Peninsula with Focus on Offshore Energy Development

Felix Nieto[1], Teresa Simoes[2]

[1] CITEEC, University of A Coruña, A Coruña, Spain; [2] National Laboratory for Energy and Geology, Lisbon, Portugal

Summary. In face of the EU member states commitments in terms of Climate and Energy and of the Directive 2014/89/EU, especially in the line of coastal cooperation, this document presents the status of the Maritime Spatial Plans for Portugal and Spain. Also, it focuses on the approaches used by both countries and the impact that a collaboration between the two countries can bring to the Iberian Energy targets. Both plans include a significant effort in the development of offshore renewable energy systems and is therefore a starting point for the kick-off of the offshore sector in Iberia, especially in what concerns offshore wind where energy islands can have a very important role.

Keywords: energy island, National Policies, Offshore renewables

Introduction

For EU member states, the legislation triggering the definition of the maritime usages is the Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 [1] establishing a framework for maritime spatial planning. Focusing on the aspects of interest for the development of energy islands, article 5 states that "Member states shall consider economic, social and environmental aspects to support sustainable development (…) applying an ecosystem-based approach", and article 8 mentions among the relevant interactions of activities and uses to take into consideration "installations and infrastructures for the exploration, exploitation and extraction of oil, of gas and other energy resources, of minerals and aggregates, and for the production of energy from renewable sources,". Furthermore, the Directive 2014/89/EU in its article 11 states that "Member States bordering marine waters shall cooperate with the aim of ensuring that maritime spatial plans are coherent and coordinated across the marine region concerned. This is an issue of strategic significance at EU level and has been implemented at practical level through the European Maritime Spatial Planning Platform enabling the sharing of knowledge and experiences in MSP among Member States. Finally, it is remarked that article 9 stresses the importance of public engagement: "Member States shall establish means of public participation … by consulting the relevant stakeholders and authorities, and the public concerned, at an early stage …". Hence, this piece of European legislation sets the framework for the maritime spatial plans (MSPs) developed in recent year in the EU, and here we review the status of the Spanish and Portuguese ones, paying special attention to its coordination and potential trans-boundary cooperation.

Review

Timeline for Maritime Spatial Planning in Portugal and Spain:

In Spain, the Directive 2014/89/EU is transposed into national law in April 2017, setting the requirement for developing 5 different MSPs, one for each of the maritime region established in Law 41/2010 of protection for the maritime environment. The MSPs for the 5 maritime zones are named as POEM (Planes de Ordenación del Espacio Marítimo) in Spanish and went through public consultation in the frame of the process for strategic environmental declaration according to the procedure regulated by the Law 21/2013. The strategic environmental declaration was approved in December 2022, and the MSPs were finally approved in February 2023 [2]. It is important to note that the MSP is not a static document but will be periodically reviewed according to a set of indicators.

In Portugal this directive is transposed for the first time to the national law in July 2015 through the decree-law nº139/2015 30th July [3]. This document foresees the updating of a previous diploma (Decree-law n.º 38/2015, 12th of march [4]) that is referred to the law nr. 17/2014 10th of April [5] which establishes Bases of the National Maritime Space Planning and Management Policy. Later, the Resolution of the Council of Ministers RCM no. 203 203 A/2019, of December 30 [6], approves the National Maritime Spatial Planning Situation Plan (PSOEM) for the Continent, Madeira Island and Extended Continental Shelf subdivisions. However, facing the energy crisis, and the need to accelerate the renewables share in Portugal, the Portuguese Government found the need to update this plan. For that end, in September 2022, a working group was created to identify the suitable areas for offshore renewables installation including the different related aspects of MSP. The work developed was finalized in May 2023, and a consulting committee was created to develop the Action plan for marine renewable energy (PAER), that was in public consultation until the middle of the first trimester of 2024. Once the results are known and it is approved by the Government, it will integrate the PSOEM revision.

Characteristics of the MSPs in Spain and Portugal:

The MSPs for the 5 maritime regions in Spain have a common structure, with common general contents, and one specific part setting the usage planning for each specific region. Hence, zones of priority usage are defined for general interest activities such as environment or national defence, while additional zones are defined for high potential future usages. Based on the assessment of wind resources and the potential conflicts with other activities, several zones have defined with high potential for offshore wind energy, mainly in the North Atlantic maritime region and close to some of the Canary Islands. It is noted that these zones would require floating wind turbine technology due to the high depths.

In Portugal the maritime space situation plan (PSOEM) promotes compatibility between competing uses or activities. It aims to contribute to better and greater economic use of the marine environment and minimize the impacts of human activities on the marine environment. The situation plan presents itself as the present and potential portrait of the national maritime space. Represents and identifies the spatial and temporal distribution of existing and potential uses and activities, and natural and cultural values with strategic relevance for environmental sustainability and intergenerational solidarity. If the current preliminary plan is maintained, it is expected that there will be a clearer definition of the areas for RES development - 5 preliminary areas in the Portuguese western coast, especially dedicated to floating offshore wind.

Offshore grid integration:

It is remarked that the North Atlantic region MSP in Spain identifies one zone of high potential for offshore wind energy in the South of the Galicia Region, reaching the maritime border with Portugal. Furthermore, the Portuguese "preliminary" MSP considers a zone for offshore wind energy development in the North, very close to the Spanish one previously mentioned. This would be a perfect case for a transboundary offshore wind park, setting the path for the development of an integrated offshore network transmission infrastructure in the Northwest of the Iberian Peninsula. However, it is to note that the Offshore Network Development Plan (ONDP) considers for the 2040 horizon only independent radial connections for offshore renewable energy in Spain and Portugal [7]

Conclusions

This document presents an overview of the status of the Marine spatial Plans in Portugal and Spain. Both plans follow a similar approach on the identification of the areas for RES development taking into consideration the remaining socio-economic activities, present and future on the marine environment, as well as the preservation of the biodiversity. In this sense and taking into consideration the similarities on both countries in terms of the energy sector, the development of the Iberian MSPs constitute a great opportunity for both countries to continue and increase the collaboration in this sector.

References

[1] European Parliament and Council of the European Union (2014) Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for maritime spatial planning.

[2] Ministerio para la Transición Ecológica y el Reto Demográfico (2023) Real Decreto 150/2023, de 28 de febrero, por el que se aprueban los planes de ordenación del espacio marítimo de las cinco demarcaciones marinas españolas.

[3] https://diariodarepublica.pt/dr/detalhe/decreto-lei/139-2015-69905670 accessed on the 29yh of May 2024

[4] https://diariodarepublica.pt/dr/detalhe/decreto-lei/38-2015-66727183 accessed on the 29th May 2024

[5] https://www.pgdlisboa.pt/leis/lei_mostra_articulado.php?artigo_id=2081A0034&nid=2081&tabela=leis&pagina=1&ficha=1&nversao= accessed on the 29th of April 2024

[6] https://diariodarepublica.pt/dr/detalhe/resolucao-conselho-ministros/203-a-2019-127659203 accessed on the 29th may 2024

[7] ENTSO-E (European Network of Transmission System Operators for Electricity) (2024) TYNDP 2024. Sea-Basin ONDP Report. TEN-E Offshore Priority Corridor: Atlantic Offshore Grids.

AOWINDE: AN EU INTERREG Project for Supporting the Offshore Wind Industry of Galicia and North of Portugal

Pedro M. Fernández[1], Felix Nieto[2], Vicente Díaz[1], Rosa Ríos[1],

[1] CITENI, Ferrol Industrial Campus, University of A Coruña, Ferrol, Spain; [2] CITEEC, University of A Coruña, A Coruña, Spain

Summary. The AOWIND project, funded by the EU Interreg Programme, supports the offshore wind industry established in Galicia – North of Portugal. The University of A Coruña is responsible for identifying the industries in the Euroregion working in the sector, developing a virtual pilot for a transnational offshore park, and identifying technological developments at an early stage, such as modular floating energy islands, transferring this information to the relevant stakeholders in the Euroregion.

Keywords: offshore wind industry, Euroregion Galicia – North of Portugal, Interreg Programme, virtual pilot, technology surveillance, capacity mapping.

Introduction

The approval in 2023 of the Maritime Space Plans (MSP) for Spain has triggered the interest for offshore wind energy among energy companies and investors. Most of the high potential areas identified in the Spanish MSP for offshore wind energy are located in the North-western Atlantic area, requiring floating technology due to the high depths. Although Portugal has not approved yet its MSP, it is well-known that its Atlantic coast enjoys high winds. Henceforth, *Windfloat Atlantic*, a prototype floating wind park comprising 3 units, has been in operation since 2020 in North of Portugal region, close to Viana do Castelo.

It is evident that the deployment of offshore wind energy capacity is a must for Spain and Portugal; nevertheless, this should be linked to the development of the already existent local offshore industry. The AOWINDE Interreg project acts as a catalyser for aligning the efforts done by public administrations, industry associations, universities and research centres in Galicia and North of Portugal to support the development and modernization of the offshore wind industry in the Euroregion.

AOWINDE goals and achievements at the University of A Coruña

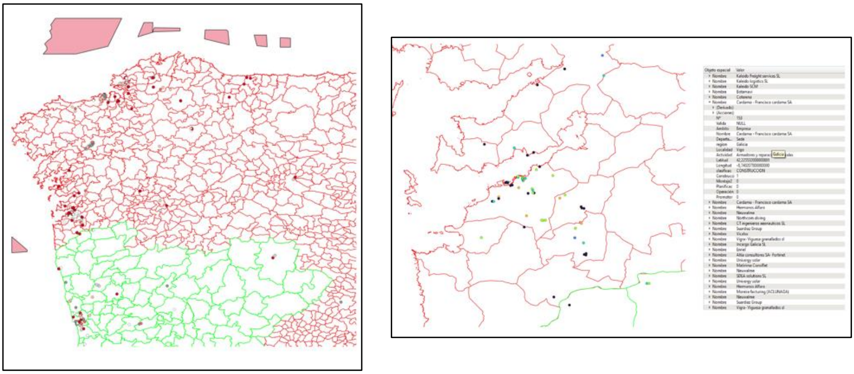
The Atlantic Offshore Wind Energy (AOWINDE) project is funded by the programme Interreg VI-A Spain – Portugal (POCTEP) 2021-2027. The consortium comprises 9 partners from the Galicia – North of Portugal region: Galician Association of Metal Industries and Associated Technologies (ASIME), Galician Regional Government, University of Vigo, University of A Coruña, Portuguese Association of Metallurgic Industries, Metal-mechanics and Similar (AIMMAP), Viana do Castelo City Council, Polytechnic Institute of Viana do Castelo, Institute for Systems and Computer Engineering, Technology and Science (INESC TEC), and the Centre for Technological Support for the Metal-mechanic Industry (CATIM).

The overarching goal of the project is to support the offshore wind industry in the region and gather relevant information that might help in industrial support policies strategic decision making at industrial level. Evidently, this is achieved by multiple actions that converge in the general objective, and the University of A Coruña is leading three main tasks:

a) Identification of the existent industrial actors within the offshore sector in the Euroregion, aiming at identifying actual capabilities, synergies, and potential gaps in the value chain. This mapping of capabilities aims at becoming a key tool in the definition of industrial policies and support actions for the sector.

b) Development of a virtual pilot model for a transnational offshore wind park. This pilot model relies on a comprehensive approach that considers not only construction costs and energy prices, but many other inputs and outputs such as the global logistical chain, and economic and labour flows associated with the construction, operation and maintenance of the virtual offshore park.

c) Technological surveillance whose purpose is to identify the state of the art in well established technologies along with potentially disruptive technological advances. The goal of this activity is to generate reports of interest for the industry in the Euroregion, so that they can plan their innovation path or improve their technology readiness for a better positioning in the global market.



a) b)

Fig. 1. Example of the Offshore Industry Map including GIS data a) General view Galicia – North of Portugal; b) South Galicia area, including companies' data.

The project comprises several other tasks that are led by other partners in the consortium such as the study of potential environmental impacts caused by the offshore industry, or the design of training programmes aligned with the needs of the industry in the Euroregion.

Conclusions

The Interreg project AOWINDE aims at providing the support that is currently required by the Galicia – North of Portugal offshore industry for its fast development, with the goal of becoming a global actor in the offshore wind sector. The University of A Coruña is leading the activities whose goals are to guide future industrial policies, understand the economical and labour flows within the Euroregion linked to offshore wind parks, and support the technological development of the industries.

Radiative Cooling: Fundamentals and Potential Applications

M. Pinar Mengüç [1]

[1] Center for Energy, Environment and Economy
Ozyegin University, Istanbul, Türkiye

Summary. Radiative Cooling can be achieved by a various techniques as discussed in the references provided below. These references are chosen from our own studies as we have been developing different approaches for radiative cooling over the years from sustainable materials, to micro-scale planar layers to nano-scale structures.

Keywords: radiative cooling, greenhouse gas emissions.

Introduction

Understanding the fundamentals of passive radiative cooling is important for thermal management related to buildings and different types of industrial systems. The principle of such cooling phenomena is based on reflecting incident radiating heat from the sun and the surroundings in a spectrally selective way (1, 2). If a surface is desired to be radiatively cooled it must have the large reflection of solar energy at the visible wavelength range and the highest radiation emission at the atmospheric window range (8-13 μm wavelength range). With such an approach, we can significantly reduce the cooling load on buildings and industrial systems, which help us to minimize the greenhouse gas emissions, as it will help decreasing the air-conditioner use in warm climates during the summer months. However, finding or designing materials capable of selectively absorbing and emitting is a challenge.

Conceptual Design

Among these studies, the use of sustainable materials for buildings were discussed in references (3-5). In these papers, we experimentally investigated the radiative cooling properties of natural materials and plants, and compared their performance with other materials. In experiments, Fourier transform infrared spectroscopy (FT-IR) experiments were conducted in order to measure the spectral absorbance and find the effective absorptivity and emissivity, and then calculating the corresponding power of cooling values of the samples. In FT-IR spectroscopy, precise measurements of the reflectivity of materials can be performed between 1 to 20 mm wavelength regime. After measuring the intensity of the reflected light, the information is processed to generate the absorption and reflection spectra. In addition, results from a recent study (6) demonstrate that the some special sand particles from islands can be used for radiative cooling purposes. Due to their abundance, low cost, and excellent thermal properties, they have potential for extensive use in building within islands.

It is also possible to construct devices for radiative cooling. A careful selection of layers would form a composite structure which can be used for radiative cooling, as discussed in (7-10). Also, nano-structured systems can be used innovative approaches as outlined in (11-13).

Conclusions

We believe that the concept of radiative cooling by any one of these techniques may contribute to the energy eco-system of islands to minimize the cooling cost, and to maximize the efficient operation of the islands energy systems in line with the main philosophy of harvesting maximum energy in natural or man-made islands.

References

[1] J. R. Howell, M. Pinar Mengüç, K. Daun, and R. Siegel, "Thermal Radiation Heat Transfer: Seventh Edition, CRC Press, 2021.

[2] M. Pinar Mengüç and M. Francoeur, "*Light, Plasmonics and Particles*," Elsevier, May 2023.

[3] R. Family and M. P. Mengüç, "Materials for Radiative Cooling: A Review," *Procedia Environ Sci*, vol. 38, pp. 752–759, 2017, doi: 10.1016/j.proenv.2017.03.158.

[4] Roxana Family, M. Pinar Mengüç 'Analysis of Sustainable Materials for Radiative Cooling Potential in Buildings,' *Sustainability*, Vol. 10(9), p. 3049, 2018.

[5] Roxana Family, M. Pinar Mengüç, Serdar Çelik 'Coupled Heat Transfer Analysis for Concrete and Green Roofs to Evaluate Radiative Cooling for Buildings,' *Springer Heat and Mass Transfer*, (Wärme- und Stoffübertragung), 2020 (6), HAMT-D-19-00610R2.

[6] Ahmet Hocaoğlu and M. P. Mengüç, "Radiative Cooling by Sand," (in preperation).

[7] MA Keçebas, MP Menguc, A Kosar, K Sendur, 'Passive radiative cooling design with broadband optical thin-film filters,' *Journal of Quantitative Spectroscopy and Radiative Transfer*, RAD'2016 SI, Volume: 198, Pages: 179-186, 2017.

[8] M. A. Kecebaş, M.P. Mengüç, A. Koşar, K. Şendur, "Spectrally Selective Filter Design for Passive Radiative Cooling," *Journal of Optical Society of America – B*, Vol. 37(4), pp. 1173-1182, 2020, DOI: 10.1364/JOSAB.384181.

[9] Niloufar Pirouzfam, M.P. Mengüç, K. Şendur, "Colorization of Passive Radiative Cooling Coatings using Plasmonic Effects", *Solar Energy Materials and Solar Cells*, 253, 112225, 2023.

[10] Ali Mohammad Kecebaş, M. Pinar Mengüç, Kürşat Şendur, "On the Spectral Emissivity Profiles for Radiative Cooling", *ACS Applied Optical Materials*, 2023 (10.1021/acsaom.3c00092).

[11] A. Didari, M. P. Mengüç, "Biologically Inspired Designer Nanostructures for Radiative Cooling Applications", NanoRad 2017, The Third International Symposium on Nano-Micro Scale Radiation Transfer, KAIST, South Korea, July 26-28, 2017.

[12] Azadeh Didari, M. Pinar Mengüç, 'Biomimicry designs for passive optical solutions for nanoscale radiative cooling applications,' in NANOSTRUCTURED THIN FILMS XI, SPIE, Edited by A. Lakhtakia and TG Mackay, Vol. 10731, Article No: 107310C, DOI: 10.1117/12.2320504, 2018

[13] A. Didari and M. P. Mengüç, "A biomimicry design for nanoscale radiative cooling applications inspired by Morpho didius butterfly" *Nature Scientific Reports*, Vol. 8, p. 16891, 2018.

Accuracy Assessment of Wind Velocities Over the Sea Based on Geospatial Data

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Summary. Wind velocity magnitudes obtained from satellite data are compared with anemometric data from a mast, presenting a reasonable agreement.

Keywords: energy island, satellite data, anemometer, wind speed, SNAP

Introduction

In March 2024, Antonio Álvarez, stayed for two weeks at LNEG under the supervision of Teresa Simoes conducting a Short-Term Scientific Mission (STSM) sponsored by MODENERLANDS to gain expertise in the use of satellite data for assessing wind speeds over the sea. In this abstract, the outcomes of the STSM are presented, including further collaboration with Jonas Snæbjörnsson.

Conceptual Design

The fundamental outcome of the STSM has been the development of a piece of software capable of automatically produce the instantaneous wind velocity maps over the sea for a selected region. The velocity magnitude is obtained from the CMOD5 algorithm [1] applied over regions of 2x2km2. This is a tedious task, notably when a relatively large number of satellite photographs are considered. The software developed addresses the following tasks: application of the orbit file, thermal noise removal, removal of ground range detected (GRD) border noise (due to the interface between land and sea), application of a speckle filter, object discrimination and land detection, using algorithms integrated on Sentinel Application Platform (SNAP) and shoreline coordinates from available databases, wind field estimation, and terrain correction.

There are several sources of uncertainty in the assessment of wind velocity magnitude based on the postprocessing of satellite photographs, such as the thermal noise associated with radar antennas, speckle noise, and level of cloud coverage. Another issue to consider is the proximity to the coast, as the processes of reflection and diffraction of the waves impact the linkage between waves and wind. One of the main difficulties in the validation of satellite-based wind speeds is the scarceness of observed data over the sea, as the installation of meteorological masts or floating LIDARS in the sea is complex and expensive [2]. The goal of this work is to assess the level of accuracy that could be offered by satellite data at relatively close distances from the coast. For validation, data measured at the Hvassahraun weather station will be used. The meteorological mast is located on a lava field in Reykjanes (Iceland) close to the sea, and it is fitted with 3-D sonic anemometers (Thies-3D) in 2 m, 10 m, 20 m, and 30 m heights, plus a Young-5106 propellor anemometer at 10 m height. In figure 1, the velocity magnitude field at 10m height obtained from a satellite image taken on the 7th of July of 2022 at 7:58:59 is provided. In figure 2, the wind velocity record at 30 m height at the meteorological mast is reported. The 10-minute average wind velocities obtained from these different sources are reported in Table 1.

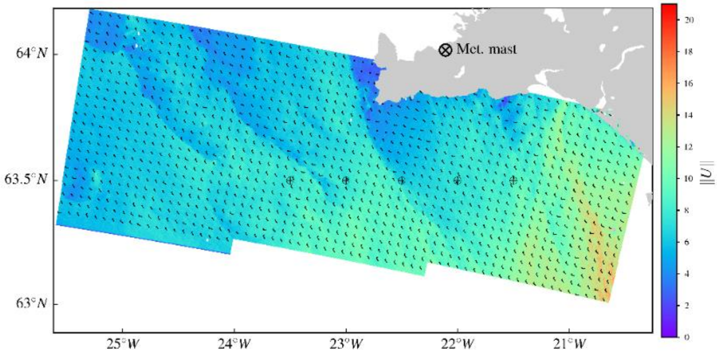

Fig. 1. Instantaneous wind magnitude field at 10m height. Crosses represent where the mean wind velocity is calculated.

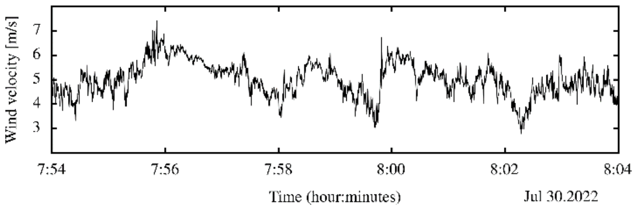

Fig. 2. Time-history of instantaneous wind velocity recorded at 30 m height.

Table 1. 10-minute wind magnitude in m/s at different locations.

	Mast	23.5W,63.5N	23.0W,63.5N	22.5W,63.5N	22.0W,63.5N	21.5W,63.5N
$\overline{\|U\|}_{10'}$	5.0	7.58	7.13	6.39	7.31	8.54

Conclusions

A single case comparison with anemometric data recorded at the Hvassahraun meteorological mast shows an over-prediction of the mean wind velocity, although it should be noted that the peak wind velocity at 30 m height in the mast, is 7.4 m/s. It must be noted that no correction has been applied for the different location of the measure points; therefore, further improvement in the prediction of the mean velocity is expected after applying such techniques. Further cases are being studied.

References

[1] Hersbach, Hans. CMOD5-An improved geophysical model function for ERS C-band scatterometry. ECMWF, 2003.

[2] Spence R. et al., Determining the Real Measurement Uncertainty of Floating LiDAR. PO.054. Wind Europe 2024.

Energy assessment of potential location for Energy Island in the Adriatic Sea

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Summary. This study identified a suitable location for Energy Island in the Montenegrin part of the Adriatic Sea, considering solar and wind energy potential, marine traffic, protected areas, bathymetry, and visibility impact. The potential energy generation of Energy Island was estimated.

Keywords: Energy Island, energy potential, solar energy, wind energy

Introduction

Energy Island helps achieve SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation and Infrastructure), and SDG 13 (Climate Action). To identify the region with the highest solar and wind energy potential (Fig. 1) the Global Solar Atlas [1] and New European Wind Atlas [2] were used. Montenegro is characterized by high irradiation around 1600 kWh/m^2, and solar duration of over 2000 h per year. The wind speed is from 5 to 8 m/s, while power density is up to 400 W/m^2. Considering energy potential and exclusion criteria (sea depth, ports and vessel density, military zones, protected areas, etc.) location (41.8 lat, 19.09 long) was selected for the Energy Island (Fig. 1).

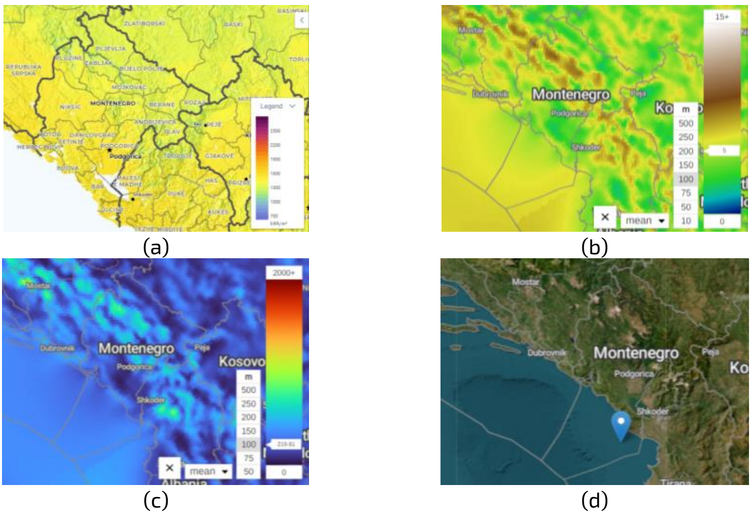
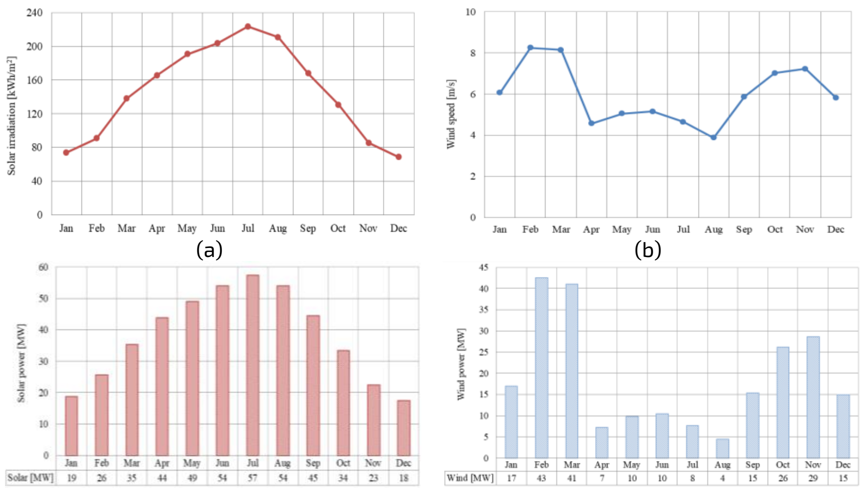


Fig.1. a) Global horizontal irradiation [1], b) Wind speed at 100 m above the sea level, c) Power density at 100 m above the sea level, d) Location for offshore Energy Island

Conceptual Design

The Energy Island consists of solar panels (model Sunmodule Plus SW 300 [3]) with a total area of 1.4 km^2 and wind turbines (Siemens Gamesa Renewable Energy SG 14-222 DD [4]). The Energy Island consists of eight wind turbines arranged in an octagonal shape while the solar panels are placed in the center. Considering the number of wind turbines and the distance between turbines (10 diameters) Energy Island occupies 28.2 km^2. The monthly mean solar irradiation for the selected location obtained from the PVGIS tool [5] for the onshore site closest to the selected location is from 68 to 223 kWh/m^2 (Fig. 2). For the selected location, the monthly mean wind speed at 100 m above sea level obtained from the New European Wind Atlas [2] is from 3.9 to 8.3 m/s (Fig. 2). The mean monthly energy production from solar panels is from 18 to 57 MW (Fig. 2), while mean monthly energy production from wind turbines is from 4 to 43 MW. The total mean monthly energy production of Energy Island is from 33 to 77 MW (Fig. 2). 67% of energy production is contributed from solar and 33% from wind resources.



(c) (d)

Fig. 2. a) Mean monthly solar irradiation, b) Mean monthly wind speed, c) Energy production from solar panels, d) Energy production from wind turbines

Conclusions

The deployment of offshore Energy Island for the exploitation of wind and solar energy in the Montenegrin part of the Adriatic Sea could produce 497 GWh of energy annually. Three Energy Islands placed in the selected location can eliminate coal from the Montenegrin energy mix. The findings of this research could be useful to policymakers for the creation of a clean energy transition plan in Montenegro. This research was based on open-source tools to enable the applicability of methodology selection of for suitable locations to support future offshore Energy Island projects worldwide.

References

[1] Global Solar Atlas, https://globalsolaratlas.info/map
[2] New European Wind Atlas, https://map.neweuropeanwindatlas.eu
[3] Sunmodule Plus SW 300, https://www.altestore.com
[4] Siemens Gamesa, https://www.siemensgamesa.com
[5] PVGIS, European Communities, 2001-2021, https://re.jrc.ec.europa.eu/pvg_tools/en

An Unsupervised Damage Detection Method for an Operating Wind Turbine Blade Under Environmental and Operational Conditions

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Summary. This paper addresses the challenge of assessing the long-term health and integrity of civil structures through continuous dynamic monitoring, complicated by high data dimensionality, data sparsity, and variations in environmental and operational conditions (EOVs). To tackle these issues, an unsupervised method is proposed for reducing data dimensionality to detect damage in an operational V27 wind turbine blade (WTB) under varying EOVs. The study utilizes data from accelerometers installed on one of the blades at the Technical University of Denmark (DTU). Initially, a variety of features are extracted from the time-series data, including time-domain, frequency-domain, and time-frequency domain features. Principal Component Analysis (PCA) is then applied to reduce data dimensionality, and the Mahalanobis squared distance is used to evaluate different sensors, ultimately identifying a single sensor for effective damage detection. The performance of this reduced feature set is validated using unsupervised learning methods, specifically the Isolation Forest (IF) and Autoencoder. The findings contribute to the development of effective structural health monitoring methods for wind turbine blades, addressing challenges posed by environmental and operational variability.

Keywords: Onshore Wind turbines, Health monitoring, Unsupervised learning, Environmental and operational variables.

Introduction

Wind-generated electricity is now one of the most cost-effective green energy sources. However, as WTBs increase in size to meet growing energy demands, they face environmental challenges like dynamic loads and precipitation, which can cause defects such as cracks and delamination [1]. Detecting and addressing these defects promptly is crucial for maintaining operational efficiency and preventing major failures. Structural Health Monitoring (SHM) methods based on vibration are effective because they detect damage by identifying changes in vibration responses using Damage Sensitive Features [2]. To manage the high dimensionality of raw acceleration data, SHM techniques employ Feature Extraction (FE) to convert this data into a format suitable for Machine Learning algorithms. This process involves analyzing data in time, frequency, and time-frequency domains to extract relevant information. However, these features may also reflect non-damage-related changes caused by EOVs such as temperature, wind, and rotational speed, complicating damage detection [3]. Thus, distinguishing DSFs from undamaged and damaged structures is essential, using strategies categorized into supervised and unsupervised learning. Supervised methods need labeled data, which can be limited, while unsupervised methods typically use data from healthy structures [4].

