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 Coordinator

Dear reader,

In this sixth newsletter, you will find a summary of the main results of the intermediate validation at lab scale conducted at the FMAKE facilities. During this validation, the components developed during the WATEREYE project that are part of the validation test were tested. This lab scale test environment aimed to validate the developments related to thickness measurements (including the measurement location), sending the data to the WATEREYE Database, and displaying the data on the 3D visualisation tool.

You will find also updates on the activities that SINTEF-I, SINTEF-E and TU Delft are developing with regards to corrosion in the splash zone and wind farm management tools respectively.

In terms of Communication & Dissemination, video recordings of the validation sessions and the *Cluster Event* are already available in our official YouTube channel.

This period has also been very productive in terms of scientific content generation, especially for TU Delft, highlighting five publications either accepted or presented in different wind energy conferences.

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 accurately predict the need for future operations & maintenance (O&M) to reduce its costs, which can represent up to 30% of the Levelised Cost of Energy (LCOE) (an estimated LCOE of 70€/MWh in 2030), and to increase the annual energy production from the offshore wind thanks to an accurate structural health monitoring and control of the Offshore Wind Farms.

For this purpose:

1. WATEREYE aims to develop high-accuracy, fast-response, and non-invasive ultrasound smart sensors to detect and estimate corrosion levels by analysing wall thickness, which will be integrated into a high-precision indoor "drone-based mobile platform" inspection system capable of monitoring the entire critical area.
2. Design a robust wireless communication system and a custom protocol that will prevent data losses or corruption even in a harsh environment.
3. Collect, store, and provide efficient access layers for the wind turbine data to ensure optimal understanding of structural health.
4. Develop accurate mathematical corrosion models for offshore wind turbine structures to characterize the corrosion phenomena in the wind turbine tower.
5. Develop condition-based maintenance tools for fault diagnosis; corrosion prognosis algorithms; decision support to define predictive O&M; and fault-tolerant control of offshore wind structures.
6. Develop control algorithms for adaptive O&M strategies of individual wind turbine and the overall plant. The WATEREYE monitoring system will determine the condition of the structures. This information, together with O&M tasks, will minimise the need for human inspection, vessel transfer, and optimising onshore logistics.

Visit us at www.watereye-project.eu to extend this information

Download here our leaflet to get more details about WATEREYE concept and methodology

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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

Intermediate validation successfully conducted in Belgium

The integration and validation tests on lab scale were done in the mockup tower that was installed in Belgium. The main goals of the intermediate validation are:

- Do the first integration tests of different parts developed within the WATEREYE project.
- Maximize the success of the final validation of the project.
- Simulate "relevant environment" as close as feasible on lab scale.

These tests were conducted inside a mock up of a wind turbine tower consisting out of a steel structure of 32 panels which can easily be built-up and dismantled. A camera was mounted to follow the activities from outside safely.

The test set-up was also composed by four fixed sensor nodes, one mobile sensor node attached to the drone, four UWB anchor nodes for indoor positioning, the drone, the WATEREYE computer (WEC) and the analysis software (diagnosis and prognosis tool and Decision Support Tool).

The following was tested:

- 4 UWB anchors fixed to the top of the tower, the drone and the fixed sensor nodes could be localized.
- The LiDAR based positioning worked well. Enough asymmetry is required to make the orientation work. In the mock-up, the openings (used as doors) were not sufficient to give this asymmetry. The fact that the tower was not circular (but a polygon with 16 edges) was visible in the measurements.
- The drone was controlled by pilot. Approaching and fixing the drone to the requested location was difficult, but it worked.
- Having the anchors positioned at strategic locations close to the waypoints gives better results for the altitude calculations based on ranging information.

The data could be visualized on the 3D visualisation tool. This means that the full data flow worked (US measurement unit > WATEREYE Computer > WATEREYE Database (external server) > 3D visualisation tool). The measurements (thickness measurement and localization) also gave good quantitative results.
The fact that some issues were found, and solved, during these integration (and pre-validation sessions), proved that they were a useful step before doing the final validation.

