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Wind engineering for modular sustainable energy islands: project proposals and synergies for international collaborative research

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SUMMARY:
Based upon the participation of the three authors in the activities promoted by the MODENERLANDS COST Action, two transnational access proposals of interest within the topic of Sustainable Energy Islands were submitted and eventually selected with in the frame of the ERIES project consortium. The two wind-related research projects address wind effects on solar panels and harbour cranes. The main objectives and contributions are reviewed, and some synergies are outlined.

Keywords: MODENERLANDS, ERIES, wind engineering

1. INTRODUCTION

The EU has set the ambitious target of reaching carbon neutrality by 2050 while achieving energy independence. This goal requires a substantial increase in renewable energy capacity, comprising scientific and technological developments not available now or at an incipient stage. The research community must play a pivotal role in this "green revolution" by exploring new concepts in renewable power generation, adopt multidisciplinary approaches in research, and set solid frameworks to support collaborative research. One of these new concepts in green power generation is the "Energy Island" that according to the Danish Energy Agency website (2023), "serves as a hub – or green power plant - that gathers electricity from the surrounding offshore wind farms and distributes it to the electricity grid". A similar concept is planned in the Belgian part of the North Sea (Fig. 1).

Fig.1: Draft plans for Belgian artificial energy island, by Belgian Electricity Operator Elia. Credit: Engie

The Princess Elisabeth Island will occupy an area of about 5 hectares. Both islands will play a pivotal role in the transition to more sustainable energy in the North Sea.
Modular sustainable energy industry is a further development of this concept that has gained momentum in recent years thanks to collaborative frameworks such as the COST Action "Modular Energy Islands for Sustainability and Resilience (MODENERLANDS)" that fosters collaboration among researchers of very different backgrounds. This network of researchers expands the original concept by considering the combination of multiple green energy sources such as wind, waves and solar, as well as modularised offshore floating platforms (MODENERLANDS, 2023). The work introduced in this abstract is the result of the collaboration initiated among the authors in the frame of this COST Action.

The development of research ideas from conception to tangible results with engineering significance requires time, substantial effort and access to the state-of-the-art infrastructure; remarkably, when the research aims at pushing the boundaries of the current knowledge. In wind engineering, there is a limited number of world-class research facilities, where the access is commonly enabled only to the respective institutional members, i.e., other users have rarely access to perform research in these facilities. However, the EU has been providing a decisive push for enabling the access to top research facilities for research teams proposing advanced research ideas, therefore removing barriers for science. The Programme HORIZON. 1.3.2 – Opening, Integrating and Interconnecting Research Infrastructures, has funded the project ERIES "Engineering Research Infrastructures for European Synergies" (CORDIS, 2023) whose main objective is "providing transnational access to advanced research infrastructures in the fields of structural, seismic, wind and geotechnical engineering". Detailed information about research goals and areas of this project are available on the ERIES website (2022).

The authors are members of two different User Groups that presented research proposals in the framework of the January 2023 Transnational Access Selection and Evaluation Call of ERIES project. This call is instrumental to support the collaborative research outlined on the topic of sustainable energy islands. In this abstract, the selected proposals are described, highlighting the potential advancement in knowledge, and the general objectives. Furthermore, the synergies among COST Action, EU Research Infrastructures Programme and national research projects are remarked.

2. WIND ACTIONS ON SOLAR PANELS

Solar energy is one of the power sources considered in the framework of the MODERNERLANDS COST Action on modular sustainable energy islands. Over the years, wind effects on solar panels have been studied, but generally considering only quasi-steady Atmospheric Boundary Layer (ABL) conditions (Kozmar and Grisogono, 2021). However, non-synoptic wind effects have not been studied so far, although it is estimated that a large percentage of damages caused by wind in USA is due to non-synoptic wind actions and local windstorms. A first research proposal, named ERIES SOLAR aims at better understanding non-synoptic wind loads on solar panels. A wind-tunnel testing campaign is proposed for the WindEEE Dome of Western University (Canada), which has extensive experience in wind actions on solar panels and non-synoptic wind studies at laboratory scale. The main goals of the proposed research are the following:

- Characterization of non-synoptic wind flows in the test chamber of the WindEEE Dome.