Principal component analysis (PCA) is a commonly used unsupervised approach for mitigating EOVs, reducing dimensionality for damage detection. PCA projects feature vectors onto a sub-space where minor principal components indicate damage, assuming major PCs are influenced by EOVs [5]. However, linear PCA might not handle non-linear EOV influences well. To improve differentiation between damaged and healthy conditions, kernel-based PCA, a non-linear variant, has been developed. Selecting the best PCs remains challenging, so anomaly detection methods like Isolation Forest (IF) and autoencoder are used to validate PCA's effectiveness [6]. These methods are non-parametric and can create flexible, non-linear boundaries efficiently. This paper proposes an unsupervised method to reduce dimensional space and detect damage in an operational V27 WTB under varying EOV conditions, using data from 12 accelerometers on a turbine blade at the DTU. Various features are extracted, PCA is applied, and the performance of the optimal feature set is validated using IF and autoencoder, showing reliability and robustness in recognizing damage.

Conceptual Design

The study utilized experimental data from a monitoring campaign on a 225 kW Vestas V27 wind turbine near Roskilde, Denmark. Equipped with 12 accelerometers and an electro-mechanical actuator, one blade underwent artificial damage by adjusting trailing edge openings. This led to five health states: undamaged, 15 cm, 30 cm, and 45 cm openings, and a repaired state depicted in Fig. 1.

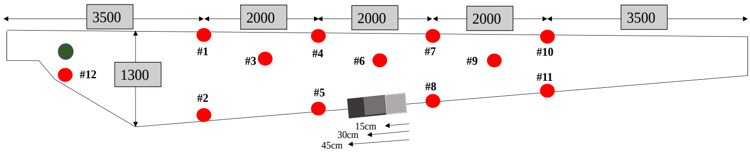

Fig. 1. The schematic diagram of the WT blade (not to scale) shows the location of the actuator (green circle), sensors (red circles), and damage locations (grey tone rectangles). The main spar is indicated by dashed lines.

Conclusions

This study proposes an unsupervised method using PCA for dimensional reduction to detect damages in WTBs under varying environmental and operational conditions, validated with IF and Autoencoder. By addressing high-dimensional data challenges and EOVs, this research advances anomaly detection techniques for WTBs only with one sensor. However, optimizing principal components to balance damage detection and EOV mitigation requires further investigation.

References

[1] M. McGugan and L. Mishnaevsky Jr, "Damage mechanism based approach to the structural health monitoring of wind turbine blades," *Coatings*, vol. 10, no. 12, p. 1223, 2020.

[2] R. Lotfi, B. Kargar, A. Gharehbaghi, M. Afshar, M. S. Rajabi, and N. Mardani, "A data-driven robust optimization for multi-objective renewable energy location by considering risk," *Environment, Development and Sustainability*, pp. 1-22, 2022.

[3] D. Tcherniak and L. L. Mølgaard, "Active vibration-based structural health monitoring system for wind turbine blade: Demonstration on an operating Vestas V27 wind turbine," *Structural Health Monitoring*, vol. 16, no. 5, pp. 536-550, 2017.

[4] H. Sarmadi, A. Entezami, and F. Magalhães, "Unsupervised data normalization for continuous dynamic monitoring by an innovative hybrid feature weighting-

selection algorithm and natural nearest neighbor searching," *Structural Health Monitoring*, p. 14759217231166116, 2023.

[5] A.-M. Yan, G. Kerschen, P. De Boe, and J.-C. Golinval, "Structural damage diagnosis under varying environmental conditions—Part I: A linear analysis," *Mechanical Systems and Signal Processing*, vol. 19, no. 4, pp. 847-864, 2005.

[6] B. Gunes, "One-class machine learning approach for localized damage detection," *Journal of Civil Structural Health Monitoring*, vol. 12, no. 5, pp. 1115-1131, 2022.

A Zero-Carbon Offshore Island Concept Integrated with Different Renewable Energy Sources in Western Black Sea of Türkiye's Coastal

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Summary. There is a lot of discussion about offshore energy hubs, sometimes known as energy islands, and how important they will be in the process of decarbonizing the energy industry. Leading the way from industry, the idea of establishing Offshore Energy Island (OEI) to capitalize on offshore wind potential in Northern Europe has gained traction in national and European political discourse. With those motivations, this research work provides on optimization analysis of different renewable energy sources on desired OEI to compensate energy demand and capture the CO_2 at Western Black Sea Offshore Region of Türkiye. HOMER-Pro software program has been utilized so as to optimize different renewable energy sources like wind and wave energies on desired OEI. Additionally, a comprehensive hydrogen production analysis from produced electricity has been carried out.

Keywords: Offshore energy island, Renewable energy optimization, Hydrogen production, HOMER

Introduction

Comparing integrated offshore wave–wind farms to traditional (onshore) wind farms reveals a variety of benefits: (*i*) the decrease, if not outright disappearance, of the noise and visual impact due to the shoreline's distance, (*ii*) generally speaking, higher wind speeds over the sea compared to over land, (*iii*) reduced turbulence, which increases the windmills' efficiency. In the literature, there are some cases integrations of wind and wave power for several purposes [1-5]. Integrated grid designs are found to be superior than farm-specific connections after evaluating a variety of hypothetical offshore hub designs and their distributional impact on linked countries [6,7]. The objective of this study is to assess an OEI with various renewable energy sources at Western Black Sea Offshore Region of Türkiye in order to compensate the energy demand. Furthermore, a thorough examination of hydrogen synthesis from generated power has been performed.

Conceptual Design

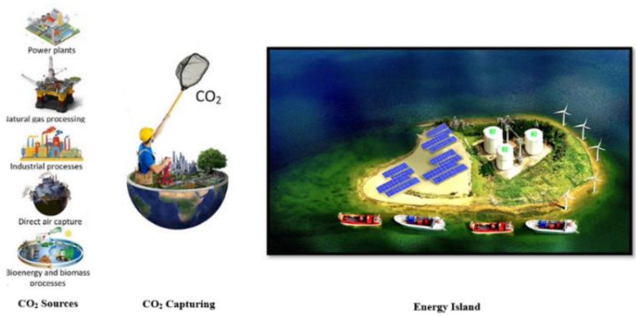

Fig. 1. Demonstration of an energy island concept

Conclusions

The maximum fields of wind, swell, and mixed wave power during a 40-year period (from 1979 to 2018) are displayed in Fig. 2. The southwestern area continues to lead with wind wave powers of about 1000 kW/m. Moreover, a number of high-power locations are identified, including the area next to Crimea's southern coast, the northeastern portion of the sea between Novorossiysk and the Kerch Strait, and the southeast portion of the sea offshore Turkey. There are two distinct locations of highest wave energy in the spatial distribution of maximum swell waves, and these are the northeastern and southwest coasts. Swell waves in these areas have a 500 kW/m maximum power.

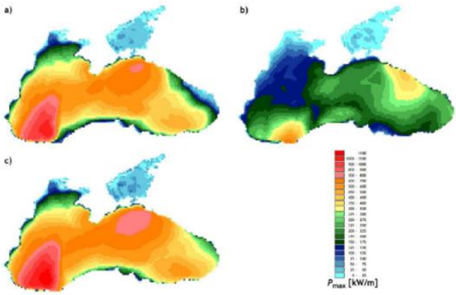

Fig. 2. Wind sea, a) the maximum power, b) swell, c) mixed waves in 1979-2018 [8]

The seasonal distribution of the U100 parameter is shown in Fig. 3, with winter occurring from December to January-February; spring occurring from March to April-May; summer occurring from June to July-August; and fall occurring from September to October-November. A high of 9.16 m/s is anticipated in the vicinity of the Azov Sea during winter, as opposed to a potential value of 8.81 m/s in the western Black Sea. The numbers drop to 7.88 m/s (spring), 6.61 m/s (summer), and 8.19 m/s (autumn) for the Azov Sea and 7.42, 6.33, and 7.53 m/s (black sea), respectively, in less active seasons.

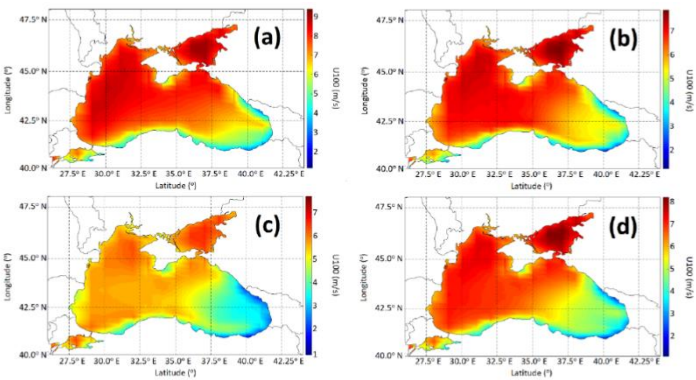

Fig. 3. Distribution of seasonal average values based upon the ERA5 dataset for the time interval 2002–2021: (a) winter; (b) spring; (c) summer; (d) autumn [9]

The findings of HOMER simulation have been demonstrated in Fig. 4. It is clearly pointed out the values of monthly average wind speeds are close to each other. However, the values obtained from April, May and June are less than those occurred other months. The maximum average wind speed has been observed in December with the value of 5.52 m/s. It has been also pointed out that this result is well matched with the findings ensured by Ref. [9].

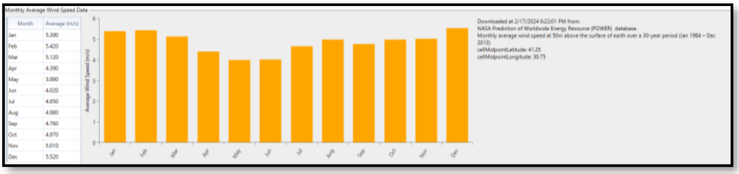

Fig. 4. Monthly average wind speed from HOMER simulation

In the light of findings mentioned above, the best location of desired OEI has been decided at Western Black Sea Offshore Region of Türkiye. It has also been decided that wave and wind renewable energy sources will be installed. It will be decided which technologies will be employed in terms of better optimization. Therefore, this analysis will be tackled as a continuation of this line of research.

References

[1] Babarit, A., Ahmed, H. B., Clément, A. H., Debusschere, V., Duclos, G., Multon, B., Robin, G. Simulation of electricity supply of an Atlantic Island by offshore wind turbines and wave energy converters associated with a medium scale local energy storage. Renewable Energy, 31(2), 153-160, 2006. DOI: 10.1016/j.renene.2005.08.014

[2] Bekçi, E., Koca, K., Bashir, M. F. Design analysis of a wave energy converter for hydrogen generation near shoreline of Black Sea. Process Safety and Environmental Protection, 186, 1-9, 2024. DOI: 10.1016/j.psep.2024.03.080

[3] Fusco, F., Nolan, G., Ringwood, J. V. Variability reduction through optimal combination of wind/wave resources–An Irish case study. Energy, 35(1), 314-325, 2010. DOI: 10.1016/j.energy.2009.09.023

[4] Iglesias, G., Carballo, R. Wave resource in El Hierro—An island towards energy self-sufficiency. Renewable Energy, 36(2), 689-698, 2011. DOI: 10.1016/j.renene.2010.08.021.

[5] Henfridsson, U., Neimane, V., Strand, K., Kapper, R., Bernhoff, H., Danielsson, O., Bergman, K. Wave energy potential in the Baltic Sea and the Danish part of the North Sea, with reflections on the Skagerrak. Renewable energy, 32(12), 2069-2084, 2007. DOI: 10.1016/j.renene.2006.10.006.

[6] Konstantelos, I., Pudjianto, D., Strbac, G., De Decker, J., Joseph, P., Flament, A., Veum, K. Integrated North Sea grids: The costs, the benefits and their distribution between countries. Energy Policy, 101, 28-41, 2017. DOI: 10.1016/j.enpol.2016.11.024

[7] Houghton, T., Bell, K. R. W., Doquet, M. Offshore transmission for wind: Comparing the economic benefits of different offshore network configurations. Renewable Energy, 94, 268-279, 2016. DOI: 10.1016/j.renene.2016.03.038

[8] Divinsky, B. V., Kosyan, R. D. Climatic trends in the fluctuations of wind waves power in the Black Sea. Estuarine, Coastal and Shelf Science, 235, 106577, 2020. DOI: 10.1016/j.ecss.2019.106577

[9] Onea, F., Manolache, A. I., Ganea, D. Assessment of the black sea high-altitude wind energy. Journal of marine science and engineering, 10(10), 1463., 2022. DOI: 10.3390/jmse10101463

Conceptual Design of FPVS For Large Water Bodies as a Contribution to the Energy Production

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Summary. Floating PV systems (FPVS) are widely used worldwide lately on lakes, hydropower reservoirs, industrial ponds, quarry, and mine lakes or offshore. They contribute to the minimized occupation of useful land, protect from algal blooming, decarbonization of electrical production sector and water evaporation decrease. This study suggests the conceptual design of FPVS on natural and artificial lakes in Serbia and investigates the potential energy production for several locations, with continental climate. The results of simulations showed that the annual energy output varies from about 1000 kWh to up to 1200 kWh with fixed angle FPVS, and from about 1300 kWh to 1600 kWh in case of tracking FPVS.

Keywords: clean energy production, FPVS, large water bodies, decarbonization

Introduction

The idea of implementation of FPVS to existing electricity grids on large water bodies such as natural and artificial lakes, contributes to the clean electricity production and decarbonization goals. Studies showed that FPVS can be a great contributor to other renewable energy sources for electricity production. Cazzaniga et al. investigated the contribution of FPVS to the hydropower electricity production plant and concluded that production can be 65% higher if the 10% of the basin is covered additionally with the FPVS [1]. This combined electricity production contributes to the compensation of stochastic nature of solar energy and minimised necessity for energy storage systems. On the other hand, FPVS can be beneficial for the areas without the electrical grid, if they are integrated with the battery storage system [2].

Conceptual Design

Selecting an optimal location for the FPVS is of a great importance, since the electricity production directly depend on the geographic and site characteristics of the selected area. This study investigates the potential of electricity production at the six largest lakes in the Republic of Serbia using PVGIS software. The locations of lakes are depicted with a concern to the possibility of connection to the existing electricity grid. One location is depicted in eastern part of the Republic of Serbia, one on the south-east, and four of the lakes are located on the western side of the country. All the locations have the possibility of application to the existing grid. The Republic of Serbia has a very adequate climate for the usage of solar systems, with an average global solar radiation energy about 1400 kWh/m2. The proposed model of FPVS consists of: floats, mooring system, lighting protection system, combiner box, PV modules, inverter, transformer, connectors to the grid. Using the PVGIS software, various simulations were done. The results for annual energy outputs are obtained for fixed and tracking FPVS. The results showed that the annual energy output varies from about 1000 kWh to up to 1200 kWh with fixed angle FPVS, and from about 1300 kWh to 1600 kWh in case of tracking FPVS [3].

Conclusions

The best location concerning electricity production potential and availability of existing grid is the location of Vlasina lake, but on the other hand, its rare nature with a variety of endemic species and the fact that it is under the highest level of nature protection makes this location less attractive for FPVS. Other locations can also offer reasonable electricity production, and the second best is Djerdap lake location, while the lowest energy production can be obtained for Perućac Lake, which is located on the west side of the country. It is very important to mention that all the aspect of location selection, concerning the protected natural areas must be considered during the process of the appropriate location selection for the FPVS. With such approach, FPVS offers a significant contribution to the clean electricity production and the decarbonization of energy sector.

References

[1] R. Cazzaniga, M. Cicu, M. Rosa-Clot, P. Rosa-Clot, G.M. Tina, C. Ventura, Floating photovoltaic plants: Performance analysis and design solutions, Renewable and Sustainable Energy Reviews 81 (2018) 1730–1741. https://doi.org/10.1016/j.rser.2017.05.269.
[2] C.P. Nazir, Coastal power plant: A hybrid solar-hydro renewable energy technology, Clean Energy 2 (2018) 102–111. https://doi.org/10.1093/ce/zky010.
[3] T. Bajc, D. Kostadinović, Potential of usage of the floating photovoltaic systems on natural and artificial lakes in the Republic of Serbia, J Clean Prod 422 (2023). https://doi.org/10.1016/j.jclepro.2023.138598.

Conceptual Design for Modular Energy Island in Sustainable Energy Production in Crete

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Summary. In order to propose an offshore floating energy island that could satisfy the energy demand of Crete using only renewable power sources. To achieve this goal several sub-tasks had to be completed, such as i) the positioning of the energy island in Crete's waters, based on the available wind, solar and wave sources' potential, environmental and social aspects; ii) the determination of the current electricity demand and iii) the conceptual design of the floating structure along with a selection of technologies that allows to harvest renewable energy sources. All of these would bring Crete a step closer to becoming energy independent and sustainable. A rough financial estimate of the project was made, and potential future challenges were identified. Finally, it was concluded that Crete has great potential to host an innovative project like this and that its re-sources are so rich that storage and export of a potential energy surplus should be thoroughly examined. As a result, a conceptual proposal for Crete's first floating energy island is presented here.

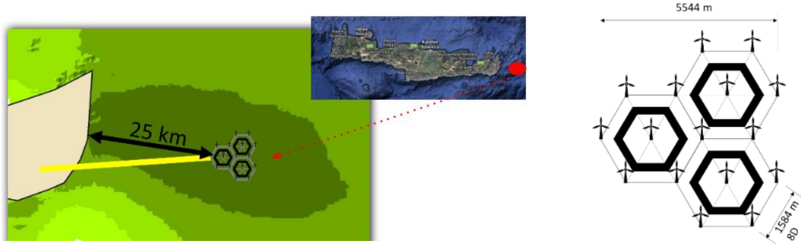
Keywords: sustainable energy island, conceptual design, modular systems, Crete

Introduction

The Region of Crete recently joined the "Clean Energy for EU Islands Initiative" which aims for islands to produce sustainable and low-cost energy. The project intends to help islands reduce energy costs and increase production using renewable sources, lower greenhouse gas emissions and create new jobs and opportunities for the local communities, amongst many other objectives [15]. The environmental problems associated with traditional energy production methods have pushed research and industry to think of innovative sustainable solutions that sup-ply the required energy demand. On top of this, islands have usually suffered from high energy prices due to their dependence on imported gas and oil from the mainland. Thus, the idea of self-sufficient islands in terms of energy has been present for over a couple of decades now, especially because of the rich resources many islands hold [2-4].

Conceptual Design

The conceptual design of the island was separated into three key objectives i) the positioning of the energy island in Crete's waters, based on the available wind, so-lar and wave sources' potential, environmental and social aspects; ii) the determination of the current electricity demand and iii) the conceptual design of the floating structure along with a selection of technologies that allows to harvest renewable energy sources. Since a balance between the objectives is crucial for this, the process was iterative, and the shape and technologies of the proposal were modified several times until the energy demand was satisfactorily met. In the following section, the most suitable location, the energy demand calculated, and the conceptual design is presented. The design of the floating energy island was an iterative process. But not only in terms of choosing the best location but also balancing the output required from all three different energy sources considered. In this balance, it was considered the level of difficulty that each technology represents to the construction process and the financial costs associated. Since wave energy was not a significant factor in choosing the location due to its limited potential around Crete, the main two factors to balance were wind and solar potential.



(a) (b)

Fig. 1. Energy Island; a) Selected location, b) Conceptual design

Conclusions

The best location for the proposed floating energy island is at the east of Crete where there is high energy potential from wind and solar sources and no interference with existing human activities. This location is also close to ports and an electrical substation that can be used for the installation, operation, and maintenance of the island. A hexagonal shape was defined for the modular platforms inspired by the structure of a honeycomb, it has been proved by previous research that this shape is highly convenient in terms of modularity. Each hexagon will have the capacity to support up to 7 wind turbines, one on each node plus one in the centre. In addition, 20% of the area in the floating platform could be used to allocate solar panels and the perimeter to provide the infrastructure for wave energy converters. Hybrid integration may be a crucial point for the success of renewable energy systems. The use of combined sustainable sources along with storage may provide the required reliability to ensure the constant supply of the system. Floating energy islands may also provide other benefits to their communities by including social projects such as the proposed desalinisation system incorporated in the wave energy converters. Ensuring constant energy production, securing the storage, and detailing the structure and construction process may be some of the biggest challenges that a project of this scale may encounter.

References

[1] "Clean energy for EU islands." https://energy.ec.europa.eu/topics/markets-and-consumers/clean-energy-eu-islands_en (ac-cessed Nov. 09, 2022).

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

[3] Y. Kuang 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.

[4] K. Sperling, "How does a pioneer community energy project succeed in practice? The case of the Samsø Renewable Energy Island," Renewable and Sustainable Energy Reviews, vol. 71. Elsevier Ltd, pp. 884–897, May 01, 2017. doi: 10.1016/j.rser.2016.12.116.

A Probabilistic Approach for the Levelized Cost of Energy of Floating Offshore Wind Farms

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Summary. This paper aims to analyze the levelized cost of energy (LCOE) of floating offshore wind farms from a probabilistic point of view. Understanding and addressing the uncertainty associated with the main parameters that influence the wind energy generated by a wind farm during its lifetime is crucial for the economic evaluation of offshore wind energy in the broader energy landscape. The methodology for probabilistic assessment of LCOE is introduced, and the uncertainty in input parameters are discussed. In a base case study, an assumed Floating Offshore Wind Farm (FOWT) consisting of 250 5-MW wind turbines is considered. The use of bias and randomness in key random variables is discussed and studied in detail. Results indicate that LCOE estimates of 15 EURc/KWh for offshore wind turbines are achievable with reasonable confidence, while estimates of 5 EURc/KWh require careful consideration of uncertainty in the wind farm's parameters. The feasibility analysis showed that financial parameters are more influenced by wind characteristics and efficient use of wind turbines than by the cost of the wind farm. This paper provides general guidance on how to carry out early-stage economic analysis of FOWFs.

Keywords: Levelized Cost of Energy (LCOE), Floating Offshore Wind Turbine (FOWT), Floating Offshore Wind Farm (FOWF), Probabilistic assessment, design lifetime.

A Mobile IOT Controlled Photovoltaic Dual Axis PV Tracker with Battery Storage

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Summary. Solar trackers have been used to increase the annual yield of solar collectors photovoltaic systems, by tilting the surface are of the panels in single or dual axis towards the sun. With dual axis tracking, the annual solar yield can be improved by more than 30%. Typical solar trackers include solar radiation sensors or estimated solar tilting based on GPS. Solar tracking systems, are typically fixed installations, where the GPS location can be determined only once, to define the tracking. Furthermore, some trackers include wind velocity meters, to reposition the tracker in the event of high wind velocities. With the development of the internet of things (IoT), solar tracking can be performed without typical sensors. In this paper, a model for developing a mobile solar tracking system based on GPS data and IoT data is presented.

Keywords: IoT, dual axis solar tracking, mobile photovoltaic

Introduction

Existing solar trackers for improving solar yield incorporate automated tilting combined with use of a GPS and solar records to anticipate optimum orientation. Global solar tracker deployment was 14.5 gigawatts in 2017 with an annual growth of 32%. Reductions in PV panel costs, combined with the added cost of tracking, has limited the technology to niche applications. The aim of the approach presented in this paper is to present a low cost method for mobile solar tracking systems, while also reducing the cost of the system due to utilization of less sensors. Design and implementation of a model based predictive control for two axis solar tracker is presented in literature [1]. Performance of photovoltaic-thermoelectric panels with different solar tracking systems is presented in [2]. An Algorithm for solar tracking with different control strategies was analysed in [3], but the analysis is based on simulink and solid works simulation. Finally, IoT base solar tracking is presented in [4], where the tracking is based on the use of the microcontroller, but the monitoring is done using IoT. In this paper, research and development of a mobile solar tracker with IoT control and monitoring is described.

Conceptual Design

Typical solar tracking solutions depend on sensor data, such as solar irradiation sensors, wind velocity sensors and similar. The main research question was whether it was possible to develop a mobile solar tracker using IoT and a single GPS sensor. The IoT technologies enable retrieving weather data, location data, sun position data from an online database, which leaves the opportunity to design a solar tracking system based on a single GPS sensor with the aid of IoT technologies. The developed solution represents a mobile solution, where the location, slope and orientation of the device depends on the user behaviour. To limit the human factor, the developed system can determine its location, slope and azimuth, before start, and determine optimal position with respect to physical terrain constraints and solar tracking.

Solar trackers include a high surface are of PV panels, mounted on a construction which enables movement and solar tracking. The surface area of the panels, can therefore impose significant stress on the construction of the system. Instead of use of anemometer, the developed solution is also based on online database wind speed data to tackle this problem. The system is a plug-and-play solution, making it easy to use by non-technical personnel. Figure 1 provides an illustration of the foldable mobile dual axis solar tracker with battery storage IoT SOLTRACK. The IoT-based solar tracking module is comprised of three controllers with the following functions:

- Raspberry Pi (hereinafter referred to as RPi) – retrieves the location of the tracker via GPS via serial communication, communicates with the inverter via MODBUS RTU, communicates with a server via a 4G modem (shares data on location, tracker orientation, battery status, PV generation etc.) and calculates the optimal the orientation of the panels towards the sun, which it sends to the Arduino Mega.
- Arduino Nano (hereinafter AN) - communicates with the IMU sensor from which it receives information about the initial orientation of the tracker (before putting the system into use), if necessary it sends this information to the Arduino Mega.
- Arduino Mega (hereinafter AM) –controls the opening/closing of the side panels and the orientation of the panels according to the information received from the other two controllers.

The controllers connect to the DC battery through a normally open switch, initiating energy supply upon switch closure. Activation of the three controllers occurs simultaneously by closing the switch adjacent to the battery. While the positioning of the mobile PV generator can be arbitrary, it is recommended that is aligns as much as possible with a North-South orientation, in order to maximize solar energy yield, thus compensating for the limited length of the cabling. Before activating autonomous operation of the solar tracking system, manual control of elevation and azimuth motors is enabled, providing a remedy for system errors. In the event of an error causing panel rotation and system shutdown, manual control allows panels to return to the initial/zero position.

Following the activation of the system by pressing of activation key, the Raspberry Pi (RPi) calculates optimal panel positions and transmits the data to the Arduino Mega (AM) via SPI in three packets, each comprising two bytes (MSB and LSB) for azimuth, elevation, and a control code. Successful matching of these packets, indicating no communication errors, prompts storage of information by the AM for subsequent consideration in panel orientation.,The AM initiates photovoltaic system movement only upon pressing a system activation key. Upon pressing the key for autonomous operation, the AM integrates data from the Inertial Measurement Unit (IMU) sensor for the starting position, the sequence begins with the opening of four side panels. Subsequently, if optimal azimuth and elevation information from the RPi is available, the tracker moves to the optimal position, constrained by the mechanical structure. Absence of prior RPi data results in open panels without movement until such information is received. If, during the period between power-on and key activation, the AM receives optimal azimuth and elevation data from the RPi, it is stored but movement is deferred until the activation key is pressed. Pressing the activation key again prompts a return to the initial/zero position recorded by the IMU sensor during the first button press, followed by the commencement of side panel closure. A subsequent activation key press initiates system opening and orientation towards the sun, if RPi information is received between the two button presses or after system reopening.

Successive button presses lead to system reassembly to the original IMU-sensor-received position during the first button press. The solar tracking algorithm of IoT SOLTRACK aims to ensure optimal orientation of the solar PV panels to maximize energy yield, while considering:

- the current location of the system;
- weather forecast and its impact on the estimated energy generation;
- mechanical constraints of the solar tracker.

The algorithm orchestrates a comprehensive analysis of a solar energy system's daily performance, emphasizing solar tracking and energy yield assessment. It dynamically computes key parameters such as solar irradiance, tracker position, and estimated photovoltaic power generation. Upon initial system activation latitude and longitude are obtained from the GPS sensor, and real-time calculations are synchronized with the adequate time zone.

(a)

(b)

Fig. 1. the IoT SOLTRACK TRL4

The activities of the COST action CA 20109 Modular Energy Islands for Sustainability and Resilience helped establish a team with necessary skills, know how and motivation for the development and implementation of the IoT SolTrack cross border technology transfer experiment. This Cross-domain Technology Transfer Experiment has received funding from the European Union's Horizon 2020 research and innovation programme under the SMART4ALL grant agreement no 872614.

Conclusions

The IoT mobile solar tracking is optimized for energy yield and solar tracking for of grid and on grid land applications. The communication and control system can be further developed and tested for floating structures. The solar tracker movement and positioning timestep would need to change in this scenario, and the impact of the possible movement of the floating structure carrying the solar tracker will impose problems for the developers. The system may be more suited for small consumers on still waters, than open waters with large wave impacts.

References

[1] I. Palomino-Resendiz, D.A. Flores-Hernández, L.A. Cantera-Cantera, N. Lozada-Castillo, A. Luviano-Juárez, Design and implementation of Model-Based Predictive Control for two-axis Solar Tracker, Solar Energy, Volume 265, 2023, 112080, ISSN 0038-092X, https://doi.org/10.1016/j.solener.2023.112080..

[2] Tri Widodo Besar Riyadi, Marwan Effendy, Bagus Radiant Utomo, Agung Tri Wijayanta, Performance of a photovoltaic-thermoelectric generator panel in combination with various solar tracking systems,

Applied Thermal Engineering, Volume 235, 2023, 121336, ISSN 1359-4311, https://doi.org/10.1016/j.applthermaleng.2023.

[3] Udit Mamodiya, Neeraj Tiwari, Dual-axis solar tracking system with different control strategies for improved energy efficiency, Computers and Electrical Engineering, Volume 111, Part A, 2023, 108920, ISSN 0045-7906,

[4] Muthukumar, S. Manikandan, R. Muniraj, T. Jarin, Ann Sebi, Energy efficient dual axis solar tracking system using IOT, Measurement: Sensors, Volume 28, 2023, 100825, ISSN 2665-9174, https://doi.org/10.1016/j.measen.2023.100825.