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Figure 1. Validation set-up at FMAKE facilities

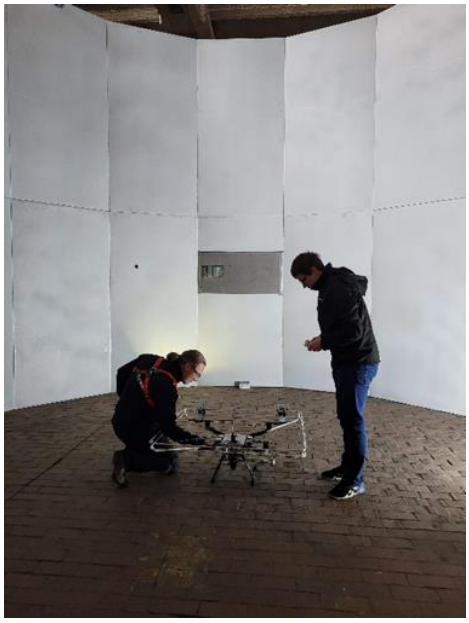

Figure 2. DD team configuring the drone before flying

In terms of communication activities, a video of the intermediate validation session has been released and available here.

Corrosion tests at splash zone

Since December 2021, 22 samples (10 coated and 12 bare steel) are being exposed to real conditions at the *Harshlab 0.5* of PLOCAN, Gran Canaria. SINTEF-I is in charge of analysing these samples after its exposure, observing for the coated samples, a high amount of corrosion creep around damage. On the other hand, coating far away from damage is intact.

Figure 3. Corrosion creep on 1-month sample (left) and on 5-months sample (right)

According to the standard, a coating system without zinc primer for offshore splash zone passes only if corrosion from scribe is <8 mm after 1/2 year of testing in laboratory test.

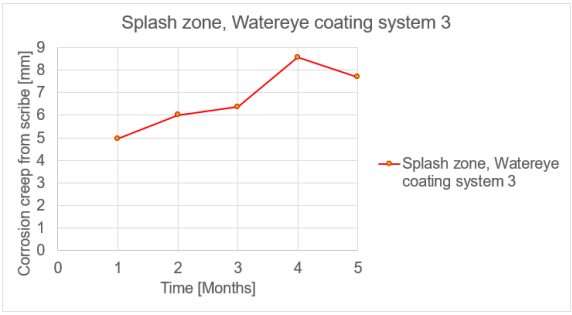

Figure 4. Corrosion creep from scribe

These results imply that coating system applied is for a splash zone, but is seen to lead to early and very high failure.

If a little damage in a badly applied coating is created early on e.g. during installation of wind turbine, more and more coating will fall off surrounding this damage. Steel at damage will corrode both horisontally – on a coating s howing high corrosion creep – and vertically – as thickness loss (corrosion depth).

Places where steel can corrode depends on the ability of the coating to withstand damages, and spread of damage.

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SINTEF-E and TU Delft developing wind farm management tools

During this period, SINTEF Energy Research continued to work in WP4 on the probabilistic wind farm analysis as well as the co-simulation of O&M planning and wind farm control. Final results will come soon.

Together with TUD, SINTEF Energy Research is implementing an integrated set-up of the wind farm management tools developed in WATEREYE. These activities are part of WP5. The different tools are connected to a wind farm simulator where different use cases and scenarios can be investigated. We are looking forward to testing our set-up!

Cluster Event on *'Use of drones and corrosion protection systems in offshore wind. Solutions for cost reduction and life extension'*

Last 29th June, the WATEREYE project organised a new Cluster Event on the '*Use of drones and corrosion protection systems in offshore wind. Solutions for cost reduction and life extension'*. This event was organised in collaboration with DURABLE and MAREWIND EU funded projects, and was composed of two blocks of presentations: "Drones applications in offshore wind" and "Corrosion protection systems and life extension". The first block was composed of presentations fom CEIT, Delft Dynamics, the Advanced Center for Aerospace Technologies and the University of Seville, whereas in the second block the latest developments of corrosion protection systems were presented by SINTEF-I and LUREDERRA.

