watereye
RESEARCH
& INNOVATION ACTIONS

WATEREYE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 851207

O&M Tools Integrating Accurate Structural Health in Offshore Energy

Welcome


Dr. Ainhoa Cortés
WATEREYE Project
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Dear reader,

This is the last newsletter of the WATEREYE project. After three years of hard work, we can proudly say that we have achieved the main objectives of the project. The project has developed a monitoring system able to remotely detect and quantify the corrosion level in certain points of an offshore wind turbine tower. Additionally, control algorithms at wind turbine and wind farm level to protect the foundation have been developed, thus reducing the risk of failure due to fatigue corrosion.

The results obtained are the outcome of years of research and development, in which the project partners have worked tirelessly for pushing the project forward.

In this newsletter you will find a summary of the most significant achievements reached during the project, as well as information about the events and meetings held lately, such as the Final Review Meeting and the Final Dissemination Event. In this last event, the final validation video was released, being now available on the WATEREYE YouTube channel.

Furthermore, a summary of the Open Access publications and datasets produced within the project is presented.

Thank you for your interest in the WATEREYE project, enjoy the reading!

Ainhoa Cortés.

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About WATEREYE

The WATEREYE integral solution will allow wind farm operators to carry out the predictive maintenance strategy in the future with the aim of reducing wind turbine downtimes and O&M costs and hence will increase the yearly electric energy from the offshore renewable wind energy resources.

For this purpose, the WATEREYE project aims to develop:

- A monitoring system able to remotely detect and quantify the corrosion level in chosen points of the tower (atmospheric and splash-zone) of offshore wind turbines as means to support the predictive maintenance (PdM) strategy and eventually to reduce considerably the operation and maintenance (O&M) costs without increasing the probability of operation failures;
- A semantic modelling technique where the acquired data will be analysed in novel ways (semantic models) to enhance prediction models;
- Control algorithms at wind turbine and wind farm level to protect the foundation, reducing the risk of catastrophic failure due to fatigue corrosion.

Thus, the WATEREYE Project will contribute by improving the offshore wind farms' operation and maintenance. Thanks to an early, smart and accurate detection of corrosion in structural components, critical failures will be predicted on time:

- ✓ Impact 1: Reduction of insurance costs
- ✓ Impact 2: Reduction of corrosion inspection effort (related to operation costs)
- ✓ Impact 3: Reduction of maintenance costs
- ✓ Impact 4: Improved availability
- ✓ Impact 5: WT and WF control integrating corrosion data

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Main achievements

The most significant achievements reached during the project are:

- **WP1: DEFINITION OF USE CASES, SYSTEM REQUIREMENTS & SYSTEM ARCHITECTURE.** Work Package 1 represents the starting point of WATEREYE project with the definition of the project framework and general system requirements to be developed during the project.

  For this purpose, a study on corrosion and its effect on the relevant parts of the wind turbine structure has been carried out, allowing the identification the main challenges that corrosion brings to marine structures. The corrosion performance depends on environmental conditions. Steel structures in offshore applications need to be protected against corrosion. Hence, external steel surfaces in the atmospheric and splash zones shall be protected by coating systems. Thus, not only structural steel but also protective coatings are defined clarifying the requirements of the WATEREYE solution.

  Production of steel samples for field exposure and laboratory testing to be used in developing a monitoring system focusing on corrosion of structural steel in these zones were planned. Moreover, during WP1 the preliminary technical definition of the solutions has been developed: smart sensors; communications; mobile-platform operating conditions; diagnostics and visualization tools; functionalities of the diagnostic, prognostic and decision support tools; WT and WF control algorithms main outputs and use cases for the WF controller.

- **WP2: SMART SENSORS, COMMUNICATIONS & MOBILE PLATFORM.**
  Work Package 2 is focused on the design of the physical components of the WATEREYE solution composed by fixed sensor nodes, a mobile node, a drone, a Drone Docking Station and the WATEREYE Computer. The monitoring system has been designed and validated in a relevant environment. After the final validation, it can be said that the system is capable of remotely estimating the wall thickness losses due to corrosion and the intra-day corrosion rate. This will be useful to reduce the maintenance costs of the atmospheric and splash zones of offshore wind turbines.

  Corrosion testing was performed by field exposure at PLOCAN's offshore test station in Gran Canaria and laboratory testing at SINTEF Industry. Corrosion is a relative slow process. It takes a long time (years in general) to induce corrosion on coated steel samples in field tests. Hence, accelerated laboratory testing was needed to produce corroded sampled within the project period. Exposed samples were evaluated visually by SINTEF Industry before samples were sent to CEIT and FMAKE for development of the corrosion monitoring system.