Performance of Clark Y Airfoil Equipped with Vortex Generators and Gurney Flaps in Dynamic Stall Conditions

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Summary. Dynamic stall increases unsteady aerodynamic loading of airfoils, thus reducing the lifetime of wind energy structures. These adverse aerodynamic load fluctuations can be mitigated using passive flow control devices (PFCDs) such as vortex generators (VGs) and Gurney flaps (GFs). Clark Y airfoil equipped with VGs and GFs was studied under dynamic stall conditions. Wind-tunnel experiments indicated that both VGs and GFs can significantly improve airofil performance, while combination of these PFCDs enabled superposition of these improvements, increasing significantly performance of the airofil in examined range of *AoAs*

Keywords: Airfoil, Dynamic stall, Vortex generators, Gurney flaps, Wind-tunnel experiments

Introduction

Airfoils experience substantial angle of attack (*AoA*) fluctuations in the typical wind energy applications, thus adverse dynamic stall may occur. Adverse effects of dynamic stall can be mitigated by increasing the maximum lift force coefficient ($c_{L,\max}$) and delaying stall to larger *AoAs* by using vortex generators (VGs) and Gurney flaps (GFs). VGs are typically placed on the suction surface of the airfoil near its LE to postpone the occurrence of dynamic stall to higher *AoAs*, increase $c_{L,\max}$, and enhance flow reattachment, e.g., Zhu et al. (2022) [1]. GFs on the trailing edge (TE) of the airfoil pressure surface yield an increase in the c_L/c_D ratio in the pre-stall conditions, which is characteristic for very small GFs, e.g., Chng et al. (2022) [2]. There is evidence that the combined use of both devices may enhance c_L/c_D ratio in the pre-stall region and a shift the flow separation to larger *AoAs*, e.g., Alber et al. (2022) [3]. A particular emphasis of the present work is on the simultaneous application of VGs and GFs onto an airfoil subjected to dynamic *AoA* alterations to solve the current lack of knowledge.

Conceptual Design

Experiments were performed in a closed-return wind tunnel featuring an open test section with low turbulence level at the Technische Universität Berlin. A wing with a constant chord c = 140 mm, designed as the Clark Y airfoil, was placed in the test section. Measurements were performed at the mean flow velocitie corresponding to Re = 180,000, i.e., Re typical for small wind turbines. Aerodynamic phenomena on the oscillating airfoil with and without passive flow control devices (PFCDs) were studied in the -10° < *AoA* < 30° and 0.00 < k < 0.15 ranges, where k is the reduced frequency. These conditions are typical for yaw misalignment of wind turbines. The effects of VGs and GFs were studied separately and concurrently. c_L, c_D and c_M were determined by integrating the pressure distribution along the top and bottom surfaces of the airfoil.

The results for the airfoil with and without VGs and GFs at *Re* = 180,000, *k* = 0.05 and 10° < *AoA* < 30° are presented by c_L, c_D and c_M diagrams, Figure 1.

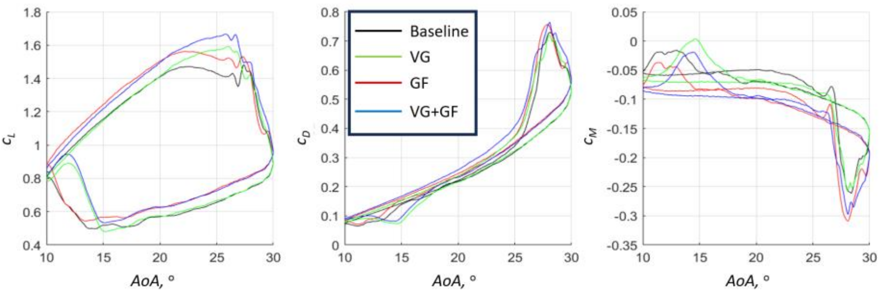

Figure 1. c_L (left), c_D (center) and c_M (right) of the Clark Y airfoil at *Re* = 180,000, *k* = 0.05 and
10° < *AoA* < 30° for beseline (black), VG (green), GF (red) and VG+GF (blue) configurations

Baseline c_L polar exhibit dynamic stall at 22° and dynamic stall vortex (DSV) induced peak in lift at 27°, that is followed by abrupt loss in c_L. Implementation of VGs prevent decrease in c_L due to dynamic stall. Dynamic stall for VG configuration happens just before loss of lift due to detachment of DSV which results in increased $c_{L,max}$. For pitching down stroke of motion, VG cause reattachment to happen at 12° which is 2° earlier compared to all configurations without VGs. GF configuration do not prevent dynamic stall but it offset c_L and c_M polars while not inducing significant increase to c_D curve. By combining VGs and GF on the airfoil, effects of both PFCD are superposed.

The support of COST Action CA20109 (MODENERLANDS), Deutsche Forschungsgemeinschaft (DFG) Project #446073296, Deutscher Akademischer Austauschdienst (DAAD), the Erasmus+ program and the Croatian Science Foundation IP-2022-10-9434 (AHEFES) is gratefully acknowledged.

Conclusions

Experimental study on influence of PFCDs on Clark Y airfoil under dynamic stall condition was conducted. It was found that both VGs and GFs improve aerodynamic performance of airfoil before and after dynamic stall occurrence. VGs reduce effect of dynamic stall and promote flow reattachment while GF increase c_L without significant increase of c_D. When VGs and GF are mounted on airfoil simultaneously benefit of these PFCD are superposed, significantly improving airfoil performance.

References

[1] Zhu, C. Y., Qiu, Y. N., Feng, Y. H., Wang, T. G., Li, H. 2022. Combined effect of passive vortex generators and leading-edge roughness on dynamic stall of the wind turbine airfoil. Energy Conversion and Management, 251,
115015.

[2] Chng, L., Alber, J., Ntouras, D., Papadakis, G., Kaufmann, N., Ouro, P., Manolesos M. 2022. On the combined use of Vortex Generators and Gurney Flaps for turbine airfoils. Journal of Physics: Conference Series, 2265, 032040.

[3] Alber, J., Manolesos, M., Weinzierl-Dlugosch, G., Fischer, J., Schönmeier, A., Nayeri, C. N., Paschereit, C. O., Twele, J., Fortmann, J., Melani, P. F., Bianchini, A. 2022. Experimental investigation of mini Gurney flaps in combination with vortex generators for improved wind turbine blade performance. Wind Energy Science, 7, 943-965.

Optimizing Offshore Floating Platforms with Digital Twins for Sustainable Energy Resource Assessment on Energy Islands

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Summary. To achieve the ambitious targets set by the European Green Deal, the EU has identified the acceleration of renewable energy deployment, particularly wind energy. This paper presents an approach to improve the design, operation, and scalability of offshore floating platforms for wind energy through the application of digital twin technology. By integrating advanced monitoring sensors, IoT and AI algorithms a framework for creating more accurate digital replicas of offshore floating platforms is proposed. These digital twins facilitate real-time interaction between the physical infrastructure and its virtual counterpart, enabling predictive maintenance, improved asset reliability, and extended lifespan while ensuring energy security and operational efficiency. The research supports the transformative potential of digitalization in wind energy systems to address important challenges such as the need for substantial investments, rapid repowering of existing infrastructure, and the social acceptance of wind energy projects. The paper discusses how modular design principles, supported by digital twin technology, can significantly contribute to the scalability and flexibility of offshore floating platforms, allowing for their adaptation to future energy needs without extensive reengineering. The application of digital twins in optimizing the productivity of wind power would revolutionize the offshore wind industry, supporting EU's goal for carbon neutrality by 2050.

Keywords: digital twins, modularized construction, offshore floating platforms, wind energy systems, sustainability

Introduction

The motivation of this paper lays in the EU strategic alignment with the European Green Deal [1], which underscores a commitment to address climatic and environmental challenges through a transformative approach aiming for a sustainable, inclusive, and prosperous society by 2050. The goal is to reduce greenhouse gas emissions by a minimum of 40% compared to 1990 levels and to increase the share of renewable energy to at least 32% by the year 2030. This critical energy transition highlights the immediate need to boost the installation rates of wind energy, particularly by quickly upgrading the capacity of existing onshore wind infrastructures. Central to realizing these objectives is the application of digital twins and digital technologies, which represent a shift in the design, operation, and maintenance of wind energy systems. The integration of digital twins allows for real-time interaction between the physical and virtual aspects of wind farm infrastructures, significantly improving decision-making capabilities, operational efficiency, and asset reliability. For instance, studies have explored aerodynamic optimizations, materials science advancements for more durable turbines, and site selection methodologies to capture wind energy more effectively [2]. Considering these efforts as important, they often overlook the potential of digital technologies to revolutionize wind energy systems further. Digital twins, which create a real-time digital replica of physical wind farm infrastructures, have started to gain attention but are not yet widely applied in the context of offshore floating platforms. The technology's capability for real-time monitoring, predictive maintenance, and simulation of wear and component health promises to reduce downtime and operational costs significantly [3]. Moreover, while there is increasing interest in using digital twins for onshore wind farms, the unique challenges posed by offshore environments—such as harsh weather conditions, logistical complexities in maintenance, and the need for highly resilient structures—are less covered [4]. These studies suggest an opportunity to improve the resilience and efficiency of offshore wind energy production through digital twins, yet detailed exploration into their application for modular and scalable offshore platforms remains limited.

Conceptual Design

In addressing the optimization and scalability challenges of offshore floating platforms for wind energy, this paper conducts a literature review focusing on three key areas: Internet of Things (IoT) and sensor technologies for data collection, the application of AI and machine learning for data analysis, and the use of fatigue analysis for simulation. The literature review examines existing scientific and technical achievements, identifying how they can be integrated into a comprehensive digital twin framework for offshore wind energy systems. The recent advancements in IoT and sensor technologies as fundamental to real-time data collection on offshore platforms were reviewed. Salam (2020) provided an of how IoT technologies enhance the monitoring capabilities of renewable energy systems, highlighting their potential to offer accurate and timely data for operational optimization [5]. This insight provides the solution to deploying IoT sensors across offshore platforms to capture data on wind speed, turbine performance, and environmental conditions. Digital twins are important in facilitating informed decision-making processes for maintenance and operations activities [4]. The current solutions lack a comprehensive digital twin-based system for the thorough failure analysis and maintenance optimization across an entire offshore wind farm. Additionally, limited research has been conducted on adequately managing operator safety and environmental conservation during operations and maintenance activities using digital twins' technology. This framework encompasses the creation of a virtual twin model, with data acquisition, storage, processing, and model construction Fig.1. The process involves three main stages: (1) Data acquisition, where gathering data from various sources such as monitoring systems, operations and maintenance records, weather data, and physical experiments; (2) Data storage and processing, where storing of the collected data is done in four distinct domains—monitoring, maintenance, test, and external data domains. This data is then subjected to extensive processing with advanced big data and statistical analysis methods to fulfil virtual model construction requirements; (3) Model building, where the data from all sources are merged. Then, the physical and rule-based models for each part of the wind farm are combined. Then, a method is used to determine the value of each component's model to identify the most important ones (Fig.1)

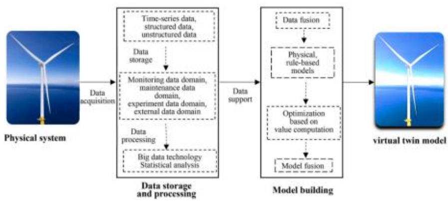

Fig. 1. The process of creating a virtual twin model for offshore wind farms [4]

Conclusions

In the paper, the focus is on improving the operation and maintenance strategies for offshore wind farms through the integration of digital twins. This approach addresses the challenge of efficiently managing the maintenance of offshore wind farms, which are subject to harsh marine environments and complex logistics. By creating a virtual twin model that mirrors the real-world behaviour of these wind farms, real-time monitoring, failure prediction, and life-cycle management will be enabled. The pressing need for innovative solutions to improve the efficiency, scalability, and reliability of offshore floating platforms for wind energy is addressed, in line with the European Green Deal's renewable energy targets.

References

[1] European Council. The European Green Deal. Consilium Europa. Retrieved from https://www.consilium.europa.eu/en/policies/green-deal/#:~:text=The%20European%20Green%20Deal%20is%20a%20package%20of%20policy%20initiatives,a%20modern%20and%20competitive%20economy.

[2] Kavari, G., Tahani, M., Mirhosseini, M. (2019). Wind shear effect on aerodynamic performance and energy production of horizontal axis wind turbines with developing blade element momentum theory. Journal of Cleaner Production, 219, 368-376.

[3] Jorgensen, J., Hodkiewicz, M., Cripps, E., Hassan, G. M. (2023). Requirements for the application of the Digital Twin Paradigm to offshore wind turbine structures for uncertain fatigue analysis. Computers in Industry, 145, 103806.

[4] Xia, J., Zou, G. (2023). Operation and maintenance optimization of offshore wind farms based on digital twin: A review. Ocean Engineering, 268, 113322.

[5] Salam, A., Salam, A. (2020). Internet of things in sustainable energy systems. Internet of Things for Sustainable Community Development: Wireless Communications, Sensing, and Systems, 183-216.

Design and Analysis of a Solar Power Plant in the Adriatic Sea

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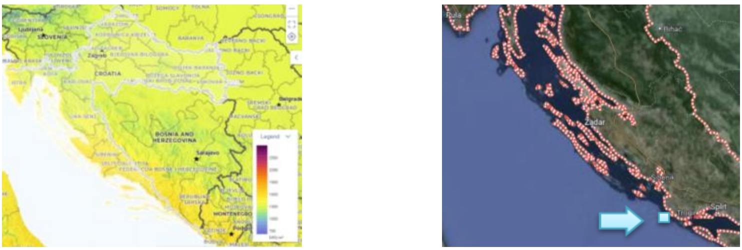
Summary. This study identified a suitable location for a solar power plant in the Croatian part of the Adriatic Sea, considering solar energy potential, marine traffic, protected areas, bathymetry, and visibility impact. The design of an offshore solar power plant was presented. The potential power generation, related carbon dioxide emission reduction, and earned carbon credit for floating solar power plant were estimated.

Keywords: CO_2 emissions, floating platform, solar power plant, solar energy

Introduction

Solar energy helps achieve SDG 7 (Affordable and Clean Energy), SDG 13 (Climate Action), and SDG 9 (Industry, Innovation and Infrastructure). To identify the region with the highest solar energy potential i.e. global horizontal irradiation (Fig. 1a) the Global Solar Atlas [1] was used. The country has between 2000 and 2700 hours of sunshine a year. Croatia is characterized by high irradiation from 1200 to 1600 kWh/m^{2}due to its geographical location. The southern coast of Croatia has the highest solar irradiation. A location (43.60 lat, 15.88 long) close to towns of Šibenik and Primošten was selected for the solar power plant (Fig. 1b). The floating solar power plant is located 5 km from shore.

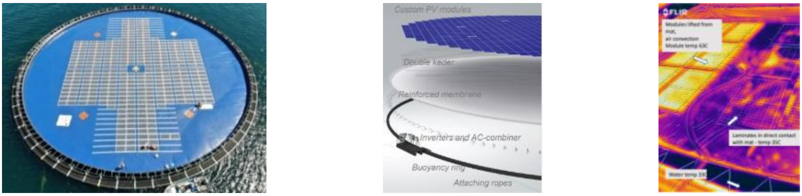


(a) (b)

Fig.1. a) Global horizontal irradiation [1], b) Location for offshore solar power plant

Conceptual Design

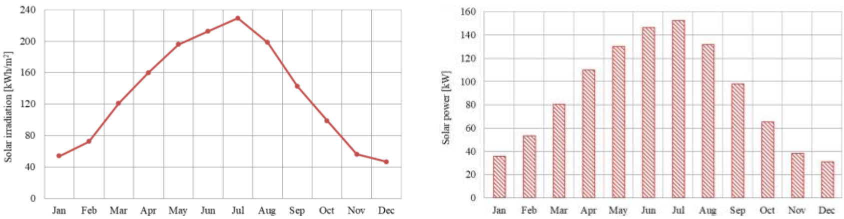
Solar panels are placed on the unique patented floating platform from the Norwegian company OceanSun [4]. This is a 1 mm thin flexible circular membrane with buoyancy rings made from HDPE (Fig. 2b). The platform has a diameter of 75 m, where 2200 solar panels (model Sunmodule Plus SW 300) are placed at a distance of 15 cm between rows. The occupied sea area of a solar power plant is 4071 m^2. Inverter stations could be placed on land or on barges next to the platform. The platform enables direct cooling of the solar panels (Fig. 2c) increasing the power output by 10%, while CO_2 is reduced by 10% compared to other floating solutions [4]. This solution uses a minimum of materials to achieve the required buoyancy i.e. has a low Levelized Cost of Energy. The hydro-elastic recyclable polymer floating membrane placed on a circular floater prevents waves from breaking and salt water intrusion.



(a) (b) (c)

Fig. 2. a) OceanSun platform, b) Elements of platform, c) Thermal image of platform [4]

The platform reduces evaporation and mitigates underwater algae growth. OceanSun has operated several pilot and demonstration facilities in Europe and Asia. Several floating platforms could be placed in selected location with shared anchors and mooring system for larger power generation. The monthly mean solar irradiation for the selected location obtained from the PVGIS tool [5] for the onshore site closest to the selected location is from 47 to 229 kWh/m^2 (Fig. 3a). The monthly mean power generation of solar power plant is from 31 to 152 kW (Fig. 3b). The highest power generation is observed during the summer months from June to August while the lowest is during the winter period from November to February. Following equations were used:
Power production: $E = H \cdot A \cdot r \cdot PR$, $CO_2\ emissions = E \cdot EF$, Carbon credit: $CO_2 \cdot 63.96$ €/t mean monthly solar irradiation H (kWh/m^2), total solar panel area A=3689 m^2, solar panel yield r=0.18, performance ratio PR=0.75, emission factor $EF = 0.206$ tCO_2/MWh [2], carbon credit price 63.96 €/t [3]



(a) (b)

Fig. 3. a) Mean solar irradiation, b) Mean power generation of offshore solar power plant

Conclusions

The deployment of a solar power plant in the Croatian part of the Adriatic Sea could annually produce 785 MWh of energy, avoid 162 tons of CO_2 emissions, and earn a carbon credit of 10346 €. The findings of this research could be useful to policymakers for the creation of a clean energy transition plan in Croatia.

References

[1] Global Solar Atlas, https://globalsolaratlas.info/map
[2] https://www.nowtricity.com/country/croatia
[3] https://carboncredits.com/carbon-prices-today
[4] OceanSun AS, Norway. https://oceansun.no/
[5] PVGIS, European Communities, 2001-2021, https://re.jrc.ec.europa.eu/pvg_tools/en

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 (Tešić Miroslav, Elvir Zlomušica i Sabina Sijačić, Elvir Zlomušica i Sabina Sijačić, 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 Tadić1, Milica Vujadinović, 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.

Conceptual Design

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.)

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)

Conclusions

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

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

[2] World Wind Energy Association: World Wind Energy Report 2009, 2010. Zlomušica, S. Zalihić, 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. Oktobar 2007.

[3] http://www.bh-news.com/index.php/component/ba/

[4] Aleksandar Tadić1, Milica Vujadinović: Wind potential and wind power development strategy in Bosnia and herzegovina Infoteh-Jahorina Vol. 10, Ref. F-30, p. 1034-1038, March 2011.

[5] Tešić Miroslav, Elvir Zlomušica i Sabina Sijačić, Elvir Zlomušica i Sabina Sijačić: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

[6] 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.

[7] 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.

[8] 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.

[9] 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.

[10] 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.

[11] 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.

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

[13] 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.

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

[15] CROENERGO.EU,http://www.croenergo.eu/Energija-vjetra-u-2014-godini-porasla-za-cak-44!-25760.aspx/, (21.03.2015.).

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

Use of Drones and Robots for Inspection and Maintenance of Wind Farms

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Summary. Maintenance of wind farms, especially offshore floating platforms, plays a crucial role in ensuring the continuous operation, efficiency, and safety of these renewable energy facilities. In this paper, we analyze the concepts for wind farm maintenance and inspections. In the near future use of robots and drones will be normal equipment used for inspection and maintenance of wind farms but in this moment the full concept of this is still not clear. Therefore, in the paper were analyzed various concepts.

Keywords: inspection, maintenance, drones, robots, wind energy systems,

Introduction

Maintenance of wind turbines is an important parameter since the cost of single maintenance as well as avoidance of potential catastrophic failures. The problems and maintenance costs are more pronounced for offshore platforms. Since we are living in the time of Industry 4.0 and Maintenance 4.0 several techniques started to be used in the maintenance of wind turbines. Trends in the maintenance of wind turbines are aimed at improving the efficiency, reliability, and sustainability of wind turbine maintenance while reducing costs and enhancing safety. Some of key trends are: predictive maintenance (Condition monitoring systems; Big Data and AI); drones and robotics (visual inspection); remote monitoring and control (SCADA systems and digital twins); advance materials and Coating; Innovative repair techniques (such as cold spray technology and laser cladding).

The use of drones and robots is the trend for maintaining systems that are used every day. Company SkySpecs is developing drones for wind turbine inspections. A concept that can be used in the near future is to have one drone capable of inspection of wind turbines. The most probable concept is use of drones for multiple inspections of wind turbines in a single drone. For example, 10 wind turbines which are located close to each other are inspected by a single drone. In this case, a drone is stationary at one wind turbine of the nearby ship with a drone nest and for example, regularly every day inspects another wind turbine. This concept has advantages since it could be used in the case when a wind turbine is operating as well as for rotor blade inspection.

A similar concept could be used for the use of robots that are capable of visual inspection (RGB and Thermal cameras) but also using laser for distance or shape measuring, or ultrasonic inspection of material as well as maintenance robots. Inspection and maintenance robots are the second-largest category of robots with 39% of all units sold and all the trends are increasing. This category encompasses a diverse range of robot types, from affordable options to high-end custom solutions.

Conceptual Design

Netland et al. explored the viability of employing robots for internal inspections of nacelle structures in offshore wind turbines. In their study, a robotic platform was designed to traverse on a rail system permanently installed within the wind turbine nacelle structure, as illustrated in Fig. 2. The utilization of this rail system was demonstrated through a prototype system equipped with a USB camera mounted on a pan-tilt mechanism, mimicking the conditions of an offshore wind nacelle. The system offers several advantages such as that they provide a straightforward and dependable method for moving an inspection robot across critical locations; it serves as an efficient means of supplying power to the robot during operations and it ensures safe traversal along a predetermined route, thus preventing any unintended deviation or damage to equipment.

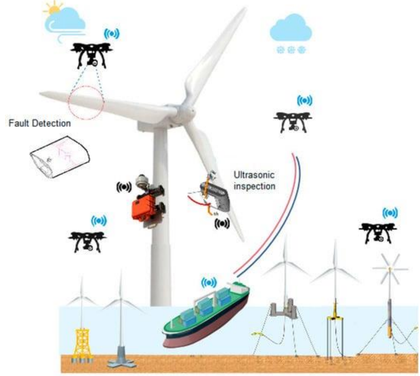

Fig. 1 Concepts of drone/robot outside inspection robot [2]

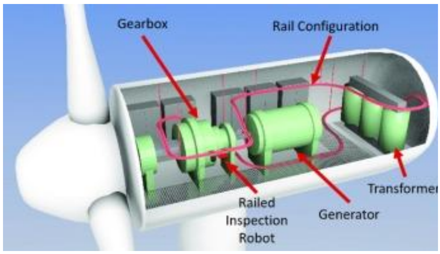

Fig. 2 A concept of a rail-guided inside inspection robot [3]

The system could offer also integration of multiple sensors, including infrared sensors for detecting friction or malfunctioning electrical systems, microphones for monitoring machinery, and compact sensors for measuring vibration and temperature levels.

Limitations of railed robots include that they require changes in the design of wind turbines. As the robot's moveability and autonomous operating are increasing our opinion is that it could be possible to create a robot for inside inspection but producers need to define dimensional and operating characteristics for the robot. Such a robot could be used only for one wind turbine, and it could be standard equipment for the wind turbine. Such robots could be also used for visual inspection but also for smaller maintenance tasks.

Conclusions

In the paper, the focus is on improving the inspection and maintenance strategies for offshore wind farms through the use of drones and robots. This trend of inspection and maintenance is inevitable since there are numerous advantages of using drones and robots and it will be significantly increased in the operation. In the paper are given concepts that are coming from the technological advances and that are already used in other industries.

References

[1] Mitchell, D.; Blanche, J.; Harper, S.; Lim, T.; Gupta, R.; Zaki, O.; Tang, W.; Robu, V.; Watson, S.; Flynn, D. A review: Challenges and opportunities for artificial intelligence and robotics in the offshore wind sector. Energy AI 2022, 8, 100146

[2] Shafiee, M.; Zhou, Z.; Mei, L.; Dinmohammadi, F.; Karama, J.; Flynn, D. Unmanned Aerial Drones for Inspection of Offshore Wind Turbines: A Mission-Critical Failure Analysis. Robotics 2021, 10, 26.

[3] Netland Ø, GD Jensen, A Skavhaug The Capabilities and Effectiveness of Remote Inspection of Wind Turbines Energy Procedia, 80 (2015), pp. 177-184.

A Coherent Strategic and Operational Plan for a Worth-Living Integrated Development of Nisyros Island

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[1] Mayor of Nisyros Island

Summary. The term sustainable development does not bring forward all aspects of development. A new term that incorporates the wellbeing of all citizens through economic development and the preservation of the environment is needed. A "Worth-living Integrated Development" could be a term that combines economic development, social development and environmental protection. A Worth-living Integrated Development may be achieved only when human societies decide to create necessary presuppositions—at the educational, research, economic, social, political, technical/technological and environmental levels—for a better world, based on the human values of peace, justice, solidarity, political, economic and social democracy and ethics, respect for nature and for the variety of cultures of all human beings.

This work presents a coherent strategic and operational plan of an integrated spatial approach that seeks multiple results in the context of a "Worth-living Integrated Development" of Nisyros based on the special characteristics of the region given by its insularity1, its rich natural and cultural heritage and its local productive potential. It combines the use of available financial sources and tools and on the basis of a unified planning with the participation of local actors, in order to achieve the maximum possible result to the benefit of the inhabitants of the island.

Keywords: worth-living integrated development, Nisyros Island.

Conceptual Design of a Renewable Energy Island: A Case Study of St. Anastasia, Bulgaria

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Summary. The paper investigates the possibility of applying the renewable islands concept to foster the implementation of a decarbonisation plan for the St. Anastasia island's energy system.

Keywords: Renewable Energy Island, conceptual design, Renewable Energy Assessment.

Introduction

The "Clean energy for EU islands" initiative of the European Commission [1] was launched in 2017 as part of the "Clean energy for all Europeans". It supports EU islands in generating their own sustainable, cost-effective energy using renewable energy sources. The latest initiative "30 Renewable Islands for 2030" [2] involves 30 islands in achieving their complete energy independence through 100% renewable sources until 2030. The only inhabited island on the Bulgarian Black Sea coast - Saint Anastasia - can also achieve energy independence through 100% renewable sources. The island is located southeast of Burgas town with coordinates 42° 28' 3.9" N, 27° 33' 11" E. Since 2001, Saint Anastasia has the status of a cultural and historical landmark. This study presents a conceptual design of a renewable energy island in St. Anastasia, Bulgaria.

Conceptual Design

The assessment of renewable energy sources in this conceptual design uses open-source database of the Global Solar Atlas [3], as well as the New European Wind Atlas (NEWA) [4]. Two scenarios for renewable island are developed. The first includes energy modules producing electricity from solar photovoltaics only. The second comprises hybrid modules of wind generators and solar photovoltaics. Energy storage facilities are also included. A brief discussion on important environmental and social aspects of achieving the island's energy independence is provided.

Figure 1. Study area: 3D model of Saint Anastasia Island, Bulgaria

Figure 2. Energy modules producing electricity from solar photovoltaics

References

[1] https://energy.ec.europa.eu/topics/markets-and-consumers/clean-energy-eu-islands_en#clean-energy-for-eu-islands-initiative

[2] https://clean-energy-islands.ec.europa.eu/news/journey-begins-30-renewable-islands-2030-ready-set-30

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

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

Abstracts – Working Group 2

Corrosion Detection Around Mooring Cables of Spar-Type Floating Offshore Wind Turbine Using Dynamic Response of the Structure

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Summary. Floating Offshore Wind Turbines (FOWT) are becoming increasingly popular due to their higher wind energy harnessing capabilities and lower visual pollution. The current study focuses on data-driven vibration-based Structural Health Monitoring (SHM) in FOWT mooring lines, where damage features are derived from wind and wave-induced acceleration signals collected along the tower. NREL 5MW OC3 Hywind spar type is considered as the benchmark model for the numerical investigation. The corrosion damage in the mooring lines submerged under the water are modelled in openFAST. The proposed data-driven framework consists of three main components. A feature extraction is initially performed on the collected dataset of dynamic response of the benchmark and damaged FOWT under moderate sea states, which is followed by a feature selection scheme based on the analysis-of-variance (ANOVA) algorithm, to eliminate irrelevant characteristics from the time domain feature set of responses. The selected feature vector is used as input to a Naive Bayes classifier (NBC) algorithm to train and test the detection model. The results show that the NBC model can detect the stiffness reduction of a mooring line with signals from measuring positions along the tower.

Keywords: FOWT, Corrosion Detection, Mooring Lines, Data-Driven

Introduction

The offshore wind energy sector is undoubtedly undergoing unprecedented growth, with projections indicating substantial expansion in the coming years [1]. For the effective achievement of these targets and the alignment with the global goals for net-zero emissions by 2050, the acceleration of the annual deployment rate of offshore wind projects is crucial [1]. Yet, the offshore wind industry faces significant challenges, which include not only the total lifecycle costs of the turbines themselves but also the inherent risks associated with these substantial investments [1]. A critical part of Floating Offshore Wind Turbines (FOWTs) that requires monitoring is the mooring lines, as their failure may lead to several catastrophic events such a drift, disconnecting the electric cable, and introducing the risk of collision with other wind turbines. For the monitoring of mooring lines, vibration-based methods constitute a fitting choice due to their several advantages such cost-effectiveness in terms of instrumentation and operation, as they require only a small number of sensors. As of now, the existing literature on vibration based monitoring for mooring lines in FOWTs is very limited. As example, Gorostidi et al. [2] employ a deep Neural Network (NN) method to detect an increase in the mass of the mooring lines of a semisubmersible FOWT due to biofouling. Therefore, the primary objective of the present study is to propose and evaluate damage detection methods that can detect corrosion around mooring cables of spar-type FOWT using dynamic response of the structure that collected using the acceleration sensors attached along the tower.

Conceptual Design

The 5MW turbine properties are adopted from the [3]. 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. The acceleration responses are derived along the tower at 6 'sensor' nodes (see Fig. 1a for sensor locations) under benchmark conditions (Healthy state) and damage state. In the next step, statistical features of response data in the time domain are extracted, which is followed by a feature selection scheme based on the analysis-of-variance (ANOVA) algorithm. The selected feature vector is used as input to a Naive Bayes classifier (NBC) algorithm to train the detection model.

The confusion matrices presented in Fig. 1b summarize the overall performance of the proposed approach with respect to the actual and predicted classes, which are based on a 5-fold cross-validation error estimation method. As can be seen the NBC algorithm has 95% accuracy in detecting the state of mooring cables with feature dataset based on recorded acceleration response of structure on tower.