For more information, the event recording is available here.

Figure 5. Cluster Event on Use of drones and corrosion protection systems in offshore wind. Solutions for cost reduction and life extension

New article of WATEREYE in the Special Edition of "Empresa XXI" magazine

On the occasion of the Wind Europe Annual Event 2022 in Bilbao, the main industrial magazine on the Basque Country, 'Empresa XXI' published an article talking about CEIT and its role and contributions to the WATEREYE project.

You can read the full special edition here.

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TECNOLOGÍA | PREDICCIÓN

CEIT IMPULSARÁ AL SECTOR O&M

LIDERA EL PROYECTO 'WATEREYE' PARA PREDECIR FUTURAS ESTRATEGIAS DE MANTENIMIENTO

El centro tecnológico Ceit, con la vista puesta en aumentar la producción anual de energía eólica marina, lidera el proyecto europeo Watereye para desarrollar una solución integral que permita a los operadores de los parques eólicos predecir con precisión las necesidades de futuras estrategias de mantenimiento.

El proyecto viene motivado por las limitaciones actuales de la eficiencia de la operación y el mantenimiento (O&M) de los parques eólicos marinos. La solución de Watereye aspira a reducir los costes de operación y mantenimiento, que pueden representar hasta el 30 por ciento del coste nivelado de la electricidad, mediante un control y una monitorización precisa de la salud estructural de los parques eólicos marinos.

A través del despliegue de sistemas de supervisión novedosos, esta solución se centrará en predecir la tasa de degradación de las estructuras marítimas por corrosión. Para ello, apuestan por el desarrollo de un sistema de sensores y monitorización, compuesto por sensores inteligentes *low-cost*, basados en tecnología de ultrasonidos, que permiten mediar el espesor de las estructuras y su pérdida de material por la corrosión.

APUESTA POR EL DESARROLLO DE UN SISTEMA DE SENSORES Y MONITORIZACIÓN

Comunicación inalámbrica

Ceit ensayó el pasado año con éxito, dentro del proyecto, un nuevo sistema de comunicación inalámbrica para plataformas eólicas offshore en Gran Canaria.

Ese ensayo supuso una oportunidad para probar el alcance y la robustez de la solución de comunicación inalámbrica que están diseñando. Según explican, probaron en el ensayo diferentes tipos de antenas, calibrando previamente el sistema para cada una de ellas. Además, testaron dos canales de UWB, uno utilizado para las comunicaciones y otro para estimar la distancia y conocer en todo momento la posición del nodo móvil.

Investigador de Ceit trabajando el desarrollo del sistema de supervisión.

Pruebas de testeo de recubrimientos.

TEKNIKER ALARGARÁ LA VIDA ÚTIL DE LAS INSTALACIONES DE EÓLICA OFFSHORE

El centro tecnológico Tekniker ha colaborado en el marco del proyecto Avansurf en el desarrollo de recubrimientos funcionales para el sector eólico offshore y nuevas tecnologías de monitorización con el fin de controlar la degradación por corrosión de los recubrimientos, resolviendo de ese modo los retos técnicos asociados a las extremas condiciones ambientales marinas.

El desarrollo de novedosos materiales y tratamientos, así como la posibilidad de controlar y monitorizar dichos materiales constituyen una gran novedad, ya que, como avanzan desde el centro, no existen a día de hoy significativas contribuciones al estado del arte.