  Both non-corroded and corroded, coated and bare steel samples in different thicknesses were used with the aim of characterizing appropriately the ultrasound sensor nodes to get higher accuracy even under harsh conditions. On the other hand, high efforts have been done to design a robust drone-based platform able to position accurately the sensor head on the wall.

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- **WP3: STRUCTURAL HEALTH MONITORING, DIAGNOSIS, PROGNOSIS & CONTROL TOOLS FOR INDIVIDUAL WIND TURBINE.**
  The main goal of WP3 is to develop algorithms and software tools for ensuring integral intelligent processing of the inspection data generated both by the novel smart sensors developed in WP2 and by the data coming from WTs to optimise the O&M of a single WT.

  In WP3, it is planned to propose models for corrosion and coating degradation relevant for the environmental conditions and material under study. Currently, electrochemical tests are running, collecting the necessary data for validation of the corrosion models. In addition, a corrosion simulation tool has been implemented to generate corrosion data that resemble field data as close as possible.

  Furthermore, a 3D visualization tool has been developed to facilitate the visualization of measured absolute and relative thickness at different positions and times on the WT to support the analysis and decision-making progress for predictive maintenance.

  A corrosion prognosis methodology has been designed by incorporating a corrosion model and a corrosion indicator (wall thickness) which will be extracted from the US signal.

  Moreover, a load reduction control algorithm is developed for offshore turbine tower. The control algorithm is designed to mitigate the loads by reducing the loads induced by the blade imbalance and tower vibration damping control. It is also feasible to be integrate to the wind farm controller in WP4.

  At sensor level, measurement data and data-driven models were used to detect the onset of (uniform) corrosion, a prognosis of future material thickness and remaining useful life (RUL) before the critical thickness is reached.

- **WP4: WIND FARM CONTROL AND MANAGEMENT TOOLS.**
  The WATEREYE wind farm management tools are part of the overall solution with the objective to reduce O&M costs by extending the lifetime of offshore wind turbines. On the one hand, the usually more remote location results in higher O&M cost due to reduced accessibility and longer vessel transfers. On the other hand, offshore wind turbines operate in a harsher environment with extreme wind and wave loads increasing the probability that mechanical or electrical equipment fails. Failures may occur in a variety of components in the wind turbines and electrical collection system. The focus of WATEREYE lies on the protection of turbine towers from failure by preventing both corrosion and material fatigue from progressing. The WATEREYE tools dealing with preventing fatigue-based failures are collectively referred to as wind farm (WF) management tools.

  Wind farm control must deal with various uncertainties that propagate through the system and affect the remaining useful lifetime of wind turbine components. A tool for probabilistic analysis of turbine dynamics in the frequency domain was developed as well as a module of farm-scale turbulence that supports computationally efficient multiscale stochastic

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simulations in the time domain. These tools can be used to evaluate the performance of wind farm control strategies.
In WATEREYE, the wind farm control strategies prioritise power tracking while structural loads are mitigated when possible. This includes wind farm control algorithms that balance the thrust to distribute the instantaneous fatigue loads evenly between the wind turbines. Moreover, a control framework was developed that calculates the accumulated damage depending on environmental conditions and the wind farm control. The damage estimate feeds into the method for optimal O&M planning that considers potential power gains in the long and short term, power losses due to derating or shut down, maintenance costs as well as the weather forecast when scheduling maintenance tasks.

The wind farm control and management tools from WATEREYE can be used both for retrofitting existing wind turbines and in novel system developments.

- **WP5: INTEGRATION AND VALIDATION.**
The aim of WP5 is to integrate the results of WP2, WP3 and WP4 into a global WATEREYE product for Wind Farm Structural Health Monitoring (including data collection (sensing + mobile-platform + communications), modelling, diagnosis, prognosis, WT control and WF control) and to validate the WATEREYE monitoring solution in relevant environment (in the physical offshore testing facilities of PLOCAN).

The validation of the WATEREYE monitoring system in a relevant environment represents a major milestone within the project. This is the result of multiple integration and validation sessions held in Delft (The Netherlands), Trondheim (Norway), San Sebastián (Spain) and Sint-Truiden (Belgium) with the aim to maximize the success of the final validation and minimize possible failures.

Due to the unavailability to conduct the validation inside a real wind turbine tower, it was decided to build a steel structure to simulate a wind turbine tower in a "realistic and feasible way". This tower complies in terms of being producible, transportable, easy to construct and with enough similarity with a real wind turbine tower section.

Therefore, the final validation has taken place inside the hangar of PLOCAN's offshore platform, using this steel tower as the main element to which the sensors, UWB anchors and steel plate are attached.