(a) (b)

Fig. 1. FOWT model and detection result; a) NREL 5MW OC3 Hywind spar type, b) Confusion matrix

Conclusions

This research presented a data driven method for learning damage-sensitive features from acceleration response data of spar-type FOWT model using the NBC model. The results showed that NBC algorithms have 95% accuracy in identifying structural status of mooring lines.

References

[1] N. P. Anastasiadis, C. S. Sakaris, R. Schlanbusch, and J. S. Sakellariou, "Vibration-Based SHM in the Synthetic Mooring Lines of the Semisubmersible OO-Star Wind Floater under Varying Environmental and Operational Conditions," *Sensors*, vol. 24, no. 2, 2024, doi: 10.3390/s24020543.

[2] N. Gorostidi, V. Nava, A. Aristondo, and D. Pardo, "Predictive Maintenance of Floating Offshore Wind Turbine Mooring Lines using Deep Neural Networks," *J. Phys. Conf. Ser.*, vol. 2257, no. 1, 2022, doi: 10.1088/1742-6596/2257/1/012008.

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

Fatigue Mitigation of Floating Offshore Wind Turbine Structures by Adaptive Controlling Strategies

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Summary. Floating offshore wind turbines (FOWTs) have significant potential for harnessing abundant wind resources in deep-water areas. However, the challenging marine environment and dynamic forces contribute to the long-term deterioration of FOWT towers, particularly due to corrosion fatigue (C-F) in critical connections like the ring-flange. Unlike conventional structures, FOWTs can utilise active controls, such as pitching, yawing, and torque controllers, to mitigate structural vibrations and loads. Advances in smart sensing technology, coupled with real-time monitoring and early warning systems, have significantly enhanced the prognosis of current and future deterioration through accessible data. The incorporation of early warning mechanisms, as emphasized by the UN Disaster Risk Reduction Office, is vital for improving the resilience of FOWT structures. Therefore, developing refined adaptive control strategies tailored to site-specific conditions, supported by real-time monitoring and early warning, is crucial for reducing operation and maintenance (O&M) costs based on structural health. This study investigates the impact of various adaptive control strategies on the C-F deterioration of FOWT-supporting towers. Initially, multi-physics simulations are performed to establish fatigue stress spectra from site-specific wind-wave distributions using different control strategies. These spectra are then integrated into a time-variant C-F deterioration model that considers ambient corrosivity. The findings highlight severe C-F deterioration in FOWT towers caused by strong wind-wave loads, high corrosivity, and increased structural flexibility. Crucially, the results demonstrate that control strategies significantly influence C-F deterioration, particularly under specific wind velocity regions.

Keywords: Floating offshore wind turbine (FOWT), Adaptive Control, Fatigue, Ring-flange connection.

Introduction

Floating offshore wind turbines (FOWTs)[1] harness renewable energy in deep waters but face significant structural challenges due to corrosion fatigue (C-F) of bolts in ring-flange connections[2], as shown in Fig.1. These bolts, essential for the tower assemblies, endure cyclic stresses and marine corrosion, accelerating deterioration and risking premature failure. Addressing the C-F issue in FOWTs requires interdisciplinary approaches involving materials engineering, stress analysis, predictive maintenance strategies, and the integration of real-time monitoring and early warning systems. Mitigating fatigue deterioration in FOWT towers involves understanding physical cracking evolution, applying innovative control strategies, and employing early warning mechanisms to proactively identify and address potential structural failures. Proactive and adaptive control strategies, such as the pitch control, reduce structural loads and stress, enhancing the service life of the structure. Preventive strategies using advanced forecasting techniques allow pre-emptive adjustments to minimise fatigue loads, balancing energy capture with load reduction. This study investigates adaptive control strategies to reduce C-F damage in FOWT towers. A systematic approach includes an analysis of different control strategies and their impact on C-F performance, utilising a multi-physics simulation integrating structural, hydrodynamic, aerodynamic, and C-F models. A probabilistic model assesses the uncertainty and reliability of C-F life prediction. The findings highlight the critical influence of control strategies on C-F deterioration of FOWTs.

Conceptual Design

To account for corrosion-induced degradation in fatigue performance, a time-variant probability-stress-life (t-PSN) model is developed[3][4]. This model correlates fatigue strength with loading cycles and service life, incorporating mean values and statistical variability to represent material behaviour under cyclic stress in corrosive environments. By integrating the time-dependent effect of the corrosion, the t-PSN model provides a realistic basis for assessing structural integrity, crucial for FOWTs. The study utilises the IEA 15MW reference turbine, installed on a 150-meter-tall tower on the UMaine VolturnUS-S floating platform[5]. Wind speed data from Station CAPE ELIZABETH is used to model environmental conditions. Wind-wave data correlation is simplified with a deterministic curve for simulation purposes. Multi-physics simulations derive fatigue stress spectra at critical bolts using OpenFAST, a tool modelling wind forces and control systems. Three control strategies (CS0, CS1, CS2) are analysed, as listed along with the result in Table 1.

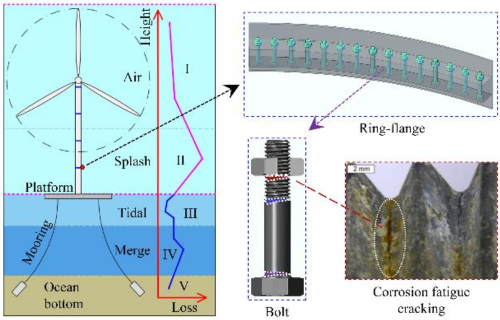

Fig. 1. Corrosion fatigue cracking of high-strength bolts in ring-flange connections of FOWTs.

Table 1. Power generation and service life of the critical bolt under different controlling strategies

Strategy	Wind velocity (m/s)			Annual power generation (MWh)	Service life of the critical bolt (years)
	Cut-in	Rated	Cut-off		
C_0	3	10.59	25	42,102	13.6
C_1	3	7	20	39,520	20.4
C_2	5	7	20	35,271	20.6

Conclusions

The study concludes that control strategies significantly affect the rate of corrosion fatigue in FOWT structures. Strategy C_0, which maximizes power generation, negatively impacts bolt reliability, leading to fast degradation. In contrast, Strategies C_1 and C_2, with operational limits, enhance bolt integrity, prioritising long-term durability over immediate power output. Future research should focus on predictive operation and maintenance protocols, incorporating digital twins, real-time monitoring, and early warning systems to enhance FOWT efficiency and durability.

References

[1] Kurniawati, I., Beaumont, B., Varghese, R., Kostadinović, D., Sokol, I., Hemida, H., ... & Baniotopoulos, C. (2023). Conceptual Design of a Floating Modular Energy Island for Energy Independency: A Case Study in Crete. Energies, 16(16), 5921.

[2] Zhang, J., Heng, J., Dong, Y., Baniotopoulos, C., & Yang, Q. (2024). Coupling multi-physics models to corrosion fatigue prognosis of high-strength bolts in floating offshore wind turbine towers. Engineering Structures, 301, 117309.

[3] Zhang, Y., Zheng, K., Heng, J., & Zhu, J. (2019). Corrosion-fatigue evaluation of un-coated weathering steel bridges. Applied Sciences, 9(17), 3461. 1.

[4] Zhu, J., Chen, Y., Heng, J., Wu, M., Zhang, Y., & Li, Y. (2024). Probabilistic corrosion-fatigue prognosis of rib-to-deck welded joints in coastal weathering steel bridges exposed to heavy traffics. International Journal of Fatigue, 108210.

[5] Allen, C., Viscelli, A., Dagher, H., Goupee, A., Gaertner, E., Abbas, N. & Barter, G. (2020). Definition of the UMaine VolturnUS-S reference platform developed for the IEA wind 15-megawatt offshore reference wind turbine. NREL, Golden, CO, US.

Effects of Inter-Module Connection Properties on Dynamic Characteristics of Self-Erecting Modular Tower

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Summary. Raising wind turbine tower height is an attractive method to capture stronger winds in regions with low wind speeds. Nonetheless, this strategy comes with constraints related to transportation, cost, assembly, and erection. In addition, the rise of modular constructions and European Green Deal targets highlight the necessity for demountable structures. This is especially important for wind turbine towers that are subject to rapid ageing due to technological development. In this regard, Self-erecting towers (SeTs) have emerged as a viable solution to overcome these limitations. In addition, designing tall constructions like SeT always involves considering the crucial aspect of natural frequencies. This paper first develops a numerical model and calibrates its results against experimental data. A parametric study is then conducted to investigate the effects of inter-module connection properties on the natural dynamic characteristics of self-erecting modular towers. Moreover, discussions on parameters are evaluated, including altering the shear and rotational stiffness of the inter-module connection across a broad range of values to encompass various stiffness levels. Finally, the effect of inter-module connection properties and the number of connections on structural behaviour and dynamic characteristics of demountable self-erecting towers is investigated and discussed.

Keywords: Experimental test, demountability, Dynamic characteristic, Inter-module connection, Self-erecting tower, Wind turbine tower,

Introduction

Demountable modular structures with easier transportation and higher sustainability have drawn much attention in the market. SeT is a modular tower system with demountable post-tensioned steel-concrete composite panels, which saves time and costs and avoids logistic challenges. SeT can be implemented onshore and offshore and is a versatile solution for single or multiple wind turbine projects, valid for any location, presenting itself as an alternative perfectly adapted to geographical areas where the use of large cranes required in the usual process of installing turbines is not economically viable [1]. Previous studies conducted a parametric analysis focused on the first natural frequency of the SeT to define its gross geometry [2]. However, there is a lack of research examining the dynamic behaviour of SeT by considering the influence of changes in inter-module connection properties. In this paper, an equivalence method based on a series of static analyses is employed to analyse the influence of inter-module connection stiffness and the number of connections on the dynamic characteristics of SeT. Several vertical and horizontal bushing connectors in Abaqus were used to simulate the behaviour of demountable bolted connections between the Panels. The properties of these connectors were calculated separately based on some static analysis in each direction.

Conceptual Design

An experimental test was conducted to determine the tension strength of a curved steel-concrete composite panel. This panel was fabricated by bolting four steel-concrete composite frames. The frames included steel tubes and a concrete part. First, the specimen was three-dimensionally simulated using Dynamic Explicit solver available in Abaqus and calibrated against the experiment. In the next step, SeT was numerically simulated by assembling the calibrated panels and bushing connectors [3]. In Abaqus, the bushing connector enables independent behaviour in three local directions and different behaviour in two flexural rotations and one torsional rotation between two nodes. The corresponding FE model is depicted in Figure 1. The coefficients of the bushing connectors in each direction were calculated through a set of linear static analyses. Finally, a parametric study was conducted to evaluate the effects of inter-module connection properties on the natural dynamic characteristics of SeT. In the parametric study, altering the shear and rotational stiffness of the inter-module connection across a broad range of values was considered.

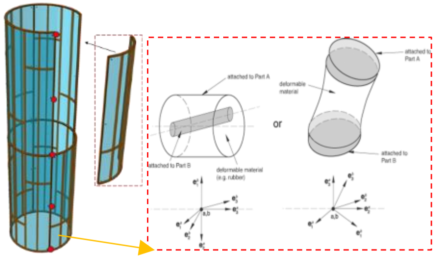

Fig. 1. Bushing connectors and SeT elements assembly

Conclusions

A calibrated numerical model was used to determine the dynamic characteristics of SeT with various inter-module connection properties. The result showed that changing the shear and rotational stiffness of demountable inter-module connections can affect the natural frequency and shape mode of SeT. In addition, the number of connections is an important parameter that can lead to changes in the dynamic characteristics.

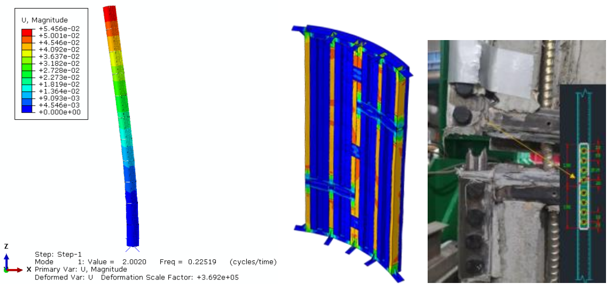

Fig. 2. First mode shape of the SeT and numerical model to validate experimental results

References

[1] C. Rebelo, “Self-Erecting Steel Hybrid and Composite Towers for Onshore Wind Turbines - two case studies,” in 10th Conference Advances in Wind Turbine Towers, 29 - 31 March, Bremen, Germany, 2023.

[2] P. G. Merino, M. M. Morales, and C. Rebelo, “Numerical Modelling of the Self-Erecting Tower for Onshore Wind Turbines,” ce/papers, vol. 6, no. 3–4, pp. 1124–1128, 2023.

[3] “Abaqus, Analysis user’s guide, Version 6.17 Dassault Systèmes, Simulia USA, 2021.”

Shapes of Artificial Energy Islands with Optimized Von Kármán Vortex Streets

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Summary. The increasing need for renewable energy leads to exploration offshore. One idea is to create artificial energy islands covering relatively large surfaces to support several types of renewable energy production, e.g. wind, solar, wave farms, desalination, hydrogen production/storage. In deeper water, one requires floating support structures unless one is constraint to shallow water to utilize existing grids. With offshore wind turbines in mind, the design of these islands is governed by wave and wind loading. Investigations of optimizing the outer boundary of an artificial island with respect to incoming environmental loadings and subsequent boundary and wakes flows at any water depth are undertaken. Concept developments are carried out by optimizing the von Kármán vortex street to minimize loadings on the island.

Keywords: energy island, fluid-structure interaction, von Kármán vortex street.

Introduction

Utilization and creating artificial islands for renewable energy is an on-going effort. In the Belgium offshore region, the first one of its kind will become reality in the near future [1] and others are likely to follow. The interesting idea of Power-to-X on islands in which renewable electricity, e.g. via wind power, to create something else (‘X’) will one day become part of our resources. The energy carrier ‘X’, e.g. renewable hydrogen may in return power heavy duty transport and utilized in industry.

The objective of this project is to educate students, advance research, and support industry in renewable energy within the field of water waves and fluid-structure interactions (FSI). Herein, with a focus on understanding the fluid flow interaction with the boundary shape to optimize the geometric design of energy islands. Vortex shedding is known to form around these bluff bodies. These von Kármán vortex streets are large scale (Fig. 1), yet smaller eddies at the boundary of the bluff bodies, are responsible for forming the wakes in the water and air stream above and their interaction. These streets indeed exist in a large range of fluid velocities and densities like air and water. The formation and visibility of von Kármán vortex streets are influenced by the incoming wind/wave speed, direction, atmospheric boundary layer and the boundary shape/topography of the islands. These vortex patterns not only provide insights into fluid dynamics but also help in understanding FSI processes and the interaction between natural and man-made structures, above, at and below the free-surface.

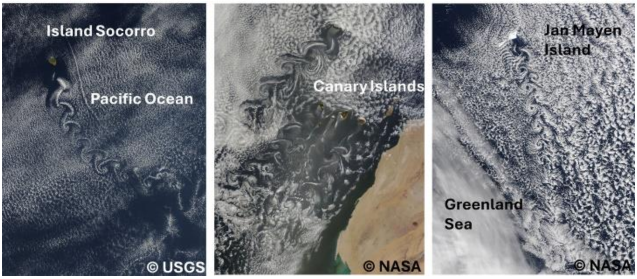

Fig. 1. Examples of von Kármán vortex streets around islands.

Conceptual Design

For certain environmental events, the vortex shedding may result in undesirable cross-flow motions especially for floating structures. A study is carried out to investigate minimization of undesirable motions by varying the geometry of the boundaries of an artificial energy island (Fig. 2). It involves modelling of both wind and waves and their interactions. A further concern examines the protection of these islands against wave impact involving add-on parapets to divert the waves offshore.

Fig. 2. Examples of configurations of artificial islands.

Conclusions

Optimizing the shape of artificial islands to reduce load and protect them against harsh environment is the focus of the present research. While the study is at the conceptual level, further research using high fidelity models are anticipated. The present work also applies to floating and fixed bottom offshore structures.

References

[1] Jan de Nul and Deme to build world's first artificial energy island. Ocean News & Technology, 2023-03, p.30-30.

Data, Models and In-Between for Physics Informed Neural Networks and Digital Twins

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Summary. Classical and physics informed neural networks allow for the creation of reduced order models, solution of direct and inverse problems and creation of digital twins.

Keywords: neural networks, physics informed neural networks, inverse problems, reduced order models, digital twins

Introduction

Using neural networks in order to replace unknown material constitutive relations in mechanics has been proposed and tested in [1], while adding physics information makes application of neural networks in mechanics more effective [2][3]. The importance of PINNs is demonstrated on a dynamic oscillator problem [4].

Constitutive Artificial Neural Networks and Data Driven FEM

Material constitutive relation, which can be based on experiments or representative volume element results in homogenization, can be replaced with suitably trained neural networks or data-driven algorithms.

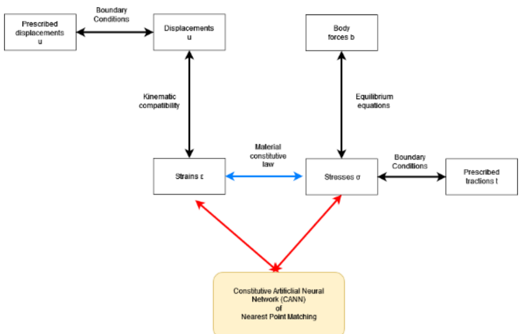


Fig. 1. Approximation of material constitutive relation through neural networks and data driven techniques on a modified Tonti's diagramm [1].

One-dimensional Oscillator solved through ANN and PINN

An 1-DOF oscillator is considered. Prediction of state in near future from measurements along time history is considered. Classical ANN is based on error due to deviations of measurements and predictions, PINN adds (or even replaces totally) the error with the one due to satisfaction of governing equations, Fig. 2. PINN leads to more powerful predictions, see Fig. 3. Result of multi-dimensional problems can be found in [4].

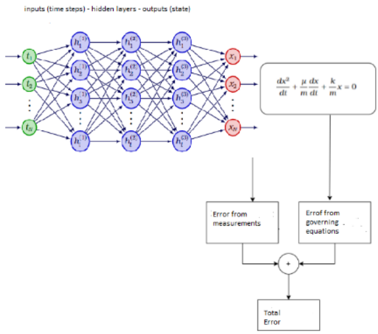
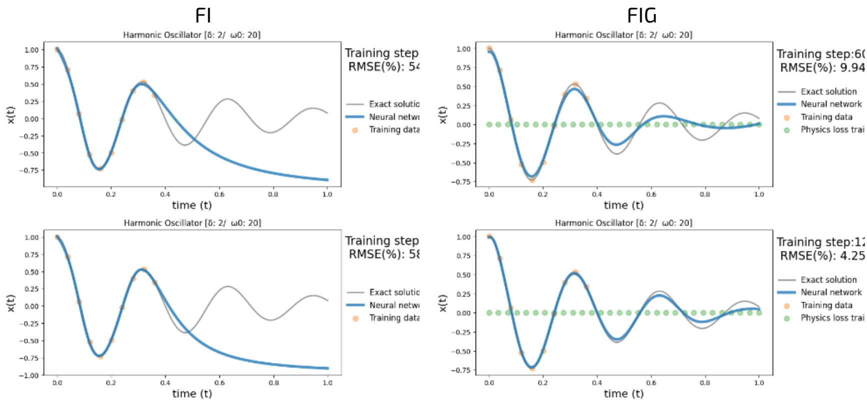


Fig. 2. Training of classical and physics informed neural networks



(a) (b)

Fig. 3. Prediction of vibration time series 1 second ahead; a) using ANN and 500, resp. 1000 iterations, b) using PINN and 6000 resp. 12000 training iterations.

References

[1] Drosopoulos, G.A., Stavroulakis, G.E., Nonlinear mechanics for composite heterogeneous structures. CRC Routledge, 2022.

[2] Stavroulakis, G., Mouratidou, A., Drosopoulos, G., Nonlinear interaction in composites using physics informed neural networks, in: WCCM2024. URL https://www.scipedia.com/public/Stavroulakis_et_al_2024a

[3] Mouratidou, A.D., Drosopoulos, G.A., Stavroulakis, G.E., Ensamble of physics-informed neural networks for solving plane elasticity problems. Acra Mechanica (in press)

[4] Kyriakou, Ch., Diploma Thesis, TUC 2023 (in Greek) https://dias.library.tuc.gr/view/97330

Towards Resilient FMEI: An SPH-Based Framework for Extreme Hydroelastic Events

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Summary. This contribution presents a novel numerical framework suited for simulation of multiscale problems pertinent to the structural dynamics, and overall integrity, of Floating Modular Energy Islands and their modules.

Keywords: Smoothed Particle Hydrodynamics, Hydroelasticity, Inter-connected Structures, Project Chrono

Introduction

When designing monolithic floating structures or large assemblies of modules at offshore locations, anticipating their response to ocean actions is crucial to ensuring the required functioning standards in operational conditions, and the necessary resilience to meet the projected life cycle. For Floating Modular Energy Islands (FMEI), this easily applies for the structure as a whole, or for some of their modules (i.e., solar floating photovoltaic (FPV) or flexible wave energy converters (WECs)). In certain conditions, dictated both by environmental loads and the structural configuration, such structures can exhibit hydroelastic behavior when represented as continuous media, or multibody wave-structure interaction (WSI), for inter-connected rigid structures. It goes that traditional approaches, based on linearized or weakly non-linear solutions of the equations of motion, may fail to capture the complex interaction established between fluid and compliant structures, which includes viscous wave-to-structure actions, and, most importantly, structure-to-wave response. Computational Fluid Dynamics-based tools (CFD), instead, are conceived to realistically represent the flow features and, possibly, two-way coupled actions of floating structures. Within the CFD panorama, the Smoothed Particles Hydrodynamic method (SPH) offers notable features for investigating WSI, thanks to its Lagrangian nature that allows for extreme deformation of the fluid mass and straightforward treatment of moving boundaries. Using the SPH-based framework of the open-source DualSPHysics software [1], we herein illustrate the development of a high-fidelity design tool able to reproduce extreme hydroelastic events and to anticipate the coupled response of flexible or jointed floating offshore structures. This approach stands out for its multiscale modeling capabilities and for the broad variety of structural configurations which it inherently supports, always relying on the effectiveness of the SPH fluid-solid interaction simulation.

Conceptual Design

The SPH method is based on the discretization of Navier-Stokes equations in correspondence to a set of computational nodes (particles), in which they are integrated based on the physical properties of the surrounding particles. Neighbor particles' contribution is weighted through a monotonically decreasing function, the so-called smoothing kernel. Within this fully Lagrangian environment, moving objects are discretized as groups of rigid SPH particles, obeying Newton's equations according to locally computed forcing conditions. The proposed approach uses a set of rigid blocks and external mechanical constraints to create elastic super elements capable of six degrees-of-freedom motion [2], eventually employed to discretize beam or plate elements. The mechanical restrictions are made available by the coupled Chrono module [3] and shaped according to linear elastic theory; inertial properties and the fluid-structure interaction computation are assigned to the solid SPH particle sets. Figure 1 displays an overview of the proposed model and its capabilities in describing complex WSI.

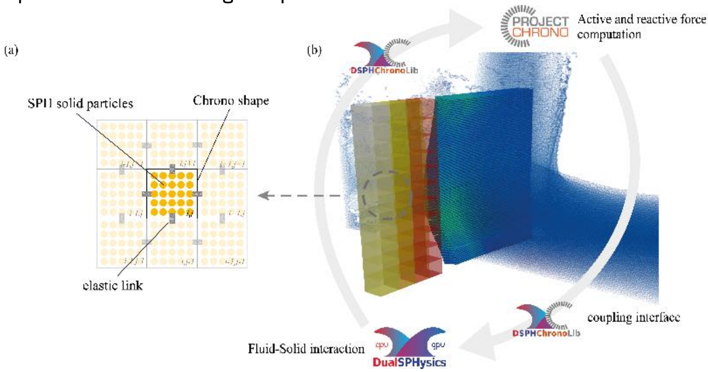

Fig. 1. Schematic representation of an elastic super element (a) and simulation of a violent hydroelastic impact within the DualSPHysics–Chorno environment (b): the fluid-solid interaction is solved by the core modulus of DualSPHysics, whereas the structure dynamics is calculated within the Chrono library; the DSPHChronoLib interface handles the communication between solvers.

Conclusions

With the proposed tool, an end-to-end design process for compliant floating structures, including a broad variety of designs and environmental loads, can be carried out with great accuracy, overcoming the limitations of the commonly used low-fidelity models when nonlinearities come into play. Besides, this approach requires relatively limited computational effort and allows for the straightforward definition of jointed structures along with continuous elastic media. Combining all the framework's features, structural and anchoring loads under realistic conditions can be correctly anticipated, as DualSPHysics also includes a coupling with MoorDynPlus to simulate mooring connections. The availability of such numerical instruments surely can help reach higher levels of technological readiness and establish guidelines for large-scale development of modular renewable energy islands, coming with affordable numerical effort, within an open-source environment, and with room for problem-dependent characterization. An STSM grant has been awarded by the Action to support the development of this project, with the overarching objective of providing WG2 members with an open-source and user-friendly instrument for enhancing FMEI design.

References

[1] Domínguez, J. M., et al. (2022). DualSPHysics: From fluid dynamics to multiphysics problems. Computational Particle Mechanics. Doi: 10.1007/s40571-021-00404-2
[2] Martínez-Estévez, I., et al. (2023). Coupling of an SPH-based solver with a multiphysics library. Computer Physics Communications. Doi: 10.1016/j.cpc.2022.108581
[3] Capasso, S., et al. (2022). A DEM approach for simulating flexible beam elements with the Project Chrono core module in DualSPHysics. Computational Particle Mechanics. Doi: 10.1007/s40571-021-00451-9

Design and Analysis Requirements of Offshore Floating Energy Islands

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Summary. Offshore Floating Energy Islands have received tremendous attention in recent years as a possibility for reliable and robust solutions to combat the climate emergency and provide sustainable energy. The floating islands are comprised of many elements and modular design and assessment of these components are a key challenge, therefore, the interaction of different systems and their role in the overall energy island is a crucial aspect of the design of these structures. This research focuses on the critical requirements to assess, analyse and test offshore floating energy islands, based on multi-criteria design considerations and the interaction of modules including wind, solar, wave, tidal and hydrogen (as energy storage and transportation solutions).

Keywords: Energy Island, Offshore Floating Structures, Wind, Wave, Solar and Tidal

Introduction

Floating Energy Island (FEI) was not very well-known in the renewable energy field a decade ago; however, there has been great attention to FEI concepts as a great solution to combat climate change and provide green renewable energy. To reach the goal of global net-zero emissions by 2050, renewable energy sources including solar, wave, tidal and wind should be used in a combined manner. Considering that 40% of the world's population lives within 100 kilometres of the coasts, floating energy islands offshore is a reasonable energy production concept solution for our future demands. Floating energy structure technology has seen considerable developments in installed capacities in the past decade. However, the development of design standards and codes of practice for floating structure technologies is required to ensure robust and reliable systems that do not have detrimental impacts on the hosting water body. This paper aims to discuss the main critical design aspects and key considerations in hydrodynamics, aerodynamics and simultaneous effects from the tidal, wind and wave load actions.

Conceptual Design

Figure 1 shows a schematic layout of a FEI which can be applied to enhance ocean space utilisation and improve energy production. It is envisaged that FEI can also be used for desalination and to provide fresh water which is in line with UN sustainable development goals. In addition, the hydrogen production and transport of it using ships can be a good opportunity for shipping hydrogen to other continents.

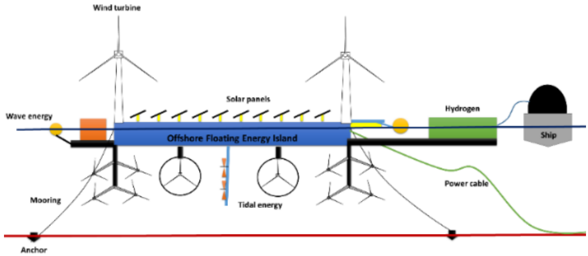

Fig. 1. Conceptual layout of floating energy island, using offshore wind, wave, and solar.

To have a reliable design, limit state analysis considering metocean, wave, wind inputs, power resource assessment, the directionality of the wave and wind, and detailed load and load effects analysis should be performed. Figure 2 demonstrates the multi-criteria considerations for the design and analysis of floating energy islands from design to shipping the products to future cities or overseas. In the first stage, the potential location can be addressed through the assessment of available renewable energy resources [1, 2]. In the technology stage, cost estimation for capital, operational and decommissioning expenditure (CAPEX, OPEX and DEPEX, respectively) as well as social, and environmental impact analysis should be included. In the design stage, the site conditions, and multi-criteria inputs including metocean and site consideration are processed. The next stage deals with the development of the technologies that might be more suitable for integration in an energy island based on reduced levelized cost of energy, carbon footprint reduction and increased ocean space utilisation and improved power production [3]. The power production can be in the form of electricity or power2x as hydrogen. The storage of hydrogen and by-products such as freshwater or oxygen needs proper process engineering for an enhanced and optimised storage system. The transport of energy either as a form of hydrogen or transmitting electricity by subsea power cables is the main scope of the last phase of integrated design. The key to proper development of energy islands is to have an integrated design and assessment where all important parameters and influencing design stages are integrated [4].

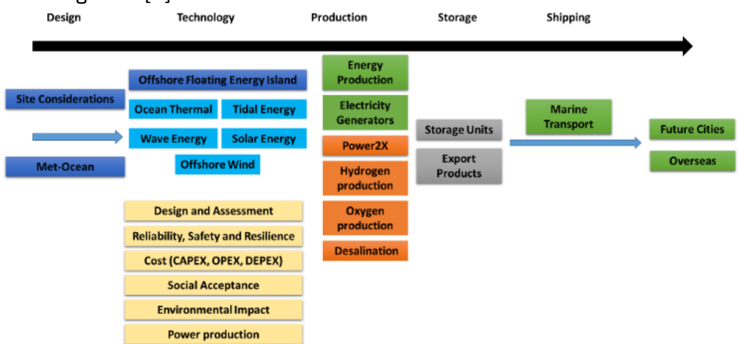

Fig. 2. Design, production and shipping of energy produced offshore using a floating energy island.

Conclusions

The design and assessment of energy islands require multi-criteria considerations which account for influence of each key parameter in parallel rather than sequential. The integrated approach not only incorporates the interactions between technologies but also accounts for multi-criteria design and assessment which is required for complex systems like floating energy islands.