Según ha explicado la directora de la Unidad de Tribología de Tekniker, Raquel Bayón, han fabricado un sensor formado por dos peines de electrodos interdigitados capaz de integrarse en el mismo recubrimiento, dentro del propio esquema de pinturas del aerogenerador, gracias a sus grandes dimensiones y bajo coste, proporcionando una fuente fiable de información de primera mano sobre el estado de la capa protectora de esas estructuras offshore. Al mismo tiempo, y dentro del ámbito de los recubrimientos orgánicos multifuncionales, han trabajado en diversas soluciones de base de pintura con mejores propiedades en cuanto a corrosión, triboocorrosión, superhidrofobicidad, flexibilidad y alta adherencia.

Ensayos en mar abierto

Los nuevos recubrimientos de Avansurf han sido validados mediante ensayos de inmersión estáticos, ensayos de corrosión cíclicos según ISO 12944 y en mar abierto. Y es que las soluciones de recubrimientos y de sensorización se han testado en condiciones reales en el Marine Corrosion Test Site 'El Bocal', un laboratorio marino ubicado cerca de Santander, y en el puerto de Mutriku (Guipúzcoa).

HAN DESARROLLADO MATERIALES QUE SE PUEDEN CONTROLAR Y MONITORIZAR

Figure 6. Special Edition of 'Empresa XXI', April 2022

Fourth Engineering Workshop in Leuven, Belgium

Last 24th and 25th May the WATEREYE consortium partners met physically in Leuven to hold the Fourth Engineering Workshop organised by FMAKE. The partners had the chance to present their developemnts and results within the different work packages. There was also time to visit the DronePort facilities in Sint-Truiden, where the intermediate validation took place.

Figure 7. WATEREYE team at the 4th Engineering Workshop in Leuven

TU Delft & FMAKE papers in Wind Energy conferences

- The paper entitled "*Active power control of wind farms: an instantaneous dispatch approach on waked conditions*" was presented at the TORQUE 2022 Conference and published in the IOP Journal of Physics: Conference Series 2265 (2), 022056. Paper available here.
- The paper entitled "*Comparison of Two Data-driven Airborne Wind Energy Oriented Long-term Weather Forecast Methods*" was presented at the 9th international Airborne Wind Energy Conference (AWEC 2021). Paper available here.
- The paper entitled "*A Switching Thrust Tracking Controller for Load Constrained Wind Turbines*" was presented at the American Control Conference (ACC) 2022. Paper available here.
- Two more papers have been accepted in the Conference on Decision and Control 2022:
  - *"An Economic Model Predictive Control Approach for Load Mitigation on Multiple Tower Locations of Wind Turbines",* Zhixin Feng, Alexander J. Gallo, Yichao Liu, Atindriyo K. Pamososuryo, Riccardo M.G. Ferrari and Jan-Willem van Wingerden.
  - *"Convex Model Predictive Control for Down-regulation Strategies in Wind Turbines",* Jean Gonzalez Silva, Riccardo Ferrari and Jan-Willem van Wingerden.
- The conference paper entitled *"Corrosion Prognostics for Offshore Wind-Turbine Structures using Bayesian Filtering with Bi-modal and Linear Degradation Models",* Brijder, R.; Helsen, S.; Partogi Ompusunggu, A. was presented at the Thirteenth International Workshop on

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Structural Health Monitoring Stanford University, March 15-17 2022.

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Events

Windfarm Operational Analysis Workshop, 4th October 2022, Madrid

Next 4th October, the Spanish Wind Energy Association (AEE) is organising a workshop on Windfarm Operational Analysis. The project coordinator, Ainhoa Cortés from CEIT, will be presenting the 'Validation results of the corrosion monitoring system based on ultrasounds', which will be held during the session 6, 'The importance of installation and further inspections'.

More info about the event can found here.

Conference on Decision and Control - Dec. 6-9, 2022, Cancun, Mexico

The 61st IEEE Conference on Decision and Control (CDC 2022) will be hosted in Cancun, Mexico, from December 6 through December 9, 2022.

