TWIND

Twinning for an Offshore Wind Energy Partnership

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D2.2 – A Portfolio of Future R&D project definitions

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1 EXECUTIVE SUMMARY

The main objective of the TWIND project is to create a network of excellence that will dynamize a pool of specialist research professionals and trainees to support the emerging offshore wind energy industry in Portugal, a sector with a very strong anticipated growth and no current dedicated training curriculum. This objective is being fulfilled through a set of strategic activities well-structured throughout the project including specific training programmes, short-term scientific meetings, long term staff visits, networking meetings, conference attendance and knowledge transfer events. The aim of these activities is to stimulate research activities that can positively impact the Portuguese economy and society. These research activities are likely to be more impactful and have a greater success if they are developed collaboratively between the TWIND consortium partners and WavEC.

This report entitled *'A Portfolio of Future R&D Definitions'* provides a snapshot of the potential research topics that could form the basis of future collaborative research and development projects. Each of the topics detailed below draws on expertise from a minimum of two consortium members and will be used to steer the scientific agenda of the TWIND programme and for several years following.

Eight broad areas for further research have been identified covering many aspects of offshore wind development, these are:

1. Numerical Modelling, CFD and Validation
2. Digital Twins and Data Analysis
3. Economic Assessments
4. Floating Wind Turbine Platform Development
5. Mooring Systems, and Dynamic Cable Designs for Floating Wind
6. Advances in O&M Operations
7. Site Selection Tools
8. Grid Integration of Renewables.

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2 INTRODUCTION

2.1 PURPOSE AND SCOPE OF THE DELIVERABLE

The purpose of this report '*A Portfolio of Future R&D Definitions*' is to provide an overview of the common and complimentary research themes that are present within the TWIND consortium in support of Task 2.3 '*Future R&D projects*'.

This report highlights the potential R&D projects which will form the basis of the scientific strategy for the TWIND project, these projects are likely to be established later in the TWIND programme and continue beyond the end of the project.

2.1 PROJECT SUMMARY

2.2.1 Short description

TWIND is a European Commission Horizon 2020 funded project with a total budget of 796 thousand Euros. Its main objective is to create a network of excellence that will dynamize a pool of specialized research professionals and trainees in the domain of offshore wind energy to support an emerging industry in Portugal in a field with a very strong anticipated growth and no dedicated training curriculum.

2.2.2. Overall description

The Portuguese Government has approved the Industrial Strategy for Ocean Renewable Energies (EI-ERO) with the aim of developing the country's offshore wind potential. According to EI-ERO, offshore renewable energies have the potential to supply 25% of the electricity consumed annually in Portugal and create a new export chain in these new technologies. The government envisages that potential exports in this field could increase up to ten times the current employment in the active sectors, with the greatest potential for exports seen in the development of the floating wind technology.

The overall objective of TWIND is to create a network of excellence that will dynamize a pool of specialized research professionals and trainers in the domain of offshore wind energy to support an emerging industry in Portugal in a field with a very strong anticipated growth and no dedicated existing training curriculum. WavEC will be the pivot research institution of the low performing Member State (Portugal) coordinating efforts with internationally leading counterparts at the EU level (Spain, United Kingdom and The Netherlands) and enhancing its excellence and innovation capacity through the exchange of knowledge with these leading research organizations. The combining capabilities of partners will open the grounds to exploit existing research results and invest in developing more knowledge.

These objectives will be fulfilled through a set of strategic activities well-structured throughout the project including specific training programmes on thematic topics, short-term scientific meetings, long-term staff visits, networking meetings, attendance to relevant conferences in the field, knowledge transfer workshops with stakeholders and an annual event. The networking activities and exchange of knowledge will stimulate research activities and highly qualified services that impact the economy and the society, thus benefitting not only WavEC and the partner organisations, but in general Portugal.

3 THE TWIND CONSORTIUM

3.1 Introduction

TWIND has the overall objective to create a network of excellence to support the emerging offshore wind industry in Portugal. To achieve this, four organisations from the EU are engaged, the group is led by WavEC (Portugal), with support from Tecnalia (Spain), the Offshore Renewable Energy Catapult (UK) and TU Delft (Netherlands). Below are brief introductions to the four members of the TWIND consortium and short summaries of each partners research interests and experiences.

3.2 WavEC Offshore Renewables

WavEC Offshore Renewables is a private non-profit research organisation located in Lisbon, Portugal, created in 2003 and devoted to the development and promotion of offshore renewable energy utilisation through the technical and strategic support to companies and public bodies. WavEC has vast experience in ocean energy and marginal experience in floating offshore wind energy technology. Participating in projects primarily categorised as Applied research and technology development, WavEC have also been engaged in the design, construction, deployment and operational phases of ocean energy programmes.