- Measurement of wind loads on scaled solar panels subjected to non-synoptic winds, obtaining six aerodynamic force and moment components.
- Computational Fluid Dynamics (CFD) simulations of various wind-load scenarios, based upon the validation of the computational results with the obtained experimental data.

The project considers the application of some innovative tools, such as:

- Flying a mini-drone equipped with a 2D sonic anemometer in the WindEEE Dome to assess the flow characteristics of the non-synoptic wind simulations at the laboratory scale. The flow speed will be corrected for drone movement and the drone-induced velocity field. Drone will be operated by researchers from the von Karman Institute.
- For the scaled array of solar panels mounted inside of the test chamber, wind speed measurements taken by the mini-drone will be combined with the PIV measurements to gain further understanding of various aerodynamic phenomena.

It is expected that the results obtained in the envisaged experimental campaign will advance the frontiers of the knowledge available on this topic, but also provide guidelines and code recommendations for solar panels affected by local and non-synoptic windstorms. Furthermore, the experimental data will be instrumental in the validation of computational simulations that will help improve the structural safety of these structures and apply non-conventional design techniques such as surrogate-based design or shape and size optimization.

3. WIND EFFECTS ON HARBOUR CRANES

The characterization of non-synoptic winds in harbours, and their effects on latticed cranes, is of great interest in the context of the development of the sustainable energy island concept due to these reasons: i) efficient logistical operations in harbours are directly linked with the feasibility and profitability of offshore power projects; ii) lessons learned from the wind characterization and crane response in harbours may be applied on offshore structures and iii) wind characteristics on artificial energy islands may be similar to standard harbour conditions.

Cranes are designed based upon the stipulations of the EN 13001-2:2014 Crane Safety – General design Part 2: Load actions, considering quasi-steady ABL wind conditions. The main goal of this project is non-synoptic extreme wind loads on harbour cranes in the Port of Genoa, as this location is prone to non-synoptic thunderstorms due to the vicinity of steep mountains. To this end, a close collaboration with the GS – WinDyn Group of the University of Genoa is expected, to build upon their superb experience in harbour wind climate and wind-tunnel testing (Repetto, 2022). The ERIES-CRANES project has the following goals:

- Field measurements of the wind field at the Port of Genoa, near container cranes, by the combined use of the WindCube 400S Wind Doppler LiDAR of the University of Genoa and a drone-mounted 2D ultrasonic anemometer operated by the von Karman Institute.
- Wind-tunnel testing of small-scale models of harbour cranes both in a stand-alone configuration but also surrounded by harbour infrastructure, using High Frequency Force Balance (HFFB). The results of the stand-alone configuration are pivotal in the subsequent validation of CFD simulations of the crane's aerodynamic response.
- Development of a validated CFD model for harbour cranes at the Port of Genoa considering also the surroundings.

Several contributions of the proposed project merit particular attention:

- Combined use of the LiDAR technology, ultrasonic anemometer mounted on a mini-drone and conventional ultrasonic and cup anemometers for characterization of short-duration wind episodes in the harbour.
- Design and testing of an extended wind-tunnel model of the Port of Genoa, including cranes, buildings and a container-carrier ship. This work will enable a comparison between field and wind-tunnel measurements, shedding more light on scale effects in modelling the built environment.
- Development of CFD models of cranes based on porous surfaces used to model lattice structures (Allegrini et al., 2018).

The project is expected to make an impact on the current state of the art by providing experimental evidence concerning the characteristics of non-synoptic winds in harbours along with aerodynamic characteristics of cranes. Moreover, the development of validated CFD models for harbour cranes will allow the analysis of various load scenarios for latticed cranes.

4. CLOSURE COMMENTS

The datasets obtained from the field and experimental campaigns conducted in the framework of the ERIES projects will be made available for the general audience using the European repository Zenodo, thus fulfilling the European Union compromise for open science.

These two projects are clearly linked with the networking opportunities provided by the COST Action MODENERLANDS. Furthermore, there are connections and synergies with ongoing projects by the proponents such as EVERBLUE awarded to the von Karman Institute or GEeh-CFD awarded to the University of A Coruña. Furthermore, it is expected that the intended PhD investigations and research projects will build upon the results of these proposed projects.

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