The IEEE CDC is recognized as the premier scientific and engineering conference dedicated to the advancement of the theory and practice of systems and control. The CDC annually brings together an international community of researchers and practitioners in the field of automatic control to discuss new research results, perspectives on future developments, and innovative applications relevant to decision making, automatic control, and related areas.

The IEEE CDC is hosted by the IEEE Control Systems Society (CSS) in cooperation with the Society for Industrial and Applied Mathematics (SIAM), and the Japanese Society for Instrument and Control Engineers (SICE).

At this conference, TU Delft will be presenting two papers:

- *"An Economic Model Predictive Control Approach for Load Mitigation on Multiple Tower Locations of Wind Turbines",* Zhixin Feng, Alexander J. Gallo, Yichao Liu, Atindriyo K. Pamososuryo, Riccardo M.G. Ferrari and Jan-Willem van Wingerden.

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- *"Convex Model Predictive Control for Down-regulation Strategies in Wind Turbines",* Jean Gonzalez Silva, Riccardo Ferrari and Jan-Willem van Wingerden.

More info about the event can be found here.

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Partner's corner

SINTEF Industry

SINTEF Industry performs contract research and delivers solutions and services to national and international customers. With our cross-disciplinary knowledge base and advanced laboratories as a base, we develop – in close collaboration with our customers – technology and solutions within a broad range of research areas and industries.

The Materials and Nanotechnology department has its expertise in metals, minerals/raw materials, polymers/composites, nanotechnology, and materials properties and utilization. Our extensive experience in research on corrosion and corrosion protection (protective coatings in particular) of offshore structures is valuable for the project.

The Materials and Nanotechnology department has created a research framework (CorrMOD, strategically internally financed project on corrosion modelling) for corrosion and corrosion modelling. The framework connects laboratory testing, mathematical models, numerical solution techniques and modelling workflow with experienced personnel working with corrosion mechanisms. The project aims at elevating our already extensive knowledge of corrosion with adapted digital technologies, thus 'digitalizing' both SINTEF and our customers through advanced research in the field of corrosion.

SINTEF Industry main contributions to this project are related to 'Corrosion testing' and 'Definition and validation of corrosion models'.

The aim of the corrosion testing task is to compare US signals to the reported results of corrosion testing performed. Corroded steel samples will be used in the development of corrosion monitoring platforms. Hence, the corrosion measured by the US signals can be compared to the actual wall thickness loss.
Steel structures in offshore applications need to be protected against corrosion. Coating systems and/or corrosion allowance are corrosion protection methods used for steel structures exposed in the atmospheric and splash zones.

US sensing on structural steel needs to consider applied coating systems and corrosion products on the steel surface. Interfaces between different materials, e.g., coating/steel, steel/corrosion product, and inhomogeneities in coatings may interfere with the US signal and affect the corrosion measurements. Hence, the corrosion protection systems must be taken into account during evaluation of the US sensor.

Samples will be exposed both in accelerated laboratory tests and filed tests. During exposure the samples will be evaluated visually. After testing, the samples will be sent to CEIT for US measurement of corrosion, i.e. steel thickness loss. In parallel, detailed examination of corroded samples including adhesion measurements on coatings and cross-sectional investigation of corrosion will be carried out at SINTEF to characterize coating degradation and corrosion accurately. In this way US measurements can be correlated with accurate physical measurements.

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With regards to the definition and validation of corrosion models, corrosion and coating degradation models relevant for the environmental conditions and materials will be proposed. Coating degradation (i.e. area with failed coating) and corrosion (i.e. the wall thickness loss) will be described as a function of time. This will be based on relevant data from literature and field testing.

Attention will be devoted to climatic conditions like time of wetness (TOW), temperature and concentration of aggressive species (e.g. chlorides) in order to find correlations. These correlations are expected reveal which parameters that determine coating degradation and corrosion rates. Future development in coating degradation and corrosion will be described by simple mathematical models that will be tuned by input from the sensor measurements.