The WATEREYE system is mainly formed by five subsystems: the Fixed Sensor Nodes, the Mobile Sensor Node, the Drone, the UWB Anchors and the WATEREYE Computer (WEC). The real solution will have two more modules: the Drone Docking Station (DDS), which will enable the interaction between the WEC and the Drone; and the WATEREYE Server, which will integrate the WATEREYE Database and the tools to predict the Remaining Useful Lifetime (RUL) of the structure.

In this final validation the following interactions have been tested:
  - UWB Anchors - Mobile Sensor Node
  - Mobile Sensor Node - Drone

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- Mobile Sensor Node - WEC
- Fixed Sensor Nodes - WEC
- WEC – Server

The WATEREYE monitoring solution has been validated both at lab scale in Sint-Truiden (Belgium) and in relevant environment at the PLOCAN's offshore platform in Gran Canaria (Spain). Therefore, it can be concluded that the validation of the WATEREYE monitoring system has been successfully conducted.

- **WP6: EXPLOITATION AND DISSEMINATION.**
  The main goal is to maximize the impact of the project through communication and dissemination activities (C&D), as well as to maximize the exploitation of results. Several communication and dissemination activities have been carried out within the project, resulting in a dedicated website, and social media profiles (Twitter, LinkedIn, YouTube) whereby disseminating the project results. Posters, roll-up and triptychs have been created to be handed out in events and conferences.

  Furthermore, a newsletter campaign has been launched, in which the latest advancements of the project were disseminated among stakeholders. Promotional videos have been produced and made available in the dedicated YouTube channel of the project. Collaboration and engagement with related EU funded projects have been promoted through the organization of cluster events, creating a space for discussion and synergies creation.

  With regards exploitation, 19 different WATEREYE products have been identified, classified under Key Exploitable Results (KERs). For each KER, an exploitation and business plan have been developed.

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Meet the WATEREYE Team

*Click on logos to access the partner's webpage

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Follow us and share it

We would like to encourage you to follow us on our [website](), [Twitter](), [LinkedIn]() and [YouTube]() official channel as well as to tag @watereyeproject in your tweets to circulate news, publications or events on our Twitter feed. In the same way, we encourage you to use @WATEREYE PROJECT in your LinkedIn public actions regarded to WATEREYE.

WATEREYE News

WATEREYE Final Review Meeting, 29th November, 2022, Brussels, Belgium

The Final Review Meeting of the WATEREYE project took place in Brussels, in the Delegation of the Basque Country in the EU. During the meeting, results and achievements of the different Work Packages were presented by the project partners to the Project Officer, allowing for discussion on future plans. This meeting marks the end of the project started in 2019.

Figure 1. WATEREYE project consortium in the Final Review Meeting

WATEREYE Final Dissemination Workshop, 20th October, 2022, Gran Canaria, Spain

Figure 2. WATEREYE Final Dissemination Event poster

The WATEREYE project celebrated its Final Dissemination Workshop at PLOCAN's facilities in Gran Canaria (Spain). Project partners representatives, interested local stakeholders and members of the External Experts Advisory Board attended in person to this event, which also could be followed online via Zoom.

During this event the main achievements obtained in order to implement new monitoring, diagnosis, forecast and control tools in offshore wind farms to adopt intelligent predictive decisions of operation and maintenance were shown.

The event sets the successful closure of the project in terms of dissemination, which has been able to achieve its objectives contributing to continue with technological advances for the energy transition.

Representatives from the private sector, such as marine renewables developers, shipyards and inspection and certification bodies, who could potentially apply the results of the project in their activities in the future, also participated in the event.

In this event, the final validation video was released and is available [here]().

For more information, the event was recorded and is available [here]().

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Figure 3. WATEREYE Final Dissemination Event

Figure 4. WATEREYE 3rd External Expert Advisory Board

EEAB3, 21st October, 2022, Gran Canaria, Spain

The third External Expert Advisory Board (EEAB3) was celebrated on October, 21st at PLOCAN's facilities in Gran Canaria (Spain). Project partners and representatives of Enerocean, Wedge Global and Stratosphere were present, showing much interest in the WATEREYE research.

WATEREYE is mainly focused on the uniform corrosion at the splash and atmospheric zones, as key areas to be monitored. Taking a step further, the EEAB experts confirmed that pitting corrosion is very risky and difficult to detect, being foundations severely affected by this phenomenon.

Coating experts talked about the current development of new coatings, which could affect the performance of the ultrasound technology.