WavEC have a team of over 20 specialists with broad experience ocean and offshore wind energy, areas of expertise include numerical modelling of floating structures, economic evaluation, energy resource assessment, socioeconomics, environmental impacts assessments and engaging with regional, national and European organisations in roadmap and policy planning exercises.

3.3 Tecnalia

Tecnalia is a private research centre located near Bilbao, Spain established in 2010 following the merger of several research centres. The mission of Tecnalia is to transform technology into GDP, researchers within the organisation cover a wide range of disciplines and expertise covering all major industries and development areas. Within the Energy and Environment directorate there is a commitment to the development of renewable sources of energy from the marine environment which will contribute to sustainable economic growth and stable job creation. Tecnalia encompasses 12 years of research and development experience in the marine energy sector including the creation of two technology-based companies (OCEANTEC, NAUTILUS) and participating in 12 European Research Projects.

The team at Tecnalia has offered its knowledge and expertise to companies interested in offshore renewable energy in areas such as modelling and analysis of offshore structures, electrical transmission, materials and operations and maintenance strategies.

3.4 ORE Catapult

ORE Catapult is a research and technology organisation based in Glasgow, UK was established in 2013 and merged with the National Renewable Energy Centre in Blyth, UK in 2014. The UK’s flagship research and technology and innovation centre, combining world-class research, development, demonstration and testing facilities with leadership, industrial reach and engineering reach. ORE Catapult’s mission is to accelerate the design, deployment and commercialisation of renewable technology innovation. Working with a wide range of stakeholders and clients to support offshore wind and ocean energy developments, ORE Catapult is uniquely positioned to work with businesses of all sizes and researchers to develop, and validate technologies using a suite of assets worth £250 million.

With a pool of over 120 researchers, engineers and scientists, ORE Catapult has broad range of expertise such as electrical transmission, power train development, wind turbine blade manufacturing, modelling and testing, socioeconomic modelling and growing interest in floating offshore wind.

3.5 TU Delft

Delft University of Technology located in Delft, Netherlands is the oldest and largest university in the country. The Faculty of Aerospace Engineering is one of the largest of its kind in Europe and hosts the Delft Wind Energy Institute (DUWIND), a multi-disciplinary institute focussed on wind energy research and teaching. The research programme covers most aspects of modern wind turbine technology and tackles the multi-disciplinary research questions through inter-faculty cooperation and projects.

Wind energy research has been carried out at TU Delft for nearly 40 years, with the faculty designing the DU airfoils used on more than 50% of the modern wind turbine blades.

Researchers at TU Delft are world leading in the computational modelling capabilities (CFD for aerodynamics, fluid-structure interactions and aero-acoustics), these are combined with excellent wind tunnel facilities to test and validate models.

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4 DEVELOPING FUTURE R&D DEFINITIONS

4.1 Scientific Focus of the TWIND consortium

Prior to the TWIND project commencing and to provide an initial focus to activities within the TWIND project four general research themes were identified with an underlying theme of computational and digital models. This reflects the understanding that sound numerical model development at early stages of technology development is key part of the process to help further understand the technological challenges, focus research activities and improve expected results through life from design to decommissioning.

Within the TWIND project these research areas are focused on the challenges, current trends and future needs of fixed base and floating offshore wind turbines.

4.1.1 Numerical modelling and validation for floating offshore wind turbines

Floating offshore wind turbines are designed using comprehensive simulation codes that include the coupled effects of the aerodynamics, hydrodynamics, supporting structure and station-keeping system dynamics. Coupled and uncoupled numerical models are used to analyse different load cases including some or all of these aspects. In addition, different wind turbine control algorithms can be implemented converting a coupled analysis into an aero-hydro-servo-elastic approach.

4.1.2 High fidelity computational modelling

Recent studies conducted as part of the OC5 project have shown discrepancies between model testing and engineering tools, for example with respect to the hydrodynamic behaviour of the floater. The reason for these differences is still not well understood. CFD tools can be used to better understand the underlying physics of the phenomena, with a three-way validation where both the engineering-level modelling tools and higher-fidelity tools are compared to measurement data. The results will help inform the improvement of engineering models and guide the development of future test campaigns. As regards aerodynamics, there is also the need to assess the validity of engineering models when the turbine is subjected to large motions. Also, in this case the outcome of the CFD studies is used to advice and improve the engineering models. WavEC, Tecnalia and TUDelft are part of the follow-on project, OC6 that recently kicked off with a 4-year programme.

4.1.3 Add-ons for wind turbine blades

Wind turbine add-ons are commonly used by manufacturers to increase the performance of wind turbines. However, mostly one single type of add-on is currently used, and the design is not tuned to specific wind conditions or a specific blade. Optimisation techniques take advantage of high-fidelity tools to determine the optimal geometry and position of add-ons, considering the environmental conditions at specific locations.