References

[1] Kurniawati, I., Beaumont, B., Varghese, R., Kostadinović, D., Sokol, I., Hemida, H., Alevras, P. and Baniotopoulos, C., 2023. Conceptual Design of a Floating Modular Energy Island for Energy Independency: A Case Study in Crete. Energies, 16(16), p.5921.
[2] Østergaard, J., Christensen, E. D., Halsnæs, K., Riisager-Simonsen, C., Lisbjerg, D., Jensen, A. D., Duus, J. Ø., Madsen, H., Frandsen, H. L., Savaghebi, M., Zhang, W., Keles, D., Ladenburg, J., Vest, M. R., Seger, B., Mortensen, N. H., Sin, G., Kitzing, L., Kolios, A., Uhd, L. A. (2023). Denmark as the Energy Island Pioneer. Technical University of Denmark.
[3] Lüth, A., Seifert, P. E., Egging-Bratseth, R., & Weibezahn, J. (2023). How to Connect Energy Islands: Trade-offs between Hydrogen and Electricity Infrastructure. Applied Energy, 341, Article 121045.
[4] IEA Task 49, Integrated Design on Floating wind Arrays (IDeA), https://iea-wind.org/task49/

In-Software Simulation of Floating Modular Energy Islands: The High-Fidelity Framework of Dualsphsysics

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Summary. My work proposes the open-source software DualSPHysics as a general-purpose tool to simulate floating platforms for energy production, in which wave and wind energy can coexist.

Keywords: SPH, Project Chrono, MoorDynPlus, Wind turbine, Wave energy converter.

Introduction

Wave and wind energy research has led to the development of quite a few computational methods for the design of wind turbines and wave energy converters (WEC). By mostly targeting power production, however, most of this available modern software fleet is based on low- and mid-fidelity techniques that limit its applicability to a well-defined range of conditions. High-fidelity modeling, on the other hand, has the potential to predict the performance of offshore wave and wind energy capturing devices in a more general manner given the lesser degree of assumptions on which computational fluid dynamics (CFD) relies. Another acknowledged limitation of well-known software tools for wave and wind device simulators lies into their lack of integration with more general multiphysics tools to manage multi-body systems and their relative interconnections. DualSPHysics, an open-source solver based on the Smoothed Particle Hydrodynamics (SPH), supports the simulation of multi-body systems owing to its integration with external libraries, such as the multiphysics library Chrono [2, 3] or line dynamic solver MoorDynPlus; this software has been recently extending its capabilities for offshore structures for applications in the wave [3] and wind energy sectors [4].

Conceptual Design

To highlight the capability of DualSPHysics in simulating complex systems, which are reminiscent of floating modular energy islands (FMEI), the semi-submersible platform designed and benchmarked in [5] is herein considered. This configuration is shown in Figure 1, in which a DeepCwind platform, kept at station by three catenary lines and hosting a 5MW wind turbine, is facing regular waves. From the main cylinders, three WaveStar WECs are supported by three hinges that virtually host the power take-off system. This combination of wind and wave energy devices is initially validated under regular waves and predefined thrust wind loads on the turbine, similarly to the numerical work carried out in [5]. Preliminary results have shown that the proposed numerical model can provide very good agreement compared to the numerical tests from the reference paper. Furthermore, owing to its high-level script-based interface, the model configuration can be set up quite easily and with no additional effort for the setup of the multiphysics solvers (i.e., Chrono or MoorDynPlus).

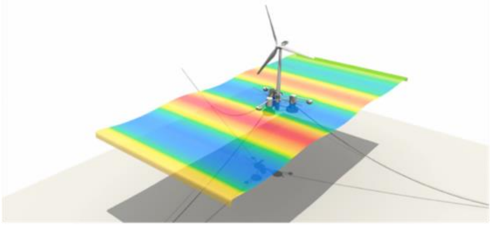

Fig. 1. Hybrid system: a floating offshore wind turbine and three wave energy converters under regular waves modeled in DualSPHysics. Reference configuration

Conclusions

Validating DualSPHysics under operational wave and wind conditions can provide an accurate and precise model in predicting environmental loads on multi-body systems intended for the simulations of energy devices. This task comes at an extra cost if compared to mid-fidelity software, being CFD-based solvers reportedly more computationally intensive. However, once this initial effort is made, the validated tool can be used with greater flexibility and potentially inform on configurations that would otherwise be out of reach for traditional engineering tools, and this can be of interest for the scope of FMEIs. Ultimately, one may consider how high-fidelity tools are an “optimal” choice when dealing with the survivability analysis of offshore devices, and FMEIs can easily be framed as such.

High-fidelity numerical models can significantly support the development and engineering of FMEIs, helping to establish recommendations and guidelines for multi-purpose platforms for energy production. Specifically, mid-fidelity numerical solutions can inform on relatively novel concepts, possibly up to Technology Readiness Level (TRL) 4, at modest costs. The use of DualSPHysics for FMEI simulations, as much as other high-fidelity simulators, can provide a significant leap forward in enhancing the understanding of the hydrodynamics that develops when considering the mechanical interaction of multiple bodies (e.g., WECs hosted by floating platforms, shared mooring systems) or when the hydrodynamic conditions extend beyond ordinary linear fields (e.g., short-range floater interaction, extreme waves). Future applications of the presented model will include two such planforms within the same computational space.

References

[1] Domínguez, J. M., et al. (2022). DualSPHysics: From fluid dynamics to multiphysics problems. Computational Particle Mechanics. Doi: 10.1007/s40571-021-00404-2

[2] Tasora A et al. (2016). Chrono: An open source multi-physics dynamics engine. In Proceedings of the European Conference on Parallel Processing (Euro-Par) (pp. 19-49). DOI: 10.1007/978-3-319-40361-8_2

[3] Martínez-Estévez, I., et al. (2023). Coupling of an SPH-based solver with a multiphysics library. Computer Physics Communications. Doi: 10.1016/j.cpc.2022.108581

[3] Tagliafierro B. et al. (2023). Numerical validations and investigation of a semi-submersible floating offshore wind turbine platform interacting with ocean waves using an SPH framework. Applied Ocean Research, 141, 103757. https://doi.org/10 .1016/j.apor.2023.103757

[4] Crespo AJC et al. (2023). On the State-of-the-Art of CFD Simulations for WECs within the Open-Source Numerical Framework of DualSPHysics. 15th EWTEC Conference 2023, University of the Basque Country, Bilbao, Spain.

[5] Jin P. et al. (2023). Optimization and evaluation of a semi-submersible wind turbine and oscillating body wave energy converters hybrid system. Energy, 282, 128889. https://doi.org/10. 1016/j.energy.2023.128889

Success Rate Focused Approach Study on Türkiye Wind Data: Wind Energy Forecasting Using Machine Learning and Design of an End-to-End MLOps Pipeline

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Summary. The study conducted a detailed comparative analysis of various machine learning models to enhance wind energy forecasts, including Linear Regression, Decision Tree, Random Forest, Gradient Boosting Machine, XGBoost, LightGBM, and CatBoost. Furthermore, it developed an end-to-end MLOps pipeline leveraging SCADA data from a wind turbine in Türkiye. This research not only compared models using the RMSE metric for selection and optimization but also explored in depth the impact of integrating machine learning with MLOps on the precision of energy production forecasts. It investigated the suitability and efficiency of ML models in predicting wind energy with MLOps integration. The study explored ways to improve LightGBM algorithm performance through hyperparameter tuning and Docker utilization. It also highlighted challenges in speeding up MLOps development and deployment processes. Model performance was assessed using the RMSE metric, conducting a comparative evaluation across different models. The findings revealed that the RMSE values among the regression models ranged from 460 to 192. Focusing on enhancing LightGBM, the research decreased the RMSE value to 190.34. Despite facing technical and operational hurdles, the implementation of MLOps has proven to enhance the speed (latency of 9ms), reliability (through Docker encapsulation), and scalability (using Docker swarm) of machine learning endeavors.

Keywords: machine learning; wind energy; MLOps; rmse; latency

Advanced Materials for Offshore Engineering: Analysing Fatigue Performance in WAAM Carbon Steel

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Summary. Additive manufacturing (AM) has recently emerged as a solution to the joint complexity in modular construction, yet its fatigue behaviour must be carefully understood. This study investigates Wire Arc Additive Manufacturing (WAAM) ER70S-6 carbon steel for applications in wind tower components. Low Cycle Fatigue (LCF) tests on printed coupons revealed that fatigue life remained consistent regardless of coupon orientation. Moreover, while WAAM materials showed promise, conventional steels doubled fatigue life under similar damage parameters.

Keywords: low-cycle fatigue, wire-arc additive manufacturing, carbon steel, ER70S-6

Introduction

Additive Manufacturing has become a versatile technology with broad applications across industries, facilitating designs that are challenging with traditional methods. Wire Arc Additive Manufacturing (WAAM) is notable for producing large steel components, though challenges persist in achieving high-quality results [1,2]. Understanding the fatigue behaviour of WAAM components is crucial for mitigating the risk of fatigue failure in critical structures subject to time-varying loading, such as offshore applications [3]. Recent advances have improved the understanding of fatigue behaviour in WAAM carbon steel [4–6], but investigations into energy-life relationships are lacking [7]. This study addresses these gaps by examining the low-cycle fatigue (LCF) behaviour of WAAM ER70S-6 carbon steel, considering loading orientation. Strain-life and energy-life relationships are derived, and a comparative analysis with conventional steel is conducted.

Conceptual Design

The feedstock material used was low-carbon AWS A5.18 ER70S-6/ISO 14341 – A – G 42 4 M21 G 3Si1 coated copper wire, 1.0 mm in diameter. Fatigue specimens were extracted horizontally and vertically relative to the printing direction of the WAAM walls and from three locations across the thickness. These samples were categorised as horizontal interior (HI), horizontal surface (HS), vertical interior (VI), and vertical surface (VS). Lastly, uniaxial LCF tests adhered to ASTM E 606-21 procedures. The analyses were conducted through three fatigue damage models: Basquin-Coffin-Manson (BCM), based on total strain amplitude; Smith-Watson-Topper (SWT) and Total Strain Energy Density (TSED), based on the dissipated energy.

Figure 1 shows the fatigue performance of the material studied in this research compared to another set of WAAM ER70S-6 [4] and conventional structural steel [8]. The investigated material exhibits inferior fatigue behaviour compared to conventional structural steels, although this inferior performance is mitigated as the strain amplitude decreases. Overall, the derived functions for the BCM model closely match, regardless of the group. Similar conclusions are drawn from the SWT and TSED models, with consistent fittings across all conditions (horizontal, vertical, and combined orientations). Overall, the models effectively predict LCF life for the studied WAAM material, which agrees with the existing literature.

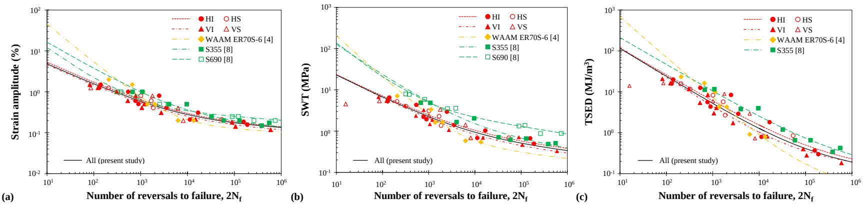

Figure 1. Comparison of fatigue performance between the tested WAAM ER70S-6 carbon steel and other conventional and additively manufactured steels: (a) strain-life relations, (b) SWT-life relations, and (c) energy-life density relations.

Conclusions

While conventional steels (S355 and S690) initially outperform the fatigue results of the examined WAAM material, this difference diminishes in the elastic-dominated region. This suggests that WAAM carbon steel, despite its slightly inferior performance, holds promise for fatigue-loaded structural components. As observed in previous literature, the lack of significant impact from coupon orientation on results further supports this conclusion. Further investigation on high cycle fatigue and fatigue crack growth is under development to expand the range of conditions studied for this material.

References

[1] Kanyilmaz A, Berto F, Paoletti I, Caringal RJ, Mora S. Nature-inspired optimization of tubular joints for metal 3D printing. Structural and Multidisciplinary Optimization 2021;63:767–87. https://doi.org/10.1007/s00158-020-02729-7.

[2] Gardner L. Metal additive manufacturing in structural engineering – review, advances, opportunities and outlook. Structures 2023;47:2178–93. https://doi.org/10.1016/j.istruc.2022.12.039.

[3] Ermakova A, Mehmanparast A, Ganguly S. A review of present status and challenges of using additive manufacturing technology for offshore wind applications. Procedia Structural Integrity 2019;17:29–36. https://doi.org/10.1016/j.prostr.2019.08.005.

[4] Zong L, Fang W, Huang C, Wang Z, Gardner L. Low cycle fatigue behaviour of wire arc additively manufactured ER70S-6 steel. International Journal of Fatigue 2023;176:107910. https://doi.org/10.1016/j.ijfatigue.2023.107910.

[5] Wang Z, Hou Y, Xu F. Experimental investigation on cyclic behaviour of wire arc additively manufactured carbon steel. Ce/Papers 2023;6:714–9. https://doi.org/10.1002/cepa.2507.

[6] Wang Z, Hou Y, Huang C, Han Q, Zong L, Chen M-T, et al. Experimental study and constitutive modelling of wire arc additively manufactured steel under cyclic loading. Journal of Constructional Steel Research 2024;213:108420. https://doi.org/10.1016/j.jcsr.2023.108420.

[7] Mendez-Morales M, Branco R, Tankova T, Rebelo C. Assessment of cyclic deformation behaviour of wire arc additively manufactured carbon steel. International Journal of Fatigue 2024;184:108307. https://doi.org/10.1016/j.ijfatigue.2024.108307.

[8] de Jesus AMP, Matos R, Fontoura BFC, Rebelo C, Simões da Silva L, Veljkovic M. A comparison of the fatigue behavior between S355 and S690 steel grades. Journal of Constructional Steel Research 2012;79:140–50. https://doi.org/10.1016/j.jcsr.2012.07.021.

Improved Dynamics of Spar-Floating Offshore Wind Turbines with Tuned Liquid Column Damper.

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Summary. The Multimegawatt floating offshore wind turbines (FOWTs) are becoming taller and slenderer to harness wind energy. These FOWTs are installed in the deep ocean bed and are subjected to constant wind-wave loading resulting in excessive vibrations. Moreover, the excessive vibrations in spar-type FOWTs may impose fatigue, which can cause unexpected failure of spar FOWT in extreme environments. Hence, to control the excessive structural vibrations of spar OWTS in harsh ocean environments, the effectiveness of a tuned liquid column damper (TLCD) is investigated. So, in the numerical study, 5MW OC3 spar FOWT is simulated under misaligned wind-wave loading. A coupled interaction model is developed using OpenFAST. It is found from the numerical simulation that TLCD is a promising solution when tuned to the lightly damped side-side direction frequency. However, the mass ratio of TLCD plays a vital role in its efficiency. It should be noted that the time histories cannot give generalized results regarding the real performance of the TLCD under the low-frequency wind-wave excitation. Moreover, the frequency response analysis, shows that TLCD significantly reduces the tower fore-aft and side-side displacement amplitude.

Keywords: Dynamics; Structural vibration control; Spar-buoy; Tuned liquid Column Damper

Introduction:

The installation of the FOWTs in deep water or complex sea bed locations is found to be economical and feasible. Commercialization of the FOWTs is a big challenge due to marine environmental loads, including wind, wave, and current, which affect theory stability and performance. Moreover, the unwanted vibration not only affects the overall structural integrity but also increases fatigue. The FOWT is a complex system consisting of mechanical and electrical components that vibrate in a certain trend under the combined wind-wave loading. Therefore, stabilizing the FOWTs under extreme ocean environments is a paramount concern. Hence, the area of vibration control for FOWTs has been a dynamic research area among scholars. These vibration control techniques are classified as active, semi-active, and passive [1]. Although considerable studies on the damping performance of TLCD on civil engineering structures have been conducted, the effectiveness of TLCD in controlling tower vibration remains unfolded. TLCD is widely adopted in civil engineering structures because of its low installation and maintenance cost and robustness to control unwanted vibrations.

Hence, in this present investigation U shaped TLCD is installed at the nacelle of the 5MW Spar FOWT to evaluate its damping mechanism. Finally, the efficiency of TLCD is determined in time and frequency domain. It is observed that, for operating condition of spar FOWT at 12 m/s wind speed, the TLCD effectively control the vibration amplitude in SS direction.

Conceptual Design

TLCD model description

A schematic diagram of a TLCD is shown in Figure 1. The flow is considered as incompressible. Av and Ah are the cross-section areas in the vertical and horizontal columns, respectively. The system parameters of the spar-FOWT used in this article are obtained from [2]. The natural frequency of the TLCD can be obtained using Equation (1)

$$\omega_d = \sqrt{\frac{2g}{L_e}} \quad \text{rad/s} \tag{1}$$

where L_e = B+2Lv is defined as the effective length. η is the head loss coefficient.
The mass of the liquid inside the TLCD can thus be calculated using Equation (2)

$$m_l = \rho(2L_v + B) \tag{2}$$

α is the ratio of A_v and A_h

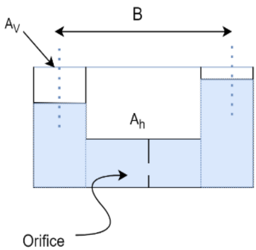

Figure 1. Schematic diagram of TLCD

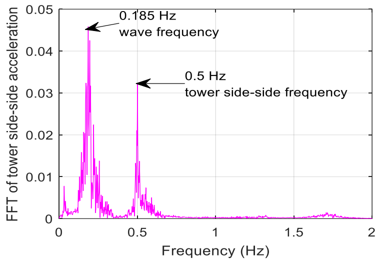

Figure 2. Tower side-side response spectrum

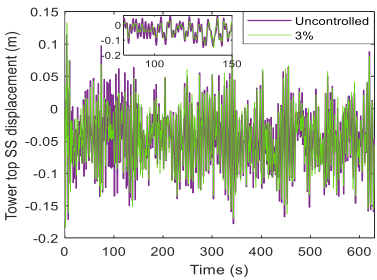

Figure 3. Time history of tower displacement in SS direction with different mass ratios of TLCD

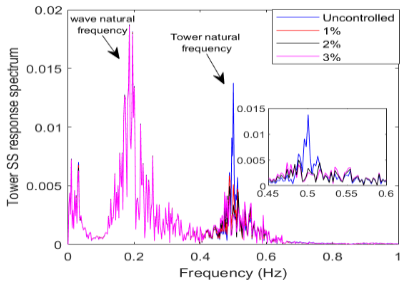

Figure 4. Uncontrolled and controlled response

Conclusions

The TLCD of mass ratio 3% is found to reduce the peak displacement response to 29%. Also, the spar roll frequency is found to be slightly suppressed under the effect of TLCD.

References

[1] Spencer Jr, B. and S. Nagarajaiah, *State of the art of structural control.* Journal of Structural Engineering, 2003. **129**(7): p. 845-856.

[2] Dinh, V.N. and B. Basu, *Passive control of floating offshore wind turbine nacelle and spar vibrations by multiple tuned mass dampers.* Structural Control and Health Monitoring, 2015. **22**(1): p. 152-176.

An Efficient Computational Model for the Dynamics of Offshore Wind Turbines' Mooring Lines

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Summary. This study fits within the present efforts in seeking renewable-energy sources, specifically, by attaining necessary information for its efficient implementation. Among established alternatives, Floating Offshore Wind Turbines (FOWT) are examined, considering their widening importance, soil consuming benefit and low landscape disturbance. The present investigation focuses on the dynamics of the mooring lines for floating platforms, delivering an accurate yet affordable approach for its deformation appraisal, considering, moreover, the interaction with the flow and with the floating platform.

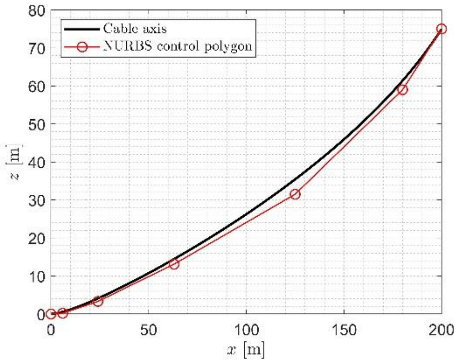
Keywords: mooring lines, fluid-structure interaction, floater, Offshore Wind Turbines.

Introduction

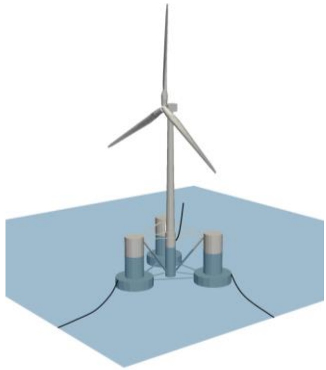
The increasing demand for energy provision was, hitherto, mostly satisfied by non-renewable resources, mainly by fossil-derived fuels. Global efforts for an energetic transition towards renewable sources of energy are now among the urgent topics of the scientific interest, and fitting within this context, the present study focuses on a current arising alternative source, namely, on wind turbines. Among its possible siting, offshore farms are unarguably provided by greater wind flows, which maximize the energetic provision but, on the other hand, may threaten structural stability and lead to its fatigue, directly (aero-dynamics) and indirectly by arising extreme waves (fluid-structure interaction). Monopile footings, which currently represent the predominant type for near-shore turbines, become, in deep-sea locations, economically and technically unaffordable whereas floating platforms may represent an optimal solution [1], requiring though an adequate mooring system. The latter covers not only the role of anchoring the structure, as it is also crucial to its stabilization, and by so ensuring the operational necessary conditions. This work therefore investigates the dynamic response of the mooring lines to the coupled effects of the impinging waves and floating platform. In this context, the mooring represents the essential link between the wind harvesting and the offshore siting, and insight of such importance, we aim to implement a procedure with precise computation of the involved dynamics.

Conceptual Design

Mooring line modeling is a key aspect for a reliable prediction of the turbine's structural response. In accordance, as mentioned above, this study intends to deliver an efficient yet precise routine for its computation. The Isogeometric Collocation analysis (IGA-C[2]) hereby represents an optimal procedure, by combining the smoothness of Non Uniform Rational Basis Functions (NURBS[3]), from Computer Aided Design (CAD) codes, with collocation methods, whose computational efficiency derives from the discretization of the strong form of the governing equations; it is thus able to reconstruct the exact geometry of the moorings undergoing large displacements [4]. In view of the line's slenderness, the problem may be simplified by approximating the sea loads using the Morison equation [5]. Moreover, the computation is resumed to the mooring centerline as sufficient representation of the whole mechanics.



(a)



(b)

Fig. 1. Mooring for offshore turbines: a) geometry reconstruction of the cable axis with NURBS,
b) illustration of a FOWT.

The spatial discretization, implemented with the IGA-C method, is ultimately improved by operating a prior subdivision of the line in subsequent patches [6]. For the dynamic analysis, the time discretization is carried out inside a Newmark implicit time-integration frame [7]. The wave loads are imposed on the platform, and its motion updates the effects accounted for on the linked anchoring end (Figure 1.b).

Conclusions

The work presents a solid procedure for the computation of the dynamics involving immersed cables, suited for the mooring of offshore wind turbines, using a multi-patch Isogeometric Collocation routine with implicit dynamics. The innovative aspect of the study consists in the coupling of the geometrically exact dynamics of the highly deformable cable with that of the rigid-body platform, which sets a cornerstone for the extension to a nonlinear model formulation. Furthermore, insight of the crucial importance of the soil-linking component to the structure's stability and consequently, service operation, future works will pursue a two-way coupling between the fluid and the platform-mooring system to thoroughly grasp the engaged dynamics.

References

[1] E. C. Edwards, A. Holcombe, S. Brown, E. Ransley, M. Hann, and D. Greaves. "Evolution of floating offshore wind platforms: A review of at-sea devices". Renewable and Sustainable Energy Reviews 183 (2023), 113416.
[2] F. Auricchio, L. Beirao D. Veiga, T. Hughes, A. Reali, and G. Sangalli. "Isogeometric collocation methods". Mathematical Models Methods in Applied Sciences - M3AS 00 (2010).
[3] F. Auricchio, F. Calabro, T. Hughes, A. Reali, and G. Sangalli. "A simple algorithm for obtaining nearly optimal
quadrature rules for NURBS-based isogeometric analysis". Computer Method in Applied Mechanics and Engineering Volumes 249–252 (2012), 15–27.

[4] E. Marino. “Isogeometric collocation for three-dimensional geometrically exact shear-deformable beams”. Computer Methods in Applied Mechanics and Engineering 307 (2016).
[5] J. Morison, J. Johnson, and S. Schaaf. “The Force Exerted by Surface Waves on Piles”. Journal of Petroleum
Technology 2.05 (1950), 149–154.
[6] D. Ignesti, G. Ferri, F. Auricchio, A. Reali, and E. Marino. “An improved isogeometric collocation formulation
for spatial multi-patch shear-deformable beams with arbitrary initial curvature”. Computer Methods in Applied
Mechanics and Engineering 403 (2023), 115722.
[7] E. Marino, J. Kiendl, and L. De Lorenzis. “Isogeometric collocation for implicit dynamics of three-dimensional beams undergoing finite motions”. Computer Methods in Applied Mechanics and Engineering 356 (2019), 548–570.

Enhancing Energy Island Efficiency: The Role of Particle Dampers

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Summary. A particle damper is a passive damping method that leverages the high-damping properties of granular materials. The proposed damper in this study aims to optimize energy dissipation by incorporating a composite blend of high-density and low-density particles. The force results indicate a balance that is sufficient to dissipate energy effectively while remaining low enough to prevent damage to the particles or the damper structure. This research focuses on the design and implementation of a particle damping system specifically for offshore wind turbines on energy islands, where harsh environmental conditions intensify structural vibrations.

Keywords: wind turbines, vibration control, particle damper, discrete element method

Introduction

Energy Islands are artificial offshore platforms designed to generate substantial amounts of renewable energy, primarily through offshore wind farms, to power nearby regions. Vibrations in the structural components of floating offshore wind turbines (FOWTs), particularly those located in deep water far offshore, can significantly reduce their fatigue life and increase maintenance needs. Particle dampers offer a promising solution for controlling these vibrations in FOWTs.

The effectiveness of a particle damper in dissipating energy is influenced by several factors, including the type of granular materials, filling ratios, particle size, and shape. Previous research has utilized rubber [1,4] and steel particles [2] to mitigate excess vibration in wind turbine towers, blades [3], and stators. This study examines the impact of various granular materials in a particle damper on vibration attenuation, with the goal of optimizing the performance of floating offshore wind turbines (FOWTs).

Conceptual Design

Particle dampers provide effective damping across a broad frequency range due to the collective behaviour of numerous particles interacting through collisions and friction. This characteristic allows them to dynamically adapt to the varying and unpredictable vibrational spectra encountered in offshore wind turbines. In this study, the particle damper is numerically modelled using Discrete Element Method software Ansys Rocky DEM. The damper consists of a steel box with dimensions of 370 mm in length (X), 300 mm in width (Z), and 100 mm in height (Y). It contains 30 spherical balls, each with a diameter of 0.01 m. The system is subjected to harmonic motion in the lengthwise direction with an excitation frequency of 2.76 Hz and an amplitude of 0.038 m. The study examines three cases: (1) using only steel balls (density ρ = 7850 kg/m^3, Young's modulus E = 200 GPa), (2) using only rubber balls (ρ = 1200 kg/m^3, E = 0.1 GPa), and (3) using an equal mix of steel and rubber balls. A schematic of the particle damper for case 3 at time=3.2s of simulation is shown in Fig. 1(a), where the red and blue colours indicate soft and hard particles, respectively. The average force on the walls in the x-direction is compared in Fig. 1(b). The normal and tangential forces on the particles are compared in Fig. 2.

Steel, being denser and harder, exhibits higher normal forces and better collisional damping, while rubber, due to its elasticity, shows tangential forces closer to those of steel. However, the use of steel can also increase wear and potentially lead to degradation of particle damper over time. The goal is to achieve optimal interactions where energy is efficiently dissipated without causing excessive wear or compaction of the damping material. Therefore, using a mix of hard and soft materials, as in case 3, where the forces are intermediate between those observed in the other two cases, can be a potential solution.

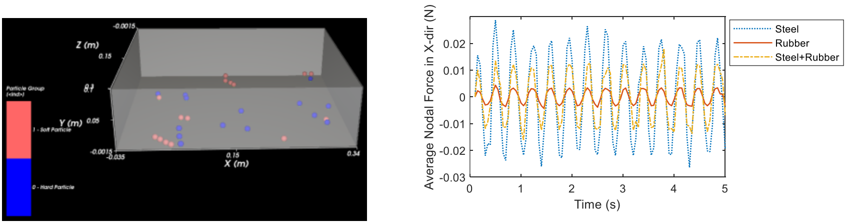

Fig. 1. (a) Schematic diagram of Particle damper at t=3.2s (b) Average force on walls over time

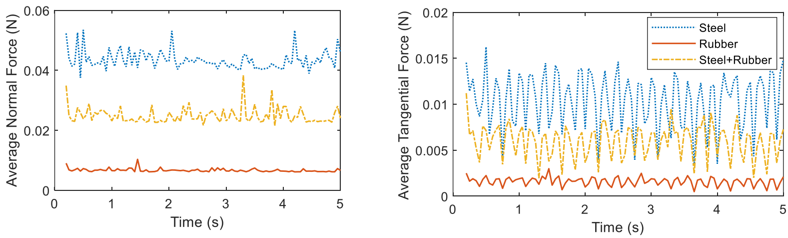

Fig. 2. Average force of particles over time (a) Normal (b)Tangential

Conclusions

Particle dampers are highly reliable for long-term wind turbine operation due to their simple design, ease of installation, and low maintenance needs make them a practical and efficient solution for mitigating vibrational issues in wind turbines. In the present study, a combination of soft and hard materials is used in the particle dampers to achieve the desired balance of damping performance and durability. This design is specifically tailored for offshore floating wind turbines on energy islands, targeting a broad range of frequencies typical of wind-induced excitations or earthquakes.

References

[1] Stauber, J. et al., Wind turbine noise attenuation using modal structural damping, In Proceedings of the INTER-NOISE and NOISE-CON Congress and Conference Proceedings, pp. 2696–2704, Hamburg, Germany, 21–24 Aug, 2016.

[2] Chen, J. et al., Experimental research on design parameters of basin tuned and particle damper for wind turbine tower on shaker, Structural Control Health Monitoring, vol.26, 2019. DOI: 10.1002/stc.2440

[3] Sandanshiv, S.R.; Chavan, U.S. Vibration suppression effects on rotating wind turbine blade using a particle damping method, vol. 29, Vibroengineering Procedia, pp. 43-48, 2019. DOI: 10.21595/vp.2019.20944

[4] Prasad, Braj Bhushan et al., Application and damping mechanism of particle dampers, Proceedings in Applied Mathematics & Mechanics, vol. 22.1, pp. e202200116, 2023. DOI: 10.1002/pamm.202200116

SPH Modeling of WECs Within Floating Multipurpose Energy Platforms

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Summary. This work deals with the numerical simulation of a multipurpose floating platform, composed of a wind turbine, an aqua-culture system, and a set of Wave Energy Converters (WECs). In particular, the study focuses on the modelling and estimating the energetic performance of the WEC devices, carried out implementing an innovative method within the SPH computational framework.