Experts in wind farms O&M informed that corrosion is a key factor during commissioning since technicians/operators may introduce some pre-mature damages during installation. Hence, it would be a good idea to monitor the structural health of the tower not only during operation, but also during commissioning.

On the other hand, it seems that monitoring the cathodic protection bars is of interest since when these blocks are degraded protection fails, and therefore corrosion can progress faster in the structure.

WATEREYE project presented at the Horizon Results Booster info session, 17th November, 2022

On 17 November 2022, during the Info Session of Horizon Results Booster, the project was presented by the coordinator Ainthoa Cortés.

At the same time, the project coordinator explained the positive experience of the project in the use of the platform. Around 658 people attended the info session.

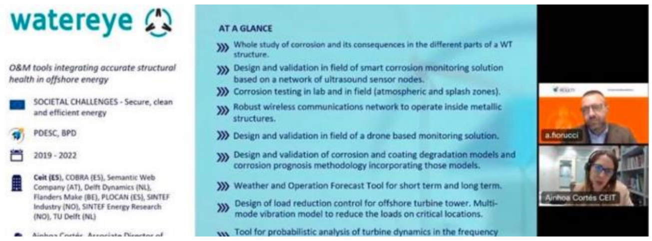

Figure 5. Horizon Results Booster info session

Furthermore, an article has been published on the WATEREYE project solution and how it has benefited from the Horizon Results Booster support services for research results exploitation and businesplan development.

Read the full article here.

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Summary of Open Access publications

During the WATEREYE project a total of 8 peer-reviewed Open Access publications have been produced:

1. U.Chathurani Thibbotuwa, A.Cortés, A. Irizar. *Ultrasound-Based Smart Corrosion Monitoring System for Offshore Wind Turbines*. Applied Sciences (January 2022). DOI: 10.3390/app12020808.
2. A.Guisasola, A.Cortés, J.Cejudo, A. de Silva,M. Losada, P.Bustamante. *Reliable and Low-Power Communications System Based on IR-UWB for Offshore Wind Turbines*. Electronics (February 2022). DOI: 10.3390/electronics11040570.
3. J. Verhelst, I. Coudron, A. P. Ompusunggu. *SCADA-compatible and scaleable visualization tool for corrosion monitoring of offshore wind turbine structures.* MDPI Applied Sciences (February 2022). DOI: 10.3390/app12031762.
4. S.Barber, L. A. M. Lima and Sakagami, Yoshiaki and Quick, Julian and Latiffianti, Effi and Liu, Yichao , R.Ferrari and Letzgus, Simon and Zhang, Xujie and , F. Hammer. *Enabling Co-Innovation for a Successful Digital Transformation in Wind Energy Using a New Digital Ecosystem and a Fault Detection Case Study*. Energies (August 2022). DOI: 10.3390/en15155638.
5. R.Brijder, C. H M Hagen, A. Cortés, A. Irizar, U. Chathurani Thibbotuwa, S. Helsen, S. Vásquez, A. Partogi Ompusunggu. *Review of corrosion monitoring and prognostics in offshore wind turbine structures: Current status and feasible approaches.* Frontiers in Energy Research, section Wind Energy (September 2022). DOI: 10.3389/fenrg.2022.991343.
6. U. Chathurani Thibbotuwa ,A. Cortés,A. Irizar. *Small Ultrasound-Based Corrosion Sensor for Intraday Corrosion Rate Estimation.* Sensors. As part of the Special Issue Smart Sensors for Structural Health Monitoring and Nondestructive Evaluation. (November 2022). DOI: 10.3390/s22218451.
7. Vásquez, J.Verhelst, R. Brijder, A. Partogi Ompusunggu. *Detection. Prognosis and Decision Support Tool for Offshore Wind Turbine Structures.* Wind (November 2022). DOI: 10.3390/wind2040039.
8. Jean Gonzalez Silva, Riccardo Ferrari,Jan-Willem van Wingerden. *Wind farm control for wake-loss compensation, thrust balancing and load-limiting of turbines.* Renewable Energies, 2023. DOI: 10.1016/j.renene.2022.11.113

Summary of Open Access datasets

During the WATEREYE project a total of 4 datasets have been created:

1. *Estimating TOF from ultrasound signal over bare steel sample of 5 mm thickness.* DOI: 10.5281/zenodo.4280715.
2. *Corrosivity at PLOCAN.* DOI: 10.5281/zenodo.5797557.
3. *Closed-loop wind farm controller (active power tracking / thrust balancing / load-limiting) for SOWFA simulations.* DOI: 10.5281/zenodo.7276417.
4. *eMPC based load reduction controller for wind turbines.* DOI: 10.5281/zenodo.7276349.