4.1.4 Whole-system digital twins of large offshore wind turbines

Digital twins are virtual representations of physical assets or processes that use recorded or real time sensor data to enable optimisation in both the design and operation of engineering systems. In the design phase of a wind turbine, digital twins can be used to safely and cost effectively simulate and test many design scenarios, thus allowing selection of only the most optimal designs for manufacture, real-world testing and eventual commercial deployment. Once a turbine is brought into operation, digital twins can be used to gather and analyse sensor data to establish the condition and health of the turbine, and so enable dynamic operational control to deliver higher reliability and performance. As offshore wind turbines continue to grow, it is of ever more importance that these increasingly expensive machines are designed and operated to maximise reliability and performance.

4.2 Inputs from TWIND activities

Following the scientific framework presented in 4.1 the TWIND project plans to run a series of senior staff exchanges and think-tank workshops to further develop the portfolio of future R&D definitions, by the end of the programme it is expected that 10 senior exchanges will have been conducted, and 3 think tanks will take place, focussing on the themes described in 4.1. At this stage in the project the consortium has carried out 1 staff exchange and 1 Think Tank, with subsequent Think Tanks and exchanges currently on hold until the COVID -19 pandemic disrupting Europe and the rest of the world has ended.

The consortium has the following think tank planned with dates pending:

Think Tank 2: Digital Tools for Offshore Wind (Digital Twins) – Bilbao, Spain, March/April 2020 – this will be delayed until summer 2020, and if not feasible to carry out will be converted to a digital workshop.

4.2.1 Think Tank 1: Numerical Modelling, CFD and Validation

The first Think Tank was carried at the Sheraton Hotel, Schiphol Airport, 29th October 2019. The focus of the workshop was on Numerical Modelling, CFD and Validation with attendees from all four partners participating.

The workshop used a recent publication 'Grand Challenges in the Science of Wind Energy'[1] to frame discussions, with three of the challenges used as the main discussion points through the session:

1. Improved understanding of atmospheric and wind power plant flow physics
2. Aerodynamics, structural dynamics and offshore wind hydrodynamics of enlarged wind turbines.
3. Systems science for the integration of wind power plants into the future electricity grid

As part of the Think Tank session attention was paid to potential areas for future collaborations between the four partners, these focussed on:

- Pushing the boundaries of current CFD and numerical modelling research to significantly improve the offshore wind industry
- Focussing projects into areas of technology development that are relevant and of interest to industrial partners
- Reflecting on the current and historic challenges and looking to solutions that can be accessed using state of the art processes.

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4.2.2 Staff Exchanges

The first Staff Exchange was carried out in February 2020 with a socio-economics researcher from ORE Catapult travelling to WavEC for a week to carry out a range of knowledge exchange and collaborative conversations (a detailed summary of this will be presented in D2.4). This exchange presented the opportunity for further collaborations and developments around the complex techno and socio-economic challenges around ocean energy and floating offshore wind developments. This will be worked up further in the coming months and with Horizon Europe coming online in early 2021, opportunities to develop this further will be evaluated.

During the Staff Exchange, the Quarterly meeting of the partners run in parallel. Possible areas of future collaboration that could be the main focus for the next staff-exchanges, summer schools and other activities were gathered (and included in chapter 5). Some of the issues that were identified during these meetings were:

- Detailed analysis of the Supply Chain to optimize costs.
- Differences between floating and fixed offshore wind projects and how this affects costs and the supply chain.

5 FUTURE R&D PROJECT CONCEPTS

5.1 Areas for future collaboration

The list of potential research topics below is provided as a guide following the discussions and interactions over the first 9 months of the TWIND project and the proposal development stage. These will be used in conjunction with D2.1 'A *Project Plan for Funding Applications'*. It is intended that WavEC, in collaboration with at least one of the TWIND partners will submit collaborative research and development bids to support research in these areas, with the goal of 5 new projects within 5 years of the project completing.

5.2 Numerical modelling, CFD and validation

The concepts below came from Think Tank 1 and are directed on the technical challenges that are arising in this space, the concepts will need to be refined and focused on applied technology developments:

- Development of a CFD or higher fidelity systems that are industrially and commercially relevant.
- Integration of CFD and numerical models to optimise speed of calculation and fidelity.
- Bridging the gap between the numerical model focussed design elements and the CFD focussed wind farm control systems to increase system interactions.
- Looking to other industries to advance our modelling understanding, for example developing panel methods as an alternative to the current BEM models used.
- Developing high fidelity models to support critical design elements and reduce the safety margins, reducing manufacturing and deployment costs.
- Improving the models for next generation export and dynamic cable deployment to improve efficiency and prevent damage.