Keywords: energy island, multipurpose floating platform, OWC, pneumatic Power Take-Off

Introduction

The use of renewable energies has been having a predominant role in reducing the environmental impact of human activities. A new concept based on the idea of combining many renewable energy sources within the same floating island has been study and is thought to be very effective. It can be highly advantageous both in terms of combined exploitation of off-shore energy sources and of cost reduction since the same infrastructure would be utilized for various purposes (Kurniawati et al., 2023). This study presents the stages required to modelling, through Smoothed Particle Hydrodynamics (SPH), a multipurpose floating platform equipped with modular units of Oscillating Water Column (OWC) devices.

Conceptual Design

The floating platform (Ruzzo et al., 2022) that inspired this investigation has been engineered and tested in the NOEL laboratory in Reggio Calabria, Italy (Fig.1(a)).

Along with a prototype of a wind turbine, the platform is fitted with an array of OWCs on its fore side. The aim of this work is to simulate the behaviour of those OWC devices (side view represented in Fig.1 (b)) integrated in this floating structure and study their energy conversion capabilities while accounting for the platform motion. The energy conversion process of an OWC involves a pneumatic Power Take-Off (PTO) system: when water oscillates in the device chamber, the compression and decompression of the trapped air determines an airflow which activates a turbine connected to a generator that transforms wave energy into electricity.

To deal with complex structures, such as the multipurpose floating platform under analysis, we first identify a simplified system on which the performance evolution of OWCs in relative motion with the water free surface is studied. Then, more degrees of freedom and interactions, such as the platform mooring system and the PTO, are included to support the full complexity of the system. Thus, a fixed stand-alone OWC is simulated through the Lagrangian Software DualSPHysics (Domínguez et al., 2022), including its PTO system. To do so, an innovative single-phase approach, as presented by Zhu et al., (2020) is employed, allowing to save computational time while keeping reasonable results. Following this initialization phase, the same model will be used to investigate floating OWCs under predefined spectrum definitions, for which reference solutions are available. Lastly, the next steps consist in coupling the OWCs with the floating platform motion and understanding the optimal configuration and distance among them to get the best energetic performance.

(a) (b)

Fig. 1. Multipurpose floating platform (reproduced from https://thebluegrowthfarm.eu/); a) platform installed in the NOEL laboratory, b) side view of the OWC modular unit. The coloring scale indicates the velocity magnitude.

This investigation is supported by COST, the results obtained during the cooperation period will be presented in final presentation.

Conclusions

An innovative tool within the SPH framework will be adopted to model effectively the pneumatic PTO system of fixed and floating OWC devices, leveraging the advantages of a Lagrangian method and, at the same time, keeping a low computational impact as only one fluid phase will be included within the targeted applications. Furthermore, the aim of the OWCs energy conversion performance study is to determine whether they are effective, and which is their optimal configuration in an FMEI framework. The outcome of this research will be informative for technical and economical processes that could eventually lead to integrate OWCs into more complex structures to balance and support the overall power production of multipurpose platforms

References

[1] Kurniawati, I. et al., Conceptual Design of a Floating Modular Energy Island for Energy Independency: A Case Study in Crete, *Energies*, *16*, 5921, 2023. DOI: 10.3390/en16165921.
[2] Ruzzo, C. et al., Field experiment on a scaled prototype of a floating multi-purpose off-shore platform: Dynamic response determination with uncertainty quantification, Applied Ocean Research, 129, 2022. DOI: 10.1016/j.apor.2022.103402
[3] Domínguez, J. M. et al., DualSPHysics: from fluid dynamics to multiphysics problems, Computational Particle Mechanics, 9(5), 867–895, Sept. 2022. DOI: 10.1007/s40571-021-00404-2
[4] Zhu, G. et al., Hydrodynamics of onshore oscillating water column devices: A numerical study using smoothed particle hydrodynamics, Ocean Engineering, 218, 108226, 2020. DOI: 10.1016/j.oceaneng.2020.108226

Innovative Data-Driven Approach for Detecting Mooring Line Damage in Floating Offshore Wind Turbines

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Summary. The reduction of mooring line stiffness significantly impacts the structural integrity and operational performance of floating offshore wind turbines posing a substantial challenge to their development. This paper proposes an innovative supervised data-driven methodology to classify structural damage induced by the reduction of mooring line stiffness in the DeepCwind semisubmersible floating offshore wind turbine. The proposed method employs acceleration data collected at the tower of a semisubmersible platform. The study presents a novelty detection method, where healthy and damaged condition data are used to train and test machine learning algorithms. Any significant deviation observed during the operational conditions is identified as damage in the mooring lines. This process consists of three main steps: data pre-processing to extract time-domain features and isolate environmental variations, training supervised machine learning classifiers using the extracted features, and conducting real-time classification to assess the damage in the mooring lines. The results demonstrate high robustness and efficiency in detecting the damage in the mooring lines under various environmental conditions. Additionally, the research highlights the feasibility of identifying damage occurs in the mooring lines by investigating the dynamic characteristics of floating offshore wind turbines, presenting new opportunities for condition monitoring of floating offshore structures.

Keywords: Semisubmersible, Mooring lines, supervised, Machine learning, damage detection, SHM.

Introduction

Floating offshore wind turbines (FOWT) can generate more energy from deeper waters compared to current shallow water fixed offshore wind turbines. However, condition monitoring of FOWT is costly and requires highly skilled technicians and specialized equipment, increasing maintenance cost. To address this challenge, Structural Health Monitoring (SHM) methods provide a practical approach to detecting the damage occurring in the structure by utilizing the modal properties as damage-sensitive features. Machine learning offers a new solution to these challenges and can predict the dynamic responses of FOWTs using the SADA methodology. This system was developed in a coupled aero-hydro-servo-elastic in-house program and a machine learning policy decision algorithm trained using experimental data of a Hywind Spar-type FOWT. The results indicated the model's capability to predict the mean values of the platform's motions[1]. Moreover, structural damage detection of FOWT blades achieved an accuracy of 99.9% using Long Short-Term Memory and Gated Recurrent Unit neural networks[2]. Additionally, predicting the mooring line tension of a spar-floating wind turbine indicated the potential of incorporating artificial neural networks in the mooring design process[3]. The literature review highlights a shortage of studies focused on detecting damage in the mooring lines of FOWTs. To overcome this limitation, this paper introduces a novel data-driven algorithm to detect the damage in mooring lines by employing the acceleration data collected along the tower height under operational conditions.

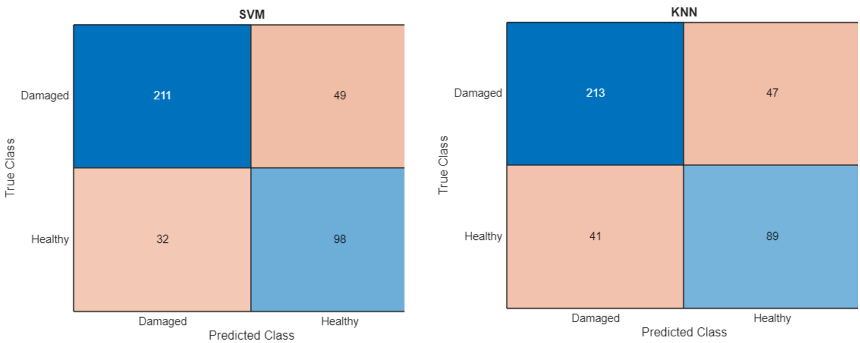
Conceptual Design

1. Methodology

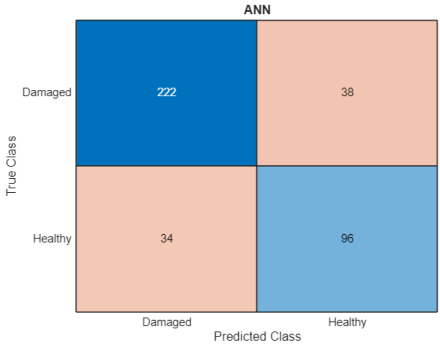
In this paper, the acceleration data collected from the tower top of DeepCwind semisubmersible platform is utilized to detect stiffness reduction damage in mooring lines. The dynamical performance of the wind turbine under operational conditions is simulated using Ansys Aqwa Software. The model is validated with both experimental data and aNYSIM numerical findings, accounting for linear and quadratic damping in the analysis. The simulations are conducted under operational conditions with a wind speed of 24m/s, and the sea state is modelled using the JONSWAP spectrum with a wave height of 6 m and a wave period of 9.5 seconds. The proposed framework comprises three main components: data pre-processing, training mode, and damage classification mode. Features are extracted from the dataset, and then the ANOVA algorithm is used to select the most appropriate features, thereby reducing the dimensionality of the dataset. The selected feature vectors serve as inputs to supervised learning models such as Support Vector Machine (SVM), K-Nearest Neighbor (KNN), and Artificial Neural Network (ANN) for classifying the damage. The model is trained on healthy and damaged data obtained under operational conditions to develop a well-trained machine-learning algorithm. Real time data is then utilized to detect the stiffness reduction damage in the mooring lines.

2. Results

The confusion matrices illustrated Figure 1 show that the proposed algorithm effectively detects damage in the mooring lines. The results highlight that the ANN algorithm achieves high accuracy in detecting the damage occurrence in the model, with an accuracy of 82%, followed by the SVM, and KNN algorithms, which achieve accuracies of 79%, and 77% respectively. Overall, the results indicate that the proposed model presents an acceptable accuracy for detecting the stiffness reduction damage that occurs in the mooring lines.



(a) (b)



(c)

Figure 2. Confusion matrix for detecting the damage occurs in the mooring lines of FOWT using, a) SVM, b) KNN, c) ANN algorithms.

Conclusions

The reduction of mooring line stiffness significantly impacts the operational performance of semisubmersible floating offshore wind turbines. To detect damage in the mooring lines, this paper presents a data-driven vibration-based damage detection methodology. The proposed algorithm is trained using acceleration data obtained at the tower top under operational conditions in both healthy and damaged states. This framework offers a robust solution for detecting stiffness reduction damage in the mooring lines and demonstrates high performance under various conditions.

References

[1] P. Chen, J. Chen, and Z. Hu, "Software-in-the-Loop Combined Reinforcement Learning Method for Dynamic Response Analysis of FOWTs," *Front Mar Sci*, vol. 7, Jan. 2021, doi: 10.3389/fmars.2020.628225.

[2] D. E. Choe, H. C. Kim, and M. H. Kim, "Sequence-based modeling of deep learning with LSTM and GRU networks for structural damage detection of floating offshore wind turbine blades," *Renew Energy*, vol. 174, pp. 218–235, Aug. 2021, doi: 10.1016/j.renene.2021.04.025.

[3] F. A. Bjørni, S. Lien, T. A. Midtgarden, G. Kulia, A. Verma, and Z. Jiang, "Prediction of dynamic mooring responses of a floating wind turbine using an artificial neural network," *IOP Conf Ser Mater Sci Eng*, vol. 1201, no. 1, p. 012023, Nov. 2021, doi: 10.1088/1757-899x/1201/1/012023.

Automated Preliminary Estimation of CAPEX and its Contribution to LCOE for FMEIs

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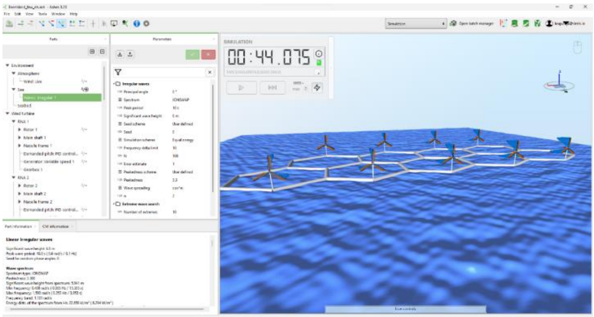
Summary. Arguably, the most important obstacle for increasing the speed of deployment of offshore renewable energy, particularly wind and solar energy, is the high levelized cost of energy (LCOE). Compared to traditional fossil energy, CAPEX plays a dominating role since the fuel is free and operations (OPEX) require much less resources. Thus, to increase the speed of deployment of offshore renewable energy, it is essential to lower LCOE by lowering the CAPEX.

Here, we focus on lowering LCOE by improving simulation, analysis and design engineering software in terms of (partly) automating both configuration of Floating Modular Energy Islands (FMEIs), preliminary design as well as estimation of CAPEX and lifetime energy production. The goals are: decreasing cost of engineering design while increasing the speed, and concurrently lowering LCOE through optimization.



Keywords: offshore renewable energy, CAPEX, FMEI, LCOE.

Introduction

FMEI is a concept that has been introduced as an idea to lower LCOE for offshore renewable energy (particularly wind and solar). The main appeal of the idea is that infrastructure can be shared among power plants (wind turbines and PV arrays).

The FMEI concept is in a very early stage and no full-scale plants have yet been built. Arguably, it is necessary to find configurations that yields both a lower LCOE than already commercialized offshore renewable energy concepts and plants and LCOE comparable with (and hopefully lower than) conventional energy technologies such as fossil fuel and nuclear.

The development, engineering and specification of FMEIs that have a sufficiently low LCOE to be considered as a serious and relevant alternative, is limited by available simulation, analysis and design engineering software. Existing engineering software suffers from the following issues (among others):

- only used for conventional structures and concepts

- requires manual work making design work expensive and time consuming
- not suitable for optimization
- long simulation time and costly simulations

Thus, the task of making FMEIs a viable and interesting concept for the important task of speeding up the transition from fossil fuel to renewable energy, is hampered by the limitations of available engineering software.

Conceptual Design

The Ashes platform for engineering software is being improved to become more feasible in the development and optimization of FMEIs.

The primary goals of the current improvements for preliminary optimization and design of Ashes are:

- Adjust (automatic or manual) the comprehensiveness (including number of load cases, duration of simulations, number of IEC DLCs etc.) to the available time and computing resources
- Facilitate quick layout/configuration, e.g. number of modules and rated power
- Enable optimization by automating generation of configuration/layout variations

Results: in particular, we are presenting the following features.

1. Generate FMEIs based on size parameters, for example number of wind turbines or total rated power.
2. Generating load cases based on a specified limited number of IEC DLCs, typically IEC DLC 1.1 and 6.2.
3. Generating corresponding metocean conditions from wind rose and wave scatter diagram.
4. Estimate the duration of the simulations given the available computer resources.
5. If necessary to reduce the duration (e.g. from 24h to overnight), go back to 1 to make larger (coarser) bins for wind and waves and/or shorter simulation time and/or fewer DLCs.
6. Run simulations, for example overnight.
7. ULS and FLS design report are automatically generated (with relatively large uncertainty). Conclude if the design is acceptable for ULS and FLS.
8. Coarse estimate of costs of the FMEI, along with both energy production and energy value over its lifetime. Thus, the CAPEX contribution to the LCOE can be estimated.

Conclusions

The usefulness and quality of this approach hinges on the closeness to a future final design as well as energy production. In particular, it will be valuable to reliably quantify the interval of uncertainty for both CAPEX and energy production/value. This can be done with benchmarking against built projects. Whereas the value of the results diminishes with an increasing interval of uncertainty, even quite large intervals (up to +/-50%) are assumed still to be useful at an early screening stage.

Abstracts – Working Group 3

Key Principles for Sustainable and Resilient Modular Energy Islands

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Summary. The present paper discusses the key principles for the development and operation of resilient and sustainable modular energy islands as analyzed in terms of COST ACTION CA201091 WG3. By discussing existing methodological approaches, it concludes with a number of critical directions towards this scope.

Keywords: modular energy islands, sustainability, resilience, risks

Introduction

Resilience describes the ability of the infrastructure, communities, and related systems to adapt, mitigate, or respond to stresses in a way that maintains, restores, or improves their essential functions. Managing resilience involves designing infrastructure to withstand current and future hazards and risks [1].

Resilient infrastructure is considered an indispensable and important action to achieve sustainable development. Building resilience into infrastructure systems is estimated to add just 3 percent to the total investment cost, a fraction that can be easily recouped with the benefits they provide during the lifetime of an infrastructure asset[2]. Modular Energy Islands are particularly exposed to hazards throughout their lifetime, particularly liable to aggressive environments including slow onset events but also catastrophic actions. The objective of this paper is to review the key principles that underpin Sustainable and Resilience Modular Energy Islands and to spearhead address methodologies for sustainability and resilience towards risk assessment.

Conceptual Design

With regards to the resilience of a system, Woods [2] identified four directions:

a) resilience as at to rebound from stressful/traumatic events and return to previous normal activities and state of equilibrium;
b) resilience is seen as the robustness of a system or capacity to manage complexity, stressors, and challenges;
c) resilience linked to extensibility when surprising events push the system beyond its boundaries; and
d) resilience in the context of sustained adaptability as a condition that the system may suffer changes over a long time scale.

Regarding a socio-technical system that includes humans, technology, and organizational settings, resilience is seen as the ability of the system to support operations and achieve goals within the context of anticipated and unanticipated events [3]. Resilience is linked to sustainability and is at the core of a cross-cutting concept for the Sustainable Development Goals (SDGs) targets. Resilience is a multi-faceted concept that draws upon various fields and disciplines [4]. Samuel and Samuel [5] identified that the energy resilience of the Caribbean Islands is linked to the shift to renewable energy, diversification of energy mix, and development of energy infrastructure, particularly the modular usage of microgrid technology. With regards to the resilience of an infrastructure linked to energy, they brought to attention four aspects: 1) building robustness of the physical infrastructure and strengthening operation; 2) resourcefulness, which ensures that infrastructure remains in operation during impact from an event; 3) recovery and speed-up of the recovery process and 4) adaptive learning to ensure that vulnerabilities and failures do not occur again in the future [5]. Energy resilience, reliability of energy supply, and efficiency are critical elements for energy security [6]. The concept of energy resilience refers to a secure supply of energy, affordable access to energy, and moderate environmental impact, despite changes and disruptions. Moreover, energy resilience is linked with the role of energy systems in developing adaptive capacity and the role of governance and policies [7]. For Pacific islands, energy resilience is linked to the adoption acceleration of renewable energy, redundancy and diversity in grids, decentralization of power generation off-grid, coordination of investments, policy and project planning, and the role of governance at all levels and cooperation [7].

Energy security is one of the key matters after the impact of natural hazards [8]. Therefore, energy islands that can provide flexibility and transmit energy to where it is most needed can have a strategic purpose. Modular energy islands can combine the production of several, such as wind and solar energies, and store excess energy during periods of excess, so power can be distributed where needed most urgently when demand peaks.

Additionally, focus should be given to the infrastructure, from the design to the installation phase [9], considering several floating installations, and/ or artificial islands [10,11].

Considering energy islands as energy hubs for variable type energy production, connectivity and energy transmission to the shore safely and stably is of vital importance. To provide stable operation and necessary resilience for such complex power systems, the energy island microgrid is supposed to include various power equipment. Large amounts of renewable production and points of common coupling, storage facilities, and transmission submarine solutions to the onshore grid hint that power system flexibility and resilience are required. The complexity of the energy island microgrid and its interaction with offshore marine generation and onshore grid impose the power system operator new operational challenges and need to use the most advanced technology and operation approaches.

Different sustainability-related or resilience-related methodologies as well as sustainability or resilience indicators and applications are being applied to infrastructure projects and can be exploited for Modular Energy islands.

Sustainability assessment offers an opportunity to define a system through key performance indicators, which are also quantifiable. The approach is generally based on Life Cycle Analysis methodologies including life cycle assessment, life cycle cost analysis, life cycle social assessment as well as other methodologies material flow analysis, substance flow analysis, energy analysis, exergy analysis, and cost-benefit analysis (single/combined methodologies).

Applications to Modular Energy Islands reflect the structural systems involved and their engineering characteristics concerning their durability, performance in service, and exposed coastal and marine environments. This is particularly important when considering the lifetime of such structures having a significant impact on the Life Cycle Assessment.

To monitor and assess the resilience of floating islands a detailed risk management approach should be followed. Critical infrastructures and higher-risk procedures need to be addressed at an early stage before the installation. When failures occur, a resilient system should continue to operate, activating a proper (per instant/case) mitigation strategy to deal with the failure and at the same time, when needed, activate alternative actions. Each action should provide input to a knowledge-gaining database to avoid future repeating threats and train the system towards resilience. That way, the failure is absorbed, and the system remains untouchable while the defense strategies are activated.

Resilience assessment refers to risk assessment methodologies including Risk matrix approaches, Failure Mode Effects Analysis, and/or using the Bowtie Model or Decision trees or dedicated approaches like the Geospatial Risk and Resilience Assessment Platform.

These approaches are particularly relevant given the extreme offshore exposure conditions and lifetime expectations of modular energy islands, in service. In particular, these systems are linked to energy infrastructure which requires reliability and continuity of service.

Conclusions

Considering the methodologies used to assess the sustainability of systems & infrastructures, the resilience monitoring approaches, and the potential risks related to modular energy islands development it is critical to carefully plan and constantly monitor the future development of these floating installations. By analyzing the processes, identifying failure modes, assessing risks, setting and prioritizing mitigation strategies, enabling predictive maintenance, demonstrating the efficient use of energy storage considering all technical, economic, environmental, and social directions, and considering optimal integration requirements, added value possibilities may arise in terms of increased reliability and improved design and operational processes.

Additionally, developing several scenarios for the future development and operation of Modular Energy Islands will enhance the preparedness of installations and opportunities for (near)optimal operation. These scenarios should be developed and tested considering the proximity from the shore, potential use of energy resources, design infrastructure possibilities, water depth, and system reliability.

In conclusion, planning towards developing resilient and sustainable modular energy islands requires proper risk identification, hierarchy, and monitoring, development of proper mitigation and sustainability-related strategies, situational awareness, resource management, installation of smart and resilient infrastructure, various stakeholder engagement, increased preparedness (coordination) to deal with emergencies, community awareness, and training.

References

[1] Khan F., Yarveisy R., Abbassi R. Risk-based pipeline integrity management: A road map for the resilient pipelines, Journal of Pipeline Science and Engineering, 2021, Volume 1, Issue 1, Pages 74-87, ISSN 2667-1433, https://doi.org/10.1016/j.jpse.2021.02.001.

[2] Woods, David D. Four concepts for resilience and the implications for the future of resilience engineering. Reliability Engineering & System Safety, 2015. 141: 5–9.

[3] Schröder-Hinrichs Praetorius, G., Graziano, A., Kataria, A. and Baldauf, M. Introducing the Concept of Resilience into Maritime Safety. In: P. Ferreira, J. van der Vorm, D. Woods (ed.), 2016. Proceedings: 6th Symposium on Resilience Engineering: Managing resilience, learning to be adaptable and proactive in an unpredictable world. 22nd-25th June 2015 at Lisbon, Portugal (pp. 176-182).

[4] Talubo, J. P., Morse, S., & Saroj, D. (2022). Whose resilience matters? A socio-ecological systems approach to defining and assessing disaster resilience for small islands. Environmental Challenges, 100511.

[5] Ade Samuel and Wendell Samuel. Energy Resilience in the Caribbean. Paper presented to 51st Monetary Studies Conference. Held at the Eastern Caribbean Central, Basseterre, St. Kitts, November 19-22, 2019

[6] Giachetti, R.E.; Van Bossuyt, D.L.; Anderson, W.; Oriti, G. Resilience and Cost Trade Space for Microgrids on Islands. IEEE Syst. J. 2021, 1–11.

[7] Darcy Small, Ashleigh Nicholls, Thomas Jeffrey, Anna Bruce, Iain MacGill, Paul Munro, Atul Raturi, Manu Rawali, Long Seng To. Energy resilience in Pacific island. Workshop background paper. 2020. Available: https://www.ceem.unsw.edu.au/sites/default/files/documents/Energy%20Resilience%20in%20Pacific%20Island%20Countries%20and%20Territories%20FINAL%20v2.pdf <accessed 31.05.2024>

[8] Weir, T., Kumar, M. Renewable energy can enhance resilience of small islands. Nat Hazards 104, 2719–2725. 2020. https://doi.org/10.1007/s11069-020-04266-4.

[9] Lister N., Muk-Pavic E., Sustainable artificial island concept for the Republic of Kiribati, Ocean Engineering, Volume 98, 1 April 2015, Pages 78-87, ISSN: 0029-8018, https://doi.org/10.1016/j.oceaneng.2015.01.013 (31.05.2024)

[10] Littlefield D., Jones W., Troll A Gas Platform, North Sea, Off Norway/ Great Modern Structures, 100 Years of Engineering Genius, 2012, Pages 262-265, Carlton Books, ISBN:978 1 78097 001 1

[11] Littlefield D., Jones W., 5M Wind Turbine, Moray Firth, UK/ Great Modern Structures, 100 Years of Engineering Genius, 2012, Pages 274-275, Carlton Books, ISBN:978 1 78097 001 1.

Utilization of Modular Energy Islands with High Green Hydrogen Production: A P2x Example

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Summary: Over the past decades, eliminating the ongoing problems of global warming has been one of the world's current aims. Therefore, renewable energy systems allow humanity to produce zero-carbon energy. Recent developments regarding renewable-based generation have led to utilize effectively. On the other hand, hydrogen production, storage, and utilization as fuel for different applications like re-electrification or catalysis for natural gas are attracting considerable interest due to their stable nature and resource diversity, contrary to solar and wind. In this context, energy islands have been established near consumption points to serve as energy hubs by producing energy with photovoltaics (PVs) and wind turbines (WTs). In these islands, the utilization of renewable-based green hydrogen production has witnessed a huge growth in hydrogen storage and its flexibility. As known, green hydrogen is generated by an electrolyzer device that is decomposed water. This paper proposes the utilization of a modular floating offshore energy island. This study is a preliminary attempt and effective solution to establish these energy islands, including green hydrogen production, considering feasibility criteria.

Keywords: Renewable energy sources (RESs), energy Islands, green hydrogen, power-to-X (P2X).

Introduction

Nowadays, 85% of the energy demand is supplied by conventional sources such as oil, coal, and natural gas. Regarding Türkiye's oil, coal, and gas reservoir, there is no promising leadership among the top countries in the world. Thus, Türkiye has such good renewable potential to produce zero-carbon energy. Reducing energy dependence is one of the national goals of our country. It is anticipated that shortly, there will be a swift transition towards renewable energy sources (RESs) like solar, wind, and hydrogen energy, focusing on these three primary resources due to their effectiveness. Green hydrogen is an essential renewable energy source alternative for meeting Türkiye's energy needs, reducing dependence on energy imports, and creating a new export item. In this context, the utilization of RESs near consumption points must be one of the primary goals for achieving these official figures, as reported by ministries. The ratios of wind and solar energy usage shares to other access resources produced from the graphs are 26.5% and 11.76%, respectively, as seen in Fig. 1 [1]. Some advances in the literature are held in [2] about a techno-economic analysis of an on-site hydrogen station supplied via renewables in HOMER, evaluating and analyzing the potential of solar power generation using PVsyst [3] and presenting an insight into the potential situation for the rooftop solar photovoltaic system designing and calculation for the faculty building with PV*SOL package software program by [4] To identify encouraging offshore wind farm locations, the wind atlas program is utilized [5]. This study aims to present the design, criteria, and utilization of modular energy islands with high green hydrogen penetration covering the power-to-X (P2X) scheme.

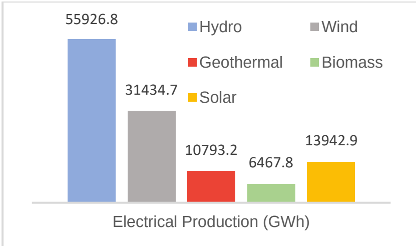

Fig. 1. Produced electricity ratio from renewable sources in Türkiye [1].

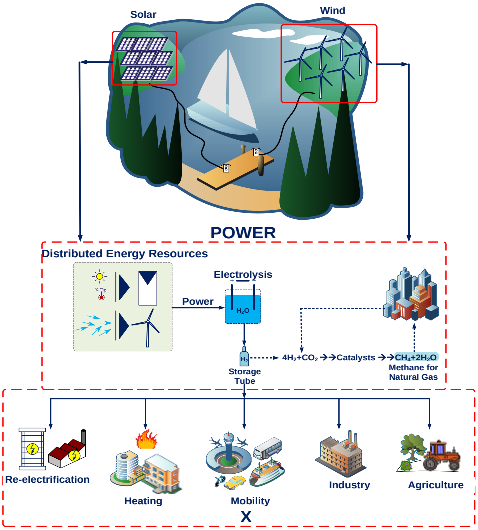

Fig. 2. Modular energy island with green energy production: General overview of P2X structure.

Conceptual Design

The site selection phase begins by considering factors such as wind resource availability, water depth, seabed conditions, and proximity to the power grid. Comprehensive environmental impact assessments are required to ensure sustainable development and minimize environmental impacts. This process examines the impacts of offshore wind farms on marine ecosystems and migratory bird routes. Strategies such as restrictions on turbine spacing and construction period are implemented to reduce negative impacts. In the design of offshore wind energy projects, elements such as turbine selection, foundation design, substation layout, and transmission infrastructure are carefully analyzed to optimize energy production and transmission efficiency and ensure structural integrity.

Conclusions

To sum up, this study has led us to conclude the possibility of establishing energy islands as an energy hub near consumption points. This proposed structure suggests satisfying both renewable-based distributed energy generation solutions such as solar-wind, which have a variable nature, and also more stable resources like hydrogen energy to use for different applications.

References

[1] Yenilenebilir Kaynaklardan Üretilen Elektrik Oranı, (2021), https://cevreselgostergeler.csb.gov.tr/yenilenebilir-kaynaklardan-uretilen-elektrik-orani-i-85810.
[2] Gökçek, M. et al., Optimum sizing of hybrid renewable power systems for on-site hydrogen refuelling stations: Case studies from Türkiye and Spain. International Journal of Hydrogen Energy, vol. 59, pp. 715-729, 2024.
[3] Endiz, M. S., Coşgun, A. E., Assessing the potential of solar power generation in Türkiye: A PESTLE analysis and comparative study of promising regions using PVsyst software. Solar Energy, vol. 266, 112153, 2023.
[4] Akpolat, A. N. et al., Performance analysis of a grid-connected rooftop solar photovoltaic system. Electronics, vol. 8 (8), 905, 2019.
[5] Argin, M. et al., Exploring the offshore wind energy potential of Türkiye based on multi-criteria site selection, Energy Strategy Reviews, vol. 23, 33-46, 2019.

