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PRESS RELEASE II

Willow Project Delivers Initial Results for Smarter Turbine Monitoring Systems

The 12 project partners have convened at the steering committee meeting, on the 20th and 21st of November of 2024 in the facilities of SIRRIS in Ghent, Belgium, to discuss project results so far which started in October 2023.

WILLOW, Wholistic and integrated digital tools for extended lifetime and profitability of offshore wind farms, aims to achieve an integrated system that will provide an open-source, data-driven health aware curtailment strategy to the offshore wind farm operators. With a **5.8 million euro budget** granted within the framework of the Horizon Europe programme, it is expected to contribute to a **50% reduction on the inspection costs**, a **5-years lifetime extension of offshore wind farms, a 4% reduction in noise pollution** and **up to 10% reduction of LCOE** (Levelized Cost of Energy), between 3.5 and 4.5 €/MWh.

Among other topics covered in the project (such as cybersecurity or optimising curtailment strategies), in the past months, the partners CEIT, C-CUBE, SIRRIS, TSI and WÖLFEL have worked together towards the design of an integrated Structural Health Monitoring (SHM) System, which will be combined with drone-based inspections. The goal is to be able to detect, identify and quantify material damages (coating degradation, pitting corrosion) combined with precise estimation of different kind of loads and complemented with drone-based visual and thermographic inspections. The data output of the developed SHM System is crucial to provide a more precise lifetime assessment of the key structural elements of offshore wind turbines: tower, transition piece foundation.

1) Loads estimations

Wölfel has been working with OpenFAST on the modelling of wind turbine support structures applicable to virtual deformation detection. The virtual sensing of fatigue-relevant quantities, such as strains, is based on structural models, including finite element models. A variety of tools are available for the development of these models, which must be created individually for each specific structure under surveillance. In this activity, they utilized the OpenFAST software for this purpose. OpenFAST is an open-source tool developed by NREL for simulating the coupled dynamic response of wind turbines. It combines models for aerodynamics, hydrodynamics, control, and structural dynamics. Typically, the wind turbine tower's structural dynamics are modeled using the ElastoDyn module, which presents a challenge in precisely considering different designs. In this activity, the SubDyn module was employed for this purpose, enabling the finite element modelling of the entire support structure. A preliminary comparison of mode shapes with those derived from alternative finite element models demonstrated a good agreement. Wölfel, thus, extended the source code to extract mass-normalized mode shapes applicable for the virtual sensing of strains along the structure.

Meanwhile, TSI has been working on a laboratory-scale model, studying the effects that structural damages can have on an offshore wind turbine's structure, aiming to learn how to detect them in their incipient phase through localized phenomena.

2) Coating degradation

Ceit has made some progress developing a Convolutional Neural Network (CNN) Model to provide the coating condition based on ultrasounds. A methodology has been defined extracting the signature echo, generating synthetic signals to simulate real echo patterns, training the CNN with the synthetic signals and testing the CNN with both synthetic and real signals. The coating model can separate the overlapped echoes and provide the location and amplitude of the echoes related to the coating. Ceit has developed a second method based on echo modelling calculating the frequency domain of the signals with the Fourier Transform. Good results estimating the coating thickness have been achieved.

Next steps are continuing with the experimental analysis using different kinds of coatings (different in material and in thickness) and improving both methods. Furthermore, Ceit will design an ultrasonic coupon to be integrated with the electrochemical coupon of C-Cube. This way, we will be able to detect and quantify changes in the coating condition correlating the data coming from both sensors and testing coating degradation in real offshore environments and different zones (splash zone, submerged zone).

C-Cube will work on the further development of coating degradation sensors based on the Electrochemical Impedance Spectroscopy method. Together with Sirris, degradation experiments will be set-up both on a laboratory scale and at the offshore Blue Accelerator test site in Belgium. The main purpose is to further develop existing physics-based prognosis models for coating degradation, allowing a more precise estimate of remaining coating life as a function of different exposure conditions (temperature and time-of-wetness) and coating type (epoxy with and without glass flake reinforcement). Sensors for continuous measurement, as well as coating coupons are being prepared. The laboratory and offshore experiments will start in Q1 of 2025.

3) Pitting Analysis

Ceit is working on the ultrasound technique to analyze how to detect and quantify pitting corrosion. To do so, several pitted samples produced by Sirris were measured. As a preliminary conclusion, we can say that the pitting attenuates and distorts the ultrasound response. A larger pit depth implies larger attenuations and distortions. On top of that, different pit shapes affect the ultrasound echo signal. Next steps are to perform acoustic simulations to generate synthetic pits with the aim of training a Convolutional Neural Network for estimating the depth/shape of the pit. Additionally, how the pits affect the frequency response of the ultrasound response will be analyzed. Once the ultrasound system is prepared for pitting corrosion, several ultrasound sensor nodes attached to pitted samples will be installed at the HarshLab test site to measure remotely how the pits grow in a real offshore environment.

In this framework, the goal of Sirris and C-Cube is to investigate the possibility to detect pitting corrosion using electrochemical techniques such as linear polarization resistance (LPR), electrochemical noise (ECN), and electrochemical frequency modulation (EFM). The long-term aim is to allow development of sensors for continuous monitoring of pitting corrosion on carbon steel. Testing on stainless steel has successfully validated the detection of pitting corrosion by observing variations in corrosion rate (LPR), current noise (ECN), and the causality factor (EFM). On carbon steel, inducing realistic pitting at a laboratory scale has proven challenging. However, noticeable deviations in the electrochemical response were observed when samples with mill scale on the surface were immersed in 3.5% NaCl for one week, indicating the occurrence of pitting corrosion, whereas this was not observed on clean steel surfaces. This highlights the potential of these techniques for detecting pitting; however, additional work is needed to refine and fully validate their applicability under a range of conditions.

The project is being carried out thanks to the collaboration of 12 partners from 5 European countries. The coordinator of the project is CEIT, a Basque technological centre from Spain, as well as ALERION, a developer of fully automated drone solutions, the BASQUE ENERGY CLUSTER, an association formed by Basque entities of the energy sector and TSI, specialists in engineering techniques and services. The Belgian partners are 24SEA, experts in SHM services of offshore structures, FLANDERS MAKE and SIRRIS, research centres, NORTHER, offshore wind farm developer and VUB, Vrije Universiteit Brussel. Finally, there is C-CUBE, a specialist in corrosion and wear from The Netherlands, SINTEF, a Norwegian research organisation and WÖLFEL, a German expert in engineering and system solutions especially in SHM offshore and onshore structures.

For more information about the project, which is funded by the European Union, visit the official website: www.willow-project.eu, follow the LinkedIn page @WILLOW Project EU and watch the video of the project.