5.3 Digital twins and data analysis

The concepts below are focussed on areas of common research and expertise. The Digital Twin concept is of growing interest within multiple industries through the wide-spread adoption of industry 4.0 and digital tools to manage assets and move to prognostic and preventative maintenance processes helping to drive down LCOE:

- Development of condition monitoring technologies such as improved sensing and data interrogation at a component level.
- Structural health monitoring technology development for blades, tower and nacelle to support reduced offshore maintenance, coupled with advanced numerical modelling and CFD from Section 5.2 could influence next generation controller systems.
- Dynamic cable monitoring and modelling to predict and prevent future failures for floating offshore wind turbines and wind farms.

5.4 Economic assessments

Economics are a critical driving force behind offshore wind development with the Levelized Cost of Energy (LCOE) being a key metric used to monitor the development of wind farms. There is also a general trend towards increasing local content in wind farms, with target levels varying across nations

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within the EU and rest of the world. Developing the models and understanding the economic impacts will be a critical part of the business and investment cases for government and private investment moving forward:

- Developing models for LCOE and economic impact of wind farm construction for Portugal and the EU.
- Defining the main differences between floating and fixed offshore wind farms and how to optimize costs.
- Cost Modelling of future turbines (larger and further away from the coast).
- How the supply chain can affect the cost models.

5.5 Floating wind turbine platform development

Taking advantage of WavEC's involvement in DEMOWFLOAT, DEMOGRAVI3 and FW Turbine projects, and the strong need for floating wind development to support UK, Spanish and Dutch offshore wind ambitions these proposed areas of collaboration look to the technological and modelling challenges moving forward:

- Floating wind turbine platform tool development – combining hydrodynamic, aerodynamic and other influences to develop a tool suitable for designing and developing floating platforms for next generation floating turbines.
- Numerical modelling for the analysis of underwater acoustics and how to reduce underwater noise during operations.

5.6 Mooring system and dynamic cable design for floating wind

Mooring systems and dynamic cables are the main differences between bottom-fixed and floating wind. Those critical subsystems and their dynamic response are being modelled and studied in the last years, but there´s still a lot of room for the development of innovations and optimized solutions:

- Modelling and tool development of mooring systems optimized for offshore wind, adapting the safety factors for the design to the requirements of the renewables sector - nowadays adopted for the oil & gas sector.
- Modelling and tool development for the design and deployment of dynamic cables to extend life and reduce the risk of failure.
- Design of high-voltage, high-power dynamic cables.
- Development of quick connection and disconnection elements both for dynamic cables and mooring lines, in order to save time in the installation and O&M stages.

5.7 Advances in O&M operations

O&M operators are looking into the use of drones for different operations. Using WavEC´s experience and spin off, Pro-Drone (blade inspection), and the need for safer and less expensive options for monitoring and O&M operations, proposed areas of collaboration could include:

- Definition of operations and limitations for the use of drones in offshore wind. For example, blade inspection or carrying light equipment from vessels to the nacelle[2].
- Layout optimization and how O&M costs can be reduced.

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- Floating O&M operations – an area of growth as the floating wind market matures.

5.8 Site selection tools

The first step in the development of a project is Site Selection. Currently for Portugal, there is a tool developed by LNEG called OFFSHORE PLAN and a higher resolution tool called OASIS from WavEC. To attract investors, there is a need for further developments that could be applied to OASIS such as:

- Analysis of complementary tools that could be added (following the example of DTOceanPlus that combines site selection with layout optimization for ocean energy technologies).
- Commercialisation of OASIS as a tool set.

5.9 Grid integration of renewables

The Covid-19 pandemic has seen an unprecedented drop in the demand for power. This lower demand has highlighted how competitive renewable resources will become in the future and how important energy storage at times of low consumption, or peak generation will become more critical moving forward. Research and development topics that have been discussed in this area include:

- The use of hydrogen for energy storage combined with offshore wind generation.
- Repowering of existing offshore wind farms.
- Optimization of grid integration of offshore wind.
- Analysis of site selection and its effect on grid integration.

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6 CONCLUSIONS

The TWIND consortium have identified nine headline topics where further collaboration will develop research projects that will be beneficial to WavEC and the Portuguese markets, as well as the wider European and overseas markets. Fixed base offshore wind turbines are on the cusp of being a mature technology, with many advancements now incremental gains to reduce the LCOE, improve operability and reduce risk around operations and maintenance. As we move forward in the TWIND project we expect to see an accelerated deployment of floating based wind turbines, this will need solutions to some of the research areas described above, and lead to a generation of new challenges resulting in further need for R&D developments.

In the short term the consortium will look to develop these concepts further through think tanks, staff exchanges and discussions to develop robust R&D plans that can be used as the framework for future funding applications.

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