Potential of Sustainable Energy Resources for Energy Islands in Kosovo

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Summary. Kosovo is exploring innovative solutions to enhance its energy sustainability, focusing on the concept of energy islands. These islands, situated on lakes, can utilize renewable energy technologies to provide decentralized and resilient energy solutions. This study evaluates the feasibility and potential of various sustainable energy resources for developing energy islands on Kosovo's artificial lakes. It primarily considers solar and wind energy. Kosovo's lakes offer ample surface area for the deployment of floating solar panels that can generate significant electricity without consuming valuable land resources, benefiting from cooler temperatures over water, which enhances efficiency. While wind conditions on lakes may vary, certain areas exhibit consistent wind patterns suitable for floating wind turbines. Integrating wind energy and solar power together with existing hydroelectric power on lakes can create a balanced and reliable energy supply.

Keywords: energy islands, renewable energy technologies, artificial lakes.

Introduction

Energy islands can be implemented on artificial lakes. Artificial lakes, such as reservoirs created by damming rivers for hydroelectric power generation or for water supply purposes, offer suitable locations for deploying energy islands. Building renewable energy infrastructure on artificial lakes helps avoid conflicts with land use for agriculture, housing, or conservation purposes. In many cases, artificial lakes are already integrated into energy systems through hydropower generation. Energy islands can complement existing hydropower infrastructure by adding additional renewable energy sources such as solar or wind power. [1]

According to the Energy Strategy of the Republic of Kosovo 2022-2031: "Ensuring a reliable supply of affordable and clean energy is essential for the economic development of Kosovo and the social well-being of citizens." "Kosovo's electricity independence will be ensured more and more through renewable energy sources".[2] Currently, the share of renewable energy sources in electricity consumption is only 6.3%.

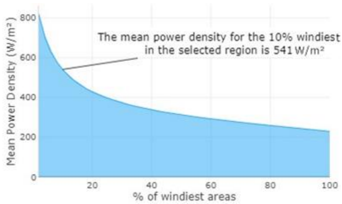
Conceptual Design

There are five major lakes in Kosovo. Other, smaller lakes are to be found in Kosovo as well. Many smaller beautiful lakes are found on the mountains. There are five major lakes in Kosovo. The biggest of these lakes is Ujmani (Gazivoda) Lake, which is located in the northwest part of Kosovo. The four biggest lakes in Kosovo are as follows:

Table I: Main lakes in Kosovo

	Lake:	Area (km²)	Altitude (m)	Depth (m)	Water volume ($10^6 m^3$)	Type	Characteristics
1.	Ujmani (Gazivoda) Lake	9.2	693	105	380	Artificial	industrial reservoir
2.	Radoniq Lake	5.06	455	30	113	Artificial	industrial reservoir
3.	Lake Batllava	3.07	600	35	40	Artificial	industrial reservoir
4.	Badovc Lake	1.7		29	26	Artificial	industrial reservoir

Ujmani Lake is shared between Kosovo and Serbia and is the largest reservoir in Kosovo. The total area of the lake is 11.9 km^2, while Kosovo possesess 9.2 km^2). The lake is formed by the damming of the Ibar River, which flows into the lake. The Ujmani Dam, is a rock-filled embankment dam, in Mitrovica, Kosovo. It was completed in 1979 and supports a hydroelectric power station which is located at its base. It has an installed capacity of 35 MW. At 101m in height, it is also the tallest dam in Kosovo.[3]



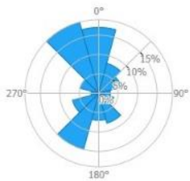


Fig. 1. Energy Island; a) The main lakes in Kosovo, b) Mean power Density at height 100m, c) Wind power rose

Referring to the World Wind Atlas, for the region of Mitrovica, Kosovo (Fig.1), data are obtained for 10% of the places with the strongest wind at a height of 100 meters, i.e. at the height where the wind turbines will be placed: Average power density of 541 W/m^2 and wind speed of 6.69 m/s . [4]

Type of preferred installed turbine: MHI Vestas Offshore V164-9.5MW, Nominal power: 9.5 MW; Rotor diameter: 164m; Height of the node: 105m; Average annual wind speed: 6.69 m/s, Power curve valid for air density of 1.225 kg/m^3. For a total loss of 10%, an annual energy production of 4.8GWh of electricity is obtained, with a capacity factor of 0.16 and Number of hours with full load of 1406 hours per year.

Kosovo has favorable conditions for the use of solar energy. Kosovo belongs to an area with solar radiation with very suitable values for the use of solar radiation for the production of electricity. The value of 1400 kWh/m^2 per year can be taken as an average for Kosovo.

Conclusions

The study underscores the importance of leveraging Kosovo's water bodies to develop sustainable energy infrastructure. Floating energy islands can enhance energy security, reduce greenhouse gas emissions, and contribute to sustainable development. Kosovo's lakes present a promising opportunity for the implementation of floating energy islands utilizing renewable energy resources. Realizing this potential will involve coordinated efforts among policymakers, investors, and environmental experts to ensure efficient and eco-friendly energy solutions. This summary highlights the potential, benefits, and considerations of developing floating energy islands in Kosovo's lakes using sustainable energy resources.

References

[1] O. Summerfield-Ryan, S. Park, "The power of wind: The global wind energy industry's successes and failures",
ScienceDirect, 2023.
[2] Energy Strategy of Republic of Kosovo, 2022-2031, Ministry of Economy, Prishtina, 2022.
[3] https://viewkosova.com/destination-category/lakes-in-kosovo/.
[4] https://globalwindatlas.info/en.

Concrete-Based Battery

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Summary. Batteries are increasingly being recognized as a practical solution for large-scale energy storage, offering flexibility and versatility in deployment. The building industry is responsible for 40% of the overall energy consumption. Cement is a widely available and inexpensive material used in construction. The porous structure of cement and its microcracks provide routes for ionic solutions to pass through, strengthening its potential as an electrolyte for design of concrete-based battery. Leveraging it for battery technology could potentially lower costs and increase accessibility. By introducing polymers capable of acting as electrolytes, the cement can facilitate electrical conduction necessary for battery operation. This integration of polymers could be a novel way to enhance the functionality of traditional construction materials.

Keywords: batteries, porous structure, concrete, polymers

Introduction

Fossil fuels have been the backbone of global energy consumption for decades due to their high energy density and relatively low cost. However, the goal of the Kyoto and Paris agreements was to minimise total emissions into the environment from energy captured from fossil resources by 2050 [1]. Intermittency in renewable energy supply, due to factors like weather variations for solar and wind power, has been a significant challenge in the widespread adoption of renewable energy sources. As such, energy storage is vital to bridge the disconnect between renewables generation and distribution for consumption [2]. Batteries are increasingly being recognized as a practical solution for large-scale energy storage, offering flexibility and versatility in deployment [3].

One of the most critical issues in modern society is the continual rise of carbon dioxide (CO_2) emissions, which play a vital role in global warming. The impact of global warming is becoming increasingly severe, with average temperature levels being exceeded each year. To limit global warming to well below 2 °C will require drastic reductions of global GHG emissions up to 2050 with subsequent negative emissions [4]. They also considered future energy supplies in the future modelling of the manufacturing processes. When implementing all the investigated strategies, an average of 65% GHG reduction was reached in 2050 at the material level, compared to the current manufacturing technologies. The construction industry is one of the main sources of CO_2 emissions, which accounts for approximately 33% of related global greenhouse gas emissions (GHC). Interventions at the material level have, however, been identified as the most effective strategies to reduce embodied GHG emissions [5]. They also considered future energy supplies in the future modelling of the manufacturing processes. The building and construction sector is a critical area with considerable influence on the economy and the environment [6]. This sector has a significant environmental impact because of its resource and energy use, as well as trash generation.

To address sustainability concerns, adopt environmentally friendly solutions, and comply with more restrict legislations, new methods for the use of concrete on batteries has been studied [7], [8], [9].

The main idea of the project is to take advantage of cement as a main raw-material and functionalized it with polymers capable of being electrolytes for a battery.

Conceptual Design

The electrolyte composition of a concrete-based battery is represented in the schematic representation of the figure 1.

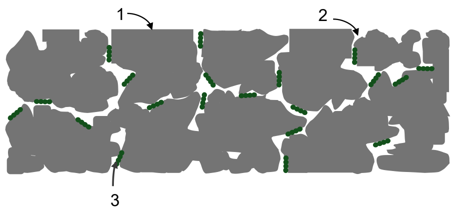

Fig. 1. Schematic concrete-electrolyte with: (1) concrete; (2) pores structures of the concrete; and (3) polymers with nanoparticles.

Conclusions

The concrete-based batteries represent an innovative approach to energy storage, leveraging the structural properties of concrete to create durable and functional energy storage systems. By embedding energy storage within the structural elements themselves, concrete-based batteries will be serving a dual purpose, providing both structural support and energy storage capabilities.

References

[1] K. Maniatis, D. Chiaramonti, and E. van den Heuvel, "Post COVID-19 Recovery and 2050 Climate Change Targets: Changing the Emphasis from Promotion of Renewables to Mandated Curtailment of Fossil Fuels in the EU Policies," *Energies*, vol. 14, no. 5. 2021. doi: 10.3390/en14051347.

[2] L. Wang, Q. Zhang, J. Liu, and G. Wang, "Science mapping the knowledge domain of electrochemical energy storage technology: A bibliometric review," *J. Energy Storage*, vol. 77, p. 109819, 2024, doi: https://doi.org/10.1016/j.est.2023.109819.

[3] H. S. Hirsh, Y. Li, D. H. S. Tan, M. Zhang, E. Zhao, and Y. S. Meng, "Sodium-Ion Batteries Paving the Way for Grid Energy Storage," *Adv. Energy Mater.*, vol. 10, no. 32, p. 2001274, Aug. 2020, doi: https://doi.org/10.1002/aenm.202001274.

[4] C. UNFCCC, "Paris agreement," in *FCCCC/CP/2015/L. 9/Rev. 1*, United Nations Bonn, 2015.

[5] F. Pomponi, J. Hart, J. H. Arehart, and B. D'Amico, "Buildings as a Global Carbon Sink? A Reality Check on Feasibility Limits," *One Earth*, vol. 3, no. 2, pp. 157–161, 2020, doi: https://doi.org/10.1016/j.oneear.2020.07.018.

[6] J. Zuo and Z.-Y. Zhao, "Green building research–current status and future agenda: A review," *Renew. Sustain. Energy Rev.*, vol. 30, pp. 271–281, 2014, doi: https://doi.org/10.1016/j.rser.2013.10.021.

[7] Q. Meng and D. D. L. Chung, "Battery in the form of a cement-matrix composite," *Cem. Concr. Compos.*, vol. 32, no. 10, pp. 829–839, 2010, doi: https://doi.org/10.1016/j.cemconcomp.2010.08.009.

[8] A. Byrne, S. Barry, N. Holmes, and B. Norton, "Optimising the Performance of Cement-Based Batteries," *Adv. Mater. Sci. Eng.*, vol. 2017, p. 4724302, 2017, doi: 10.1155/2017/4724302.

[9] E. Q. Zhang and L. Tang, "Rechargeable Concrete Battery," *Buildings*, vol. 11, no. 3. 2021. doi: 10.3390/buildings11030103.

Feasibility of Synthetic Fuel Production from Waste Heat of Integrated Iron and Steel Factories with the Help of a Floating Energy Island in Black Sea

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Summary. In this study, the technoeconomic analysis of methanol production by combining the waste heat and flue gas of an iron and steel factory with hydrogen obtained by electricity produced by floating energy island was examined.

Keywords: floating energy islands, synthetic fuels, emissions reduction.

Introduction

Iron and steel production are both energy-intensive and emission-intensive processes. Therefore, alternative, and renewable solutions are needed to reduce energy consumption and emissions in iron and steel production. In addition to using low-emission fuel in production, the main methods considered are the inclusion of hydrogen in the processes. However, in recent years, the production of synthetic fuels by combining the waste heat and carbon dioxide resulting from production with hydrogen obtained from seawater with renewable energy has emerged as a promising option for reducing emissions and permanently storing renewable energy in low volumes.

Conceptual Design

The study consists of 5 chapters. First, a region with high wind energy potential was selected, taking the iron and steel facility adjacent to the Black Sea. Afterwards, carbon dioxide and waste heat potential were determined by elemental analysis of the flue gas. A carbon capture plant was designed to capture potential carbon dioxide stored in the resource and transferred from the resource to the power plant. The energy production potential of the floating energy island was studied by determining the amount of hydrogen that would later combine with the captured carbon dioxide. Finally, by obtaining the methanol potential that can be produced according to the molar flow rates of hydrogen and carbon dioxide, the thermal and economic evaluation of the total production process was made, and the results were presented in tables and graphs. This study will be an important start to pave the way for potential collaborations with iron and steel factories located on the seashore and researchers interested in the use of synthetic fuels in the transportation of products by maritime trade. A conceptual design of the methanol production plant using renewables was demonstrated in Figure 1.

Fig. 1. Conceptual design of renewable methanol plant.

In this study, the carbon content of flue gas from an iron steel factory with a mole composition of CO_2 (6%), CO (0.6%), N_2 (71%), H_2O (17.1%) and O_2 (6.25%) [28], at a temperature of 800°C and a pressure of 0.11MPa, with a 4.95 kg/s flow rate is captured in CCP by Post-combustion capture (PCC), and the carbon dioxide from the stripper is cooled before being stored in the carbon dioxide tank, followed by compressed in the intercooled compressor (C3→C4). The water supplied from the sea is decomposed into hydrogen and oxygen in the HP with the electricity generated from the FPVP, and before the hydrogen is stored in the hydrogen tank, it is compressed in an intercooled compressor (C1→C2). The feed-effluent-heat-exchanger (FEHE) is supplied with the mixture (VIII) of the recycle gas stream and fresh CO_2 feed stream (VII) without decompression or heating. As a result, the gas flowrate to the recycle compressor is lowered, which lowers the need for electricity. The plan in this instance was to feed the combined reactants to the reactor operating at a lower end temperature while removing the dissolved CO_2 from the methanol using new hydrogen that was then mixed with the CO_2 and recycle stream. This method yields the most methanol and uses the least amount of energy per ton of output. In a primary multi-stage compressor (C1→C2), the fresh wet hydrogen supply from chlorine generation by salt electrolysis is compressed to 45 bar in (I). The mixture from the methanol plant (VI) and the carbon dioxide from the carbon capture plant are mixed in the mixing chamber and the resultant gas mixture (VII) is heated in the FEHE by the reactor outlet stream (XI) before being fed to a reactor that is isothermally operated at 50 bar. The reactor outlet stream (XII) is cooled down in the FEHE unit and another cooler (XIII) before being flashed in a separator to separate the recycled non-condensable gas components such as CO, CO_2, and H_2, from the methanol and liquid water liquid. A second compressor receives the recycle stream after it has been purged and combined with the fresh CO_2 feed stream. The compressed wet hydrogen stream (I) is fed in counter-current mode to a Stripping Column (SC), where the liquid stream of the flash is transmitted. In addition to drying the hydrogen feed and removing the light ends like CO_2 and CO, which are totally recycled, this also eliminates water from the reactor feed. The distillation column (DC), which separates water as the bottom product from methanol as the top distillate, receives the liquid bottom stream from the stripper (XIV-XV). It is important to keep in mind that employing the stripper unit results in a higher-temperature liquid outflow that contains a methanol-water mixture. As a result, the reboiler duty is lowered. A partial condenser that can yield a vapor distillate (lights), a high purity liquid methanol distillate (XVI), and water (XVII) as a bottom product is used to separate the methanol-water stream in a single distillation column. General layout of the process was provided in Fig. 2.

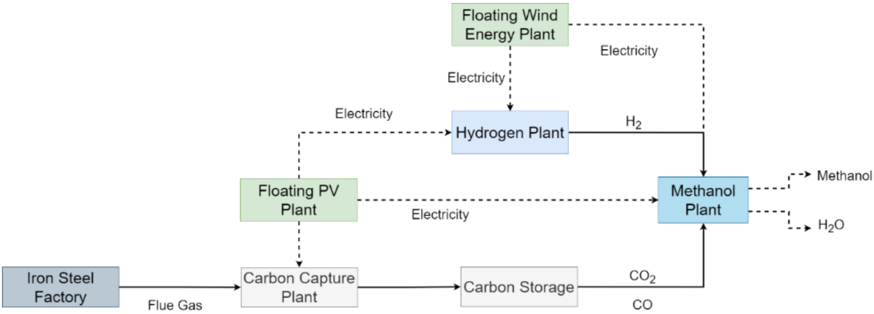

Fig. 2. General layout of proposed floating synthetic fuel production plant.

Optimal Management of Micro-Grids to Increase Flexibility and Resilience and Act as Energy Islands: An Italian Case Study

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Summary. This study describes and reports the main results of the case study of the city of Osimo located in the center of Italy, which has participated as a pilot in the H2020 projects named "INTERRFACE" [4] and "MUSE GRIDS" [5].

Keywords: micro-grids, energy islands.

Introduction

The goal of climate neutrality by 2050 can only be achieved with a high penetration of renewable energy sources. However, such a penetration leads to numerous problems in both the distribution and transmission grids [1]. One solution to increase the reliability, resilience, and energy efficiency of both the distribution and transmission grids can be the constitution of micro-grids. A micro-grid is a small-scale, localized electricity grid that can operate either independently (e.g., energy island), or be connected with national grids [2]. Therefore, micro-grids offer a local balance between the energy supply and demand while allowing the community to be an active part of the overall energy system [3].

Conceptual Design

Osimo is a historical city with a population of about 35, 000 inhabitants. The local Distribution System Operator (DSO) has only one connection point with the national Transmission System Operator (TSO). Consequently, the pilot operates as a multi-energy carrier, micro-grid on a municipal scale; indeed, the local DSO's grid hosts more than 35 MW of photovoltaic, 100 kW of small-scale hydropower plants, and a 1.2 MW-Combined Heat and Power (CHP) unit coupled with a local District Heating Network (DHN). In addition, several utilities are electrified: indeed, there are two electric heater, an electric boiler, two Electric Vehicles' (EVs) charging stations, and eighth prosumers (e.g., residential buildings).

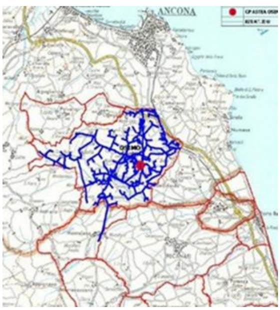

Fig. 1. Osimo's local grid

Throughout the year, the micro-grid experiences several hours (e.g., 700 – 800 hours/year) in which the energy flows from the DSO's to the TSO's grid, meaning that it can completely meet the electricity demand with renewables and distributed energy generation and thus operate in energy island mode.

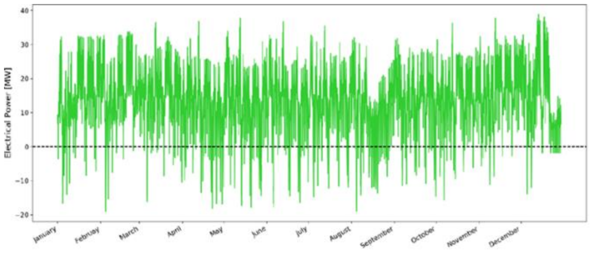

Fig. 2. Electricity exchange from the DSO's to the TSO's grid (e.g., energy island mode operation)

The high share of non-programmable renewable energy leads to congestion management problems and poor quality of distribution services due to voltage fluctuations. The objective of this study was to aggregate flexibility to mitigate congestion management problems in the DSO's grid. The aggregated flexibility resources include: i) two Battery and Energy Storage Systems (BESSs) of 100 kWh each and installed in the low-voltage DSO's grid; ii) two heat pumps with 150 and 200 kW, each of them installed at an industrial site; iii) a 105 kW-battery aggregator; and iv) prosumers equipped with smart electric water heaters with flexibility programmers.

A couple of critical low-voltage lines faced challenges with voltage fluctuations and, overall, provided a lower quality of service. Through the power generation from programmable CHP system, it was possible to provide flexibil- ity in short-term congestion management while BESSs increased the power quality in the DSO's grid. In particular, BESSs allowed to achieve a maximum voltage reduction of 2.9% and a minimum voltage increase of 5.5%.

Conclusions

Finally, it was possible to examine the Osimo's technical potential to implement demand response strategies by controlling a mix of centralised loads, distributed loads (e.g., office buildings), and energy storage technologies. Several optimisation strategies were implemented with encouraging results in terms of flexibility and resilience of the local energy system under different operating market conditions. The maximum flexibility achievable by optimally coordinating all the assets/systems installed in the city of Osimo was 1, 483 kW, which allowed to avoid a total cost for upgrading low-voltage lines of 149.98 kAC. In particular, the flexibility is provided by: i) a 1.2 MW-CHP for fulfilling the energy demand of large end-users; ii) a 51 kW-smart building acting as a collective-self consumption; iii) a 105 kW-battery aggregator; and iv) two 127 kW-local renewable energy communities.

References

[1] Y. E. G. Vera, R. Dufo-Lo´pez, J. L. Bernal-Agust´ın, Energy management in microgrids with renewable energy sources: A literature review, Applied Sciences 9 (2019) 3854. doi:10.3390/app9183854.

[2] D. Dom´ınguez-Barbero, J. Garc´ıa-Gonza´lez, M. [U+FFFD] Sanz-Bobi, A. Garc´ıa-Cerrada, Energy management of a microgrid considering nonlinear losses in batteries through deep reinforcement learning, Applied Energy 368 (2024) 123435. doi:10.1016/j.apenergy.2024.123435.

[3] M. Warneryd, K. Karltorp, , Sustainable Futures 4, cited by: 7; All Open Access, Gold Open Access, Green Open Access (2022). doi:10.1016/j.sftr.2022.100079.

URL https://www.scopus.com/inward/record.uri?eid=2-s2.0-85130716503&doi=10.1016%2fj.sftr.2022.100079&partnerID=40&md5=5b6aa1fe50b53a77020487f47ee6f970

[4] Tso-dso-consumer interface architecture to provide innovative grid services for an efficient power system (2019).

URL https://cordis.europa.eu/project/id/824330

[5] Multi utilities smart energy grids (2018).

URL https://cordis.europa.eu/project/id/824441

Grid Integration of the Energy Island

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Summary. The ambitious plans for the marine energy exploitation have resulted in the plans for the grid integration solution improvements, consequently. The first offshore wind plant platforms were used for the offshore produced MWs while nowadays plans for the first energy islands construction should accept GWs from the offshore renewables. The energy island concept should facilitate transmission of offshore generated energy to the shore and stand as the new power facility for power system operation control.

Keywords: energy island operation, grid integration, transmission solution

Introduction

The wind turbine technology is being improved, constantly, and wind turbines are bigger in both size and installed power. The onshore space is scarce, so it has to be moved offshore. The farther from the shore the better wind power potential.

Large offshore wind farms deployed in wide offshore area might need offshore point of common coupling (PCC) in order to have better energy transmission control from offshore wind farms. This necessity initiates idea of creation of an energy island as energy hub for large amount of energy generated from these offshore power facilities. First offshore wind farm platforms with all power equipment, have been hints for the first artificial energy islands.

The plans for intensive offshore wind farms and marine energy sources deployment are imposing needs for development of the energy island concept. Such first ambitious plan has Danish Energy Agency to establish two energy islands [1].

An energy island concept puts Transmission System Operators (TSOs) in the new operational challenges. Substantial amounts of marine generation need to be injected into onshore power system in certain points by submarine cables. Comparing to conventionally dispersed generation along the power system this concentrated generation could be threats for the power system stability.

Conceptual Design

The transmission interconnection solution of the energy island implies either high voltage alternating current (HVAC) or/and high voltage direct current (HVDC) submarine cables installation. Connection solutions between marine renewables generation, energy island and onshore power grid need to be scrutinized separately. So, it could be that an energy island could be interconnected with both HVAC and HVDC transmission technology what could increase installation complexity with various power equipment technology on site, on relatively small energy island area.

Also, production of large offshore wind farms, connected to grid by HVAC cables, is limited by excessive cables' reactive power generation at long distances. Reactive power compensators are required at both submarine cables' ends in order to achieve maximal active power transmission capacity [2]. As described in [3], large offshore wind farms with connection distance to PPC of 70-80 km and more have lower transmission losses if utilize DC transmission solution.

HVDC transmission solution requires offshore platform with power converters no matter on wind farm size and distance to shore. While, HVAC transmission solution, no need reactive power compensators and power transformers at both ends, necessarily. It depends on transmission distance and voltage level, wind farms size and power grid voltage level at PCC onshore [2].

Conventional concept of power system control assumes centralized control place (dispatching centre) where a power system is monitored and controlled. The large offshore wind farms with hundreds of MWs produced offshore and transmitted to the onshore grid by submarine cables is not welcome installation for the power grid stability.

A TSO is being delighted to have developed concept of energy island as "energy hub" which could act as energy crossroad and point of common coupling (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 offshore wind farms, far from a shore, could be operated from relative vicinity (from energy islands) or indirectly by controlling an "energy hub" itself. To accomplish these goals, the most advanced IT technology has to be employed by TSOs to be able to process and transmit large amount of monitoring and control data from many offshore measurements and sensors.

Furthermore, if offshore wind farms connected to PCC by power converters (AC/DC/AC), wind farm control could be easier even more since these power converters enables grid non-synchronized operation of each wind farm. Frequency stability issues would be minor in this case since each wind farm operates with its own frequency. For a stability's sake, high voltage direct current (HVDC) solution of interconnecting lines could be better solution, since at each end of HVDC transmission/interconnection line a power converter is necessary. Such solution could increase investment costs, but each project is independent, and some investment costs increase could be economic reasonable in long term.

Conclusions

Introducing the energy island concept imposes the new operational challenges to a TSO. Besides the constructional and technology complexity, the grid integration and control could imply the new advanced control approaches and techniques be applied by TSO.

Large amounts of marine energy are supposed to be collected by the "energy hub" – energy island and injected into onshore grid. Having such "energy hub", a TSO could have more options to control dislocated marine energy sources either directly from the energy island or/and indirectly controlling the energy island itself.

References

[1] https://ens.dk/en/our-responsibilities/wind-power/energy-islands/denmarks-energy-islands, accessed in April 2024.

[2] Todorovic J., 'Losses Evaluation of HVAC Connection of Large Offshore Wind Farms', Master Thesis, KTH-Royal Institute of Technology, Stockholm, Sweden, December 2004.

[3] 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.

Impact of Energy Storage on the Power System – Applications and Development Directions

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Summary. This presentation introduces the currently available technologies and actions necessary to be taken in the near future to increase the energy stored in the system, as well as the estimated costs of such investments.

Keywords: energy island, energy storage, energy system

Introduction

Increasing the storage of electricity would compensate for fluctuations in unstable generation and the energy consumption curve from the power system, and would facilitate the provision of active power reserves by transferring this function to storage facilities. Thanks to this, the time of using the available power of large sources present in the system could be increased, improving the economics of their operation, releasing without investment (directly in power plants) capacities that have not yet been used due to long-term fluctuations in the consumption curve or capacities related to the need to provide a power reserve. With sufficiently large energy storage capabilities, further unstable distributed sources could be adapted to work with the system, locating an absolute increase in power in this generation segment. This would allow shifting the focus of installed and achievable generation capacity from sources using fossil fuels towards renewable sources including energy islands, producing electricity at a variable cost close to zero while maintaining system stability.

Conceptual Design

Energy storage is defined by the following criteria:
– technical parameters: system power, amount of stored energy, full cycle efficiency, area occupied by the installation, energy density, operational period, method of connection to the (electric) energy system, level of reliability;
– investment and operating costs (unit and total);
– level of technology advancement;
– impact on the environment;
– possibility of possible expansion.

APPLICATION OF ENERGY STORAGE
Demand change and peak reduction.
Variable supply and resource integration.
The use of off-grid storage.
The three areas mentioned above are currently the most developed part of the energy storage sector, especially in terms of small investments, but energy storage also has great potential as:
Seasonal storage.
Cogeneration.

Arbitrage transactions.
Frequency adjustment.
Voltage support.
Utilization of waste heat.
Relieving the network and deferring investments in infrastructure.
Hidden reserve.
System boot.

DEVELOPMENT DIRECTIONS

By using more energy storage, the EU can reduce imports of energy and energy raw materials, improve the efficiency of the energy system and keep prices low by better integrating variable renewable energy sources. To meet this challenge, you must first:

– analyze processes associated with various work cycles to enable predictive maintenance, increased reliability and improved design and manufacturing processes;

– conduct system integration studies, focusing on how gas, electricity, heat and other infrastructure (e.g. electric car chargers, fuel stations) can be connected and complemented by gas, electricity, heat and/or fuel storage;

– conduct demonstration activities, in particular how energy storage can provide energy services and monetize the added value of the energy system;

– demonstrate the efficient use of energy storage devices;

– analyze requirements for optimal integration.

Fig. 1 shows recent and ongoing large European Community research projects financed by the Horizon 2020 program on the development of energy storage, divided into individual issues and technologies. This comparison shows that 23% of projects concern software. It is also clear that most of these technologies will find a place for small users who will need appropriate advice and service.

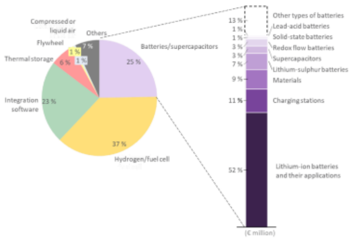

Fig. 1. Horizon 2020 energy storage projects [1]

Conclusions

Energy storage will play a key role in increasing the market share of zero and low-emission sources, significantly increasing the flexibility of the network to fluctuations in power consumption on the recipient's side, eliminating the need for the producer to follow the recipient's consumption profile. The International Energy Agency (IEA) estimates that limiting global warming to below 2°C will require increasing globally installed energy storage capacity from 140 GW in 2014 to 450 GW in 2050 [2].

References

[1] European Court of Auditors, EU support for energy storage, Briefing Paper, 2019
[2] IEA, Technology Roadmap - Energy Storage, International Energy Agency, Paris, 2014

Graphene as Promising Material for Energy Storage System

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Summary. The floating energy island aims to harness the ocean's abundant energy in the form of wind, waves and sun as renewable energy sources. However, the resulting energy must be stored if it is not used immediately. Therefore, an energy storage system (ESS) is very important to store and convert electricity and use it when needed, such as during peak hours. For this reason, different types of batteries are being studied for use in ESS. Different carbon-related materials, i.e. graphene, are very promising for such applications in batteries and supercapacitors.

Keywords: energy island, energy storage system, batteries, supercapacitors, graphene

Introduction

A fundamental feature of the electricity industry is that the level of electricity that can be produced is somewhat fixed over short periods of time. Conversely, the demand for electricity fluctuates throughout the day. Developing technologies to store electricity so that it is available to meet demand at any time represents a major change in the way electricity is distributed.

With an energy storage system (ESS), electricity can be converted into other forms of energy that can be stored and later converted into electricity when needed.

The electric grid is based on a delicate balance between the generated electricity and the needs of consumers. An efficient way to help balance fluctuations in electricity supply and demand is to store electricity during periods of high production and low demand, then feed it back into the grid during periods of low production or high demand.

Now, the rapid adoption of electric vehicles is putting even more pressure on the power system to meet the increased demand for electricity. In addition, technological advances and the growth of renewable energy markets such as solar, wind and others have become a significant driver of the need for energy storage, given the significant impact on the grid.

Conceptual Design

ESS will also help balance microgrids to achieve a stable balance between generation and load. In addition, the deployment of ESS can also provide a more reliable power supply for high-tech industrial facilities. Energy storage and power electronics have promising prospects for transforming the power industry.

Modern technologies of electricity storage systems include batteries, flywheels, compressed air, pumped hydraulic storage and others. Today, all these systems are still limited in the total amount of energy they can store, but research continues to advance these technologies at a rapid pace.

There are many types of ESS batteries: lithium-ion batteries [1], iron-flow batteries [2,3], etc. At the same time, graphene supercapacitor/battery is widely studied and looks promising for ESS applications.

Graphene (as well as reduced graphene oxide) has attracted interest and has been widely studied as an electrode material for different energy storage technologies because of its high surface area, stable chemical properties, and elevated electrical and thermal conductivity.

Conclusions

The main problem of a large part of modern batteries is a low service life. However, the addition of graphene/reduced graphene oxide can significantly extend the lifetime of these devices.

References

[1] https://www.lgensol.com/en/business-ess-battery
[2] https://www.technologyreview.com/2022/02/23/1046365/grid-storage-iron-batteries-technology/
[3] https://essinc.com/iron-flow-chemistry/

Energy Harvesting Using Auxetic, Piezoelectrics and Shunted Circuits

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Summary. An application of shunted piezoelectrics systems in energy harvesting is numerically studied. Through the vibration of the host structure and the behavior of piezoelectrics as sensors, the system can harvest energy. Previous studies have shown that the piezoelectrics and an auxetic spacing layer enhance electromechanical coupling and thus the energy production. This beneficial effect is confirmed through numerical experiments for two tested auxetic microstructures.

Keywords: piezoelectrics, shunt circuits, auxetics, smart structures, energy harvesting

Introduction

Piezoelectric energy harvesting is an innovative technology that harnesses mechanical energy from sources—such as vibrations, pressure, and motion—and converts it into electrical by the piezoelectric effect. In the case of a smart controlled structure with some, even small, energy demands, for example for semi-active control, energy harvesting can be added to a structure with shunt circuits in order to provide the small amount of energy which is required for the controller [1].

Materials with negative Poisson's ratio can be constructed with star-shaped, cut-out or perforated microstructures. An auxetic layer between vibrating structure and piezoelectric patch enhances the coupling, therefore the effectiveness of the whole system [2].

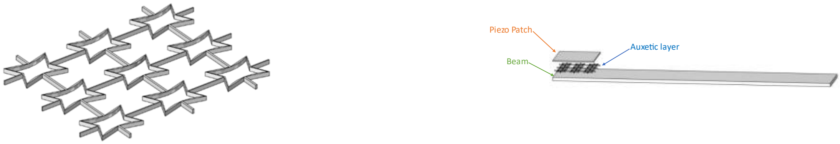
Conceptual Design

In the present investigation the structure which has been considered is similar to References [2], [3]. The host beam is made of aluminum and one piezoceramic of type PIC151. The piezoelectric patch is connected with a R-L resonant circuit. Two steel auxetic microstructures are considered. The first is a four cut-out microstructure and the second is a nine star-shaped and each one is placed between the PZT patch and the host structure, as a spacing layer. The microstructures and their addition in the whole system are illustrated in Figures 1 (a), (b) and 2 (a), (b).

In the Figure 3 (a), (b) is presented for each microstructure: the input mechanical power and the power harvested (in mW) as well as the peak voltage induced across the piezoelectric patch (in V) as a function of second eigenfrequency when the energy harvester is excited by a sinusoidal acceleration. The four cut-out auxetic possibly can ensure higher voltage, mechanical input power and electrical power harvested.

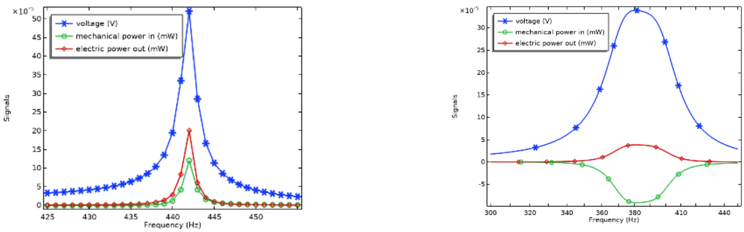
(a) (b)

Fig 3. Four cut-out auxetic microstructure; (a) 3-D view, (b) As a spacing layer between beam and piezo (Exploded view).



(a) (b)

Fig 4. Nine star-shaped auxetic microstructure; (a) 3-D view, (b) As a spacing layer between beam and piezo (Exploded view).



(a) (b)

Fig 5. Energy harvester input mechanical power and the power harvested (in mW) as well as the peak voltage induced across the piezoelectric patch (in V) vs. second eigenfrequency; (a) four cut-out auxetic microstructure, (b) nine star-shaped auxetic microstructure.

Conclusions

Following auxetic boosting of shunted piezoelectrics in vibration suppression, a concept presented in [2], the current investigation shows that output energy and power are also beneficially affected.

References

[1] G. Tairidis *et al.*, "Energy harvesting system for the power supply of a shunt piezoelectric system developed for vibration suppression," in *Proccedings of the international conference on wind energy harvesting*, Catanzaro Lido, Italy, Mar. 2018, pp. 232–236.

[2] M.-S. Daraki, K. Marakakis, G. Foutsitzi, and G. Stavroulakis, "AUXETIC ENHANCEMENT OF THE SHUNTED PIEZOELECTRIC EFFECT FOR VIBRATION SUPPRESSION," in *10th ECCOMAS Thematic Conference on Smart Structures and Materials*, Patras, Greece: Dept. of Mechanical Engineering & Aeronautics University of Patras, 2023, pp. 181–190. doi: 10.7712/150123.9776.441661.

[3] M.-S. Daraki, K. Marakakis, and G. E. Stavroulakis, "Modeling of Shunted Piezoelectrics and Enhancement of Vibration Suppression through an Auxetic Interface," *Micromachines*, vol. 14, no. 2, p. 289, Jan. 2023, doi: 10.3390/mi14020289.

Some Comments on Life Cycle Assessment of Floating Energy Islands

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Summary. Energy island is a term that encompasses an innovative and important approach developed to produce a clean solution to energy supply. However, the construction and operation of energy islands can lead to the production of significant amounts of pollutants. Therefore, it is considered essential to assess the environmental impacts caused by these islands in a life cycle perspective.

Keywords: energy island, life cycle assessment, sustainability

Introduction

The concept of energy island has different meanings such as physically isolated islands having self-sufficient electricity generation, countries isolating their electricity systems from their surroundings, regions voluntarily disconnecting themselves from the main electricity grid, and artificial islands at sea serving as hubs for electricity generation and distribution [1]. Since renewable energy is considered one of the main and lasting solutions to global climate change, these islands might have a great importance to reduce greenhouse gases through electricity generation from wind, wave and/or solar energy. Floating modular energy islands may also play a key role for energy supply as an additional power plant or as an energy hub [2].

However, floating energy islands require significant amount of materials and energy for building. Therefore, a comprehensive and cumulative life cycle assessment (LCA) is a must to better understand the environmental, economic, and social impacts. Besides, within the scope of LCA approach, impacts on marine organisms should also be investigated.

Conceptual Design

Life Cycle Assessment (LCA) is an innovative and holistic approach to measure the cumulative environmental, economic, and social impacts of any kind of product system. LCA is considered a very useful tool to observe the impacts of different life cycle stages of a product and thus, it enables a comparison between sub-processes and provides data on which process should be focused for a comprehensive improvement. Since LCA provides a comprehensive understanding on the impacts of a product, it is becoming more and more popular and its area of use is expanding.

Energy islands can be considered as very important and clean alternatives for energy supply. On the other hand, it is also essential to measure in detail the environmental impacts that artificial islands would cause. Thus, it would be possible to understand how long it takes for the electricity generated from renewable energy sources on these islands to offset the impacts caused during the island construction process.

Conclusions

This study aims to draw attention to the assessment of energy islands from a life cycle perspective, a topic that has not been studied much before. It is considered a very important necessity to evaluate the financial impacts of energy islands as well as their environmental impacts. Besides, assessing the impacts on the ecosystem is also considered a essential. In this way, environmental impacts will be minimised and a pathway will be paved for the construction and operation of energy islands in a more environmentally friendly way.

References

[1] Rettig, E. et al., The meaning of energy islands: Towards a theoretical framework, Renewable and Sustainable Energy Reviews, Vol. 187, pp. 113732, Nov. 01, 2023. DOI: 10.1016/j.rser.2023.113732.

[2] Kurniawati, I. et al., Conceptual design of a floating modular energy island for energy independency: A case study in Crete, Energies, Vol. 16(16), pp. 5921, Aug. 10, 2023. DOI: 10.3390/en16165921

Integration of Floating Photovoltaic Systems Located on the Reservoir of Hydro Power Plants in the National Energy Grid of Albania

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Summary. This work considers the integration of Floating photovoltaic (FPV) systems located on reservoirs of hydro power plants in the National Energy Grid. It is referred to the newly and foreseen Floating photovoltaic systems in water bodies. Their installation will create possibilities to provide a hybrid operation between the existing hydro power plants and the FPV units. The electricity grid infrastructure exits and their integration with minimum costs is possible. Actually, there is one successful case with 4-floating units of 500 kWp each, which operate from several years. Also, some other projects which include floating units are under consideration. The floating units will have their positive impact in the energy balance of the grid.

Keywords: floating units, water reservoir, hybrid operation, electricity grid, performance ratio.

Introduction

This work emphasizes the importance of the utilization of floating photovoltaic units in the water bodies. Based on the solar radiation potential, these units offer their contribution in the electricity generation delivered to the national grid. Based on the hydro power plant sites, the floating photovoltaic units provide an interesting solution based on distributed electricity generation. Apart of them, there are other beneficial factors related to the dual use of the water reservoirs for energy generation purpose and for siting the floating units. Another beneficial factor is the positive effect related to the cooling of the photovoltaic module placed near the water surface. For these reasons, the presence of floating devices represents an interesting option for our electricity grid.

Conceptual Design

Methodology. It is based on:

- the specific sites location characteristics;
- the values of solar irradiation on the photovoltaic array plane;
- the energy yield;
- the final yield;
- the performance ratio;
- the capacity factor, and
- the system efficiency.

Results.

Results include many other results. Between them, are shown the monthly values of the daily final yield and of reference yield.

Fig. 1. An existing Floating photovoltaic unit on the water reservoir of a hydro power plant

Fig. 2. Monthly values for the final yield

Conclusions

The presence of floating devices represents an interesting option for the electricity grid.

The presence of floating photovoltaic units represents an interesting option for distributed generation in the country.

The solar potential facilitates the installation of floating photovoltaic units in water reservoirs of many hydro power plants present in the country.

The energy performance data show interesting values, which will be beneficial for the owners of the hydro power plants.

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] Demoulias C., “A new simple analytical method for calculating the optimum inverter size in grid-connected pv plants”, Electric Power Systems Research, vol. 80, no. 10, pp. 1197–1204. 2010.

[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.

[5] Dierauf T., Growitz A., Kurtz S., Cruz J. L. B., Riley E., Hansen C., Weather-corrected performance ratio, 2013.

Insights from a Preliminary Risk Assessment Towards the Development of Modular Energy Islands

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Summary. The present paper discusses the preliminary findings of a risk assessment application under the Failure Modes Effects Analysis (FMEA) Methodology, towards the future development of Modular Energy Islands. Based on the responses collected during the COST ACTION CA201093 Training School, critical insights from the risk factors are being addressed while the suitability of the FMEA methodology is being discussed.

Keywords: modular energy islands, FMEA, risk assessment

Introduction

The concept of Modular Energy Islands (MEI) is gaining great research interest, as it holds the potential to maximize renewable energy generation, efficiently stored, transferred, and exploited to cover multiple future needs in the sustainable development and operation of dedicated floating installations. These offshore floating platforms will also be developed using cutting-edge Green Hydrogen-related technologies to support the agenda of the EU Green Deal challenges for sustainability. Building resilience of these installations is therefore critical. As part of the MODENERLANDS COST ACTION CA201094 and specifically WG3 "Network, energy storage, and resilience analysis" activities, a comprehensive preliminary risk assessment was applied towards identifying the critical factors that will define the development and operation of MEI.

Conceptual Design

The preliminary risk assessment refers to a technical exercise conducted through COST ACTION CA20109 Training School (TS), which was held in Estoril, Portugal from 25-28 September 2023, where participants were given training in specialist fields in Renewable Energy, Modular floating Islands and also the application of the FMEA Methodology. The participants in the TS were organized in different groups with PhD students having different backgrounds and specializations. Each group consisted of 7 people; 2 academic leaders and 5 PhD candidates, all actively researching renewable energy resources applications. The groups applied the FMEA under the scenario of a MEI development. Thanks to the varied expertise of the candidates, the activity allowed for a transdisciplinary approach with important discussions on the key stresses that will be expected towards the development of MEIs.

Following FMEA, risks were captured and assessed in terms of their Severity (S), Occurrence probability (O), and Detection (D), following a ten-point Likert scale [1, 2]. The Risk Priority Number (RPN) was calculated by multiplying the previously assessed values (RPN= S* O* D), availing the risk prioritization. TS participants identified Failure Modes (FM) and grouped them under 12 categories: Technical (T), Energy Generation (EG), Grid Connectivity (G), Energy Storage (ES), Economic/Financial (F), Ecological/Environmental (ECO), Legal (L), Social/Ethical (S), Business (B), Acceptance (A), Management (M) and Other (O).

[3] https://modenerlands.eu

Additionally, participants were asked to assess the recoverability of the failure mode, following again a 10-point Likert scale (1: Easy to Recover, 10: Not Possible to Recover).

Reference is made to the key output of a representative group in the TS, to assess the advantages and limitations of the application of FMEA for risk assessment of Floating Modular Energy Islands scenario, towards a sustainable solution. Based on the collected feedback, 32 risk factors were identified and assessed, the majority of which (34%) were Technical followed by Management (13%), Ecological/Environmental (13%), and Business (10%) related risks. The RPN was calculated for each one of the 32 collected FMs. Results have shown that a "lightning strike" was considered to be the most critical FM (RPN=320) followed by "fatigue included the collapse of wind power", "collision of birds with turbine blades", and "competition with conventional energy production" (120 =/<RPN <200). Eight possible FMs were assessed to have a medium risk (80=/<RPN<120) and the rest FMs were related to low or very low-risk factors. Considering the recoverability of the risks, participants considered that in three cases it is not possible to recover. Two of these modes are linked with complete damage of the installation ("airplane collision", "theft of equipment & tools") and the other with the inability to collect power ("change in climate conditions"). "Fatigue-induced collapse of wind tower" has a low recoverability possibility (R=9), while "lightning strike" and "ship collision" are linked with difficulty in recovering (R=8).

Conclusions

Based on this preliminary risk assessment several Modular Energy Islands-related risks were identified and further assessed and prioritized following the FMEA methodology. The majority of the risks were technical, ecological/environmental, business, and management-related risks. From the risks identified those linked with the total collapse of the infrastructure and inability to produce and store energy (i.e., due to climate change conditions) are those assessed as unrecoverable, while no mitigation actions exist for them. Still based on the RPN and considering the probability of occurrence instead of the severity alone, almost one-third (1/3) of the failure modes need proper and constant monitoring as they are linked with medium to high risk.

Based on the outcome of the preliminary exercise, it was concluded that FMEA can be successfully applied in determining risk factors. Yet the approach relies also on the background knowledge and expertise of the participants as it is also evident from the first identification and definition of risks. Based on the findings of this preliminary risk assessment, it is noted that the developers of future floating installations can effectively rely on FMEA to be informed of the risks and be alerted on critical aspects that need to be addressed. Future steps of this research will involve a larger number of participants, representatives of different countries/regions and stakeholder categories with varied expertise, for a robust approach in applying the FMEA methodology under the concept of Modular Energy Islands' future development and operation.

References

[1] Khan F., Yarveisy R., Abbassi R. Risk-based pipeline integrity management: A road map for the resilient pipelines, Journal of Pipeline Science and Engineering, 2021. Volume 1, Issue 1, Pages 74-87, ISSN 2667-1433, https://doi.org/10.1016/j.jpse.2021.02.001.

[2] Gargama H. and Chaturvedi S. K. Criticality Assessment Models for Failure Mode Effects and Criticality Analysis Using Fuzzy Logic. IEEE Transactions on Reliability, 2011. vol. 60, no. 1, pp. 102-110, doi: 10.1109/TR.2010.2103672.

Supporting the Participation of Energy Islands in Wholesale Electricity Markets

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Summary. Energy islands offer a viable path for increasing the penetration of marine renewable energy (RE) into the power grid. Although much research has been conducted on technical aspects of grid integration, such as how to use an energy island to serve the load of nearby regions, scarce is the literature on models supporting the optimal participation of energy islands in national wholesale electricity markets. We present a new decision-aid framework for optimal trading of variable power production in electricity markets, ideally suited to energy island managers/traders. Early findings from an empirical study indicate the benefits from strategically allocating generation capacity to heterogeneous resources in terms of reducing local production uncertainty and improving the revenue profile of energy island investors. This gradually leads to a new methodology for assessing technologically- and geographically- distributed resources that goes beyond the examination of the energy potential of committed areas but focuses on the complementarity of local generation profiles.

Keywords: energy island, renewable energy aggregation, power trading, electricity markets.

Introduction

Despite the EU's strategic priority to decarbonize power production through the large-scale integration of wind resources, energy islands and communities with a large share of wind generating capacity still face major business challenges. One of their main sources of risk is the uncertainty surrounding the timing and volume of the generated wind energy. Up until recently, EU governments have applied feed-in-tariffs and other price inceptives to secure the income of RE producers and unlock investment funds that could be used to support further expansion of the wind production network. However, government subsidies are gradually withdrawn across European countries and renewable energy producers are now obliged to sell the output of their units in wholesale electricity markets. This additionally exposes them to electricity price risk.

RE traders are typically engaged in two electricity markets, day-ahead and balancing. These provide two complementary trading outlets for the same commodity (electricity) but operate in different time frames. Producers participating in the day-ahead market place their offers for delivering a certain amount of electrical energy in any of the 24 hourly slots of the following operating day. This market typically operates 12 to 36 hours before actual delivery of power, leaving open the possibility of observing imbalances or gaps between the realized electricity production and the quantity being promised in the day-ahead market. Traditionally, system operators would be charged with the task of matching actual power supply with demand and they would do so by re-scheduling the production of dispatchable generators or asking power retailers to change their demand plan. In the new electricity market model (aka Target Model), RE producers are considered *balancing responsible parties*, in the sense that they are obliged to close possible positive or negative imbalances (i.e. energy surpluses or deficits that may occur near the time of delivery) by participating in the balancing market. Depending on whether the power system is long or short of energy, the joint participation in the day-ahead and balancing markets may result in opportunity cost or loss for the RE trader, especially in periods of high wind volatility.

Many are the studies that advocate the optimal coordination of renewable power plants, such as offshore wind farms, with storage units as a means of buffering the intermittency of wind energy generation and providing stable output to the grid (see among others [1,2]). To further facilitate the participation of local power producers and isolated energy islands in wholesale electricity markets, regulators have established a new business entity called *aggregator*. The aggregator collects the output of dispersed power plants, possibly representing different generation technologies, and trades it as a single asset in an electricity market. In return, he/she makes a payment to the producers that typically takes the form of a fixed selling price per generated MWh or a pre-agreed capacity rent per installed MW. Theorical and empirical evidence suggests that the aggregator has an improved revenue profile and higher profit potential due to his/her ability to diversify away a great deal of the volume uncertainty originating from the variability of local weather conditions.

Conceptual Design

The purpose of this presentation is to outline a new decision model aiding the participation of modular energy islands in wholesale electricity markets. Using multicriteria optimization techniques, we manage to accommodate in our model conflicting decision-making objectives, i.e. when the producers/aggregator seeks to maximize the proceeds from energy trading while placing an upper bound on the probability that his/her strategy will seriously underperform in periods of unfavourable weather or system conditions. We propose a discrete version of the newly established *Consensus Based Optimization* algorithm to deal with the computational challenges posed by the resulting mixed binary-nonlinear optimization programs.

Conclusions

The findings of our study highlight the economic and environmental gains from aggregating dispersed RE production hubs, such as modular energy islands. We show that local producers engaging in electricity market trading typically experience diminishing profit opportunities and large potential drawdown. The collective trading of various power plant outputs manages to reduce imbalance costs and thus ensure that owners maximize the economic utilization of their assets.

References

[1] M. Dadashi, K. Zare, H. Seyedi, M. Shafie-khah (2022) "Coordination of wind power producers with an energy storage system for the optimal participation in wholesale electricity markets", International Journal of Electrical Power & Energy Systems 136, 107672.

[2] S. Paul, A. P. Nath and Z. H. Rather (2020) "A Multi-Objective Planning Framework for Coordinated Generation From Offshore Wind Farm and Battery Energy Storage System" IEEE Transactions on Sustainable Energy 11 (4), pp. 2087-2097.

[3] N.S. Thomaidis, T. Christodoulou, F.J. Santos-Alamillos (2023) "Handling the risk dimensions of wind energy generation", Applied Energy 339, 120925.

[4] N.S. Thomaidis, A.-I. Moukas (2022) "Designing Efficient Renewable Energy Portfolios for Optimal Coverage of European Power Demand under Transmission Constraints", Energies 15 (22), 9375.

Strategic Innovation and Commercialization of Floating Energy Islands in Europe

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Summary. This abstract presents a strategic framework for the development, commercialization, and dissemination of floating energy islands, aimed at revolutionizing Europe's renewable energy landscape. With a focus on market-driven strategies and innovation management, it addresses the technological and operational advancements necessary for integrating such systems into the current energy market. The methodology includes a comprehensive market analysis to identify viable commercial pathways and strategic innovation processes designed to tackle the unique challenges of maritime energy systems. Key strategic areas covered include managing innovation to enhance technological and operational efficiencies; developing robust commercialization strategies involving market entry planning, partnership identification, and funding acquisition; effectively disseminating project outcomes to influence policy and shift public perceptions; and exploiting research outputs through intellectual property protection and commercial product development. The expected outcomes emphasize actionable strategies for commercializing innovative energy solutions and engaging stakeholders across sectors to support sustainable market growth. This approach underscores the importance of integrating technical innovations with strategic market insights to foster the adoption of renewable technologies and enhance energy resilience in Europe.

Keywords: floating energy islands, commercialization, market analysis.

Introduction

The urgency to transition towards renewable energy sources presents both challenges and opportunities, especially in the development and implementation of innovative technologies like floating energy islands. This abstract outlines a strategic approach that focuses on the innovation, strategy, dissemination, and commercial exploitation of these systems within Europe. By integrating advanced renewable technologies with strategic market analysis and innovative business models, this research aims to create a blueprint for successfully commercializing floating energy islands, thereby enhancing Europe's energy resilience and sustainability.

Europe's energy landscape is rapidly evolving, with a significant shift towards renewable energy sources. Floating energy islands represent a transformative approach to offshore energy generation, combining wind, solar, and wave energy on mobile platforms. This abstract discusses strategic innovations that can facilitate the integration of these islands into the European energy grid.

Objectives:

- To develop a comprehensive strategic framework for the innovation and commercialization of floating energy islands.
- To explore effective dissemination strategies that promote widespread adoption and support for these technologies.

Conceptual Design

Methodology:

- ✓ Conducting a detailed market analysis to identify **demand**, potential **barriers**, and commercial **pathways** for floating energy technologies.
- ✓ Utilizing case studies and existing models of innovation management to tailor approaches specifically suited to the unique aspects of floating energy systems.

Strategic Framework:

- Innovation Management: Outlining strategies for continuous technological improvement and integration of renewable energy technologies on floating platforms.
- Commercialization Strategies: Developing business models that ensure economic viability, including market entry strategies, partnership development, and funding mechanisms.
- Dissemination and Advocacy: Implementing communication strategies to engage stakeholders, influence policy, and promote public and private investment.
- Exploitation of Research Outputs: Detailing approaches to protect intellectual property rights while ensuring that innovations lead to practical, commercial products.

The proposed strategies are expected to yield a scalable and adaptable framework for the deployment of floating energy islands. Preliminary results from feasibility studies suggest that integrating multiple types of renewable energy sources on a single floating platform can significantly enhance energy output and reliability. The discussion will include insights into the regulatory challenges, technological hurdles, and economic assessments necessary for widespread implementation.

Conclusions

The strategic development and commercialization of floating energy islands hold the potential to significantly impact Europe's renewable energy sector. By adopting a comprehensive approach that combines innovation with strategic market insights, this framework aims to not only enhance energy resilience but also drive the region towards greater sustainability and independence in energy production.

Optimizing the Utilization of Electricity Generated on Sustainable Energy Island

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Summary. Floating sustainable energy islands are a concept where renewable energy systems, such as solar, wind, or wave power, are integrated into a floating platform or structure. The energy generated on floating sustainable energy islands can be consumed locally or exported, depending on the island's energy needs and the technical and economic feasibility of exporting the energy. Our primary objective centers around optimizing the utilization of electricity generated on sustainable energy island.

Keywords: sustainable energy island, optimization.

Introduction

Floating sustainable energy islands are a concept where renewable energy systems, such as solar, wind, or wave power, are integrated into a floating platform or structure, which can be deployed on water bodies such as oceans, seas and lakes. These structures can be designed to generate renewable energy in areas where it might be difficult or costly to build onshore renewable energy installations. Floating sustainable energy islands can also help to reduce land use conflicts, as they do not require land for construction.

The energy generated on floating sustainable energy islands can be consumed locally or exported, depending on the island's energy needs and the technical and economic feasibility of exporting the energy. Locally the energy generated can be used to power the island's needs, such as lighting, heating, and cooling, as well as any other systems or equipment that are installed on the island. However, as floating sustainable energy islands are usually mobile, they can be moved to different locations as required to supply energy to different regions or to respond to changing energy demands. Additionally, floating sustainable energy islands can be designed to provide a range of other services, such as water treatment, hydrogen production, aquaculture, or tourism, thereby increasing their overall sustainability and economic viability.

Conceptual Design

Our primary objective centers around optimizing the utilization of electricity generated on sustainable energy island, ensuring not only environmental responsibility but also operational efficiency. This electricity goes beyond immediate on-site applications, extending to storage, conversion, and integration into the broader grid.

Our team is dedicated to contributing to grid integration, particularly focusing on:

• Energy sector coupling: This involves the integration of electric transport and heating systems, coupled with a nuanced approach to utilizing energy in response to demand.

• Energy communities: We are committed to evaluating the economic viability of collaborative community projects, developing methods for equitable energy distribution among prosumers, and cultivating a shared vision of sustainable energy initiatives.

Enhancıng in the Hydrogen Storage by Novel Composıte Materıals

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Summary. As the global demand for energy continues to rise alongside concerns about climate change and environmental degradation, the imperative to transition to sustainable and renewable energy sources has never been more pressing. Among the myriad alternatives, hydrogen stands out as a promising energy carrier due to its abundance and minimal environmental impact when used in fuel cells, combustion engines, or industrial processes. However, unlocking hydrogen's full potential hinges critically on the development of safe, efficient, and cost-effective methods for its storage. Despite these advantages, the widespread adoption of hydrogen faces significant challenges, chief among them being the safe and reliable storage of this gas. Hydrogen's low density and high flammability make traditional storage methods impractical or hazardous, necessitating innovative solutions to enable its integration into existing energy infrastructure and transportation systems. Hydrogen can be stored by methods such as cryogenic liquid, chemical hydrides and adsorption. Until recently, several carbon based porous materials have been investigated extensively for hydrogen storing. In this study, it was aimed to develop novel- damson plum stones based activated carbon/silver exchanged zeolite, damson plum stones based activated carbon/Pd and graphene/silver exchanged zeolite composites for hydrogen adsorption. All the porous materials have been characterised by N_2 adsorption-desorption, t-plot, BJH desorption pore size distributions and SEM-EDX techniques. It was observed that damson plum stones based activated carbon/Pd composite showed higher hydrogen adsorption capacity than other samples. The characterization results showed that Palladium was homogeneously dispersed on the activated carbon sample surface and the composites were prepared in good quality.

Keywords: renewable energy sources, hydrogen storage, composite materials.

References

[1] Oguz Erdogan F, Kopac T. Comparison of activated carbons produced from Zonguldak Kozlu and Zonguldak Karadon hard coals for hydrogen sorption. Energy Souces, Part A: Recovery, Utilization, and Environmental Effects 2020.

[2] Oguz Erdogan F. Freundlich, Langmuir, Temkin and HarkinsJura isotherms studies of H2 adsorption on porous adsorbents. Chemistry & Chemical Technology 2019;13:129e35.

[3] Oguz Erdogan F, Kopac T. Dynamic analysis of sorption of hydrogen in activated carbon. Int J Hydrogen Energy 2007;32:3448e56.

[4] Kopac T, Oguz Erdogan F. Temperature and alkaline hydroxide treatment effects on hydrogen sorption characteristics of multi-walled carbon nanotube-graphite mixture. Journal of Industrial and engineering Chemistry 2009;15:730e5.

[5] Oguz Erdogan F, Kopac T. Adsorption behaviour of alcohol vapors on Zonguldak-Karadon coal derived porous carbons. Energy Souces, Part A: Recovery, Utilization, and Environmental Effects 2019. https://doi.org/10.1080/ 15567036.2019.1666191.

[6] Oguz Erdogan F. Comparative study of sunset yellow dye adsorption onto cornelian cherry stones-based activated carbon and carbon nanotubes. Bulg Chem Commun 2018;50:592e601.

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