Co-funded by the Erasmus+ Programme of the European Union

windEXT

Advanced maintenance, lifetime extension and repowering of wind farms supported by advanced digital tools

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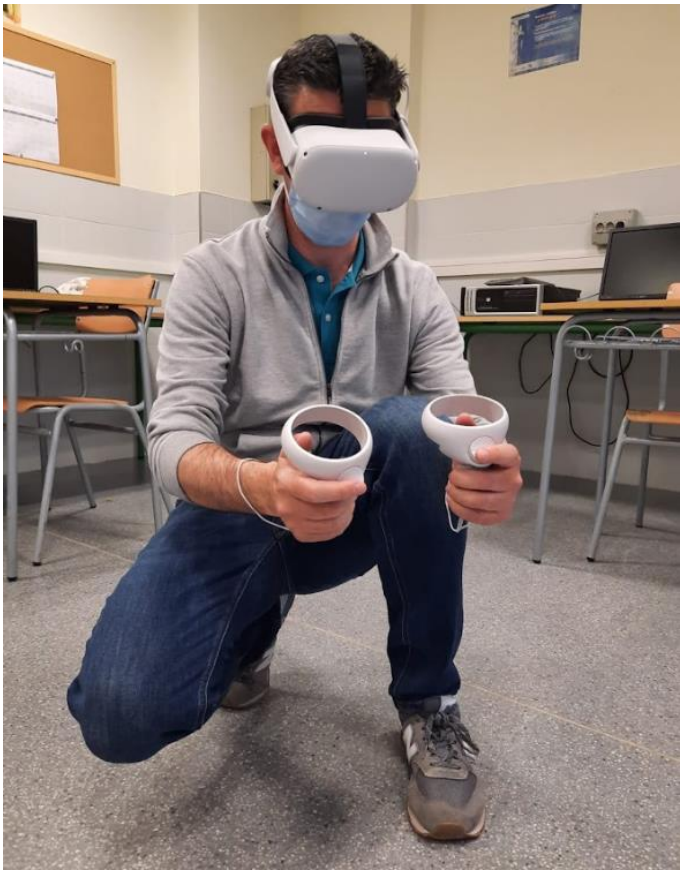


Project Overview

WindEXT is an ambitious 3-years project funded by the ERASMUS + programme of the European Union. The goal of the project is to develop and standardize specialized training integrating digital tools like Virtual Reality or 360º video tours to complete the classical theoretical methods. Furthermore, the project is an advanced integration of partners of different profiles and experiences to facilitate the exchange of knowledge between Universities, Vocational Training centers and private companies, in a model that it is now followed in different countries to facilitate the employability of students leaving both types of centres from different countries:

The goal of this approach is to reduce the LCOE of the windfarms in operation, either existing or new ones, by increase the quality of O&M services while extending the lifetime of the assets and the working HSE conditions of the maintenance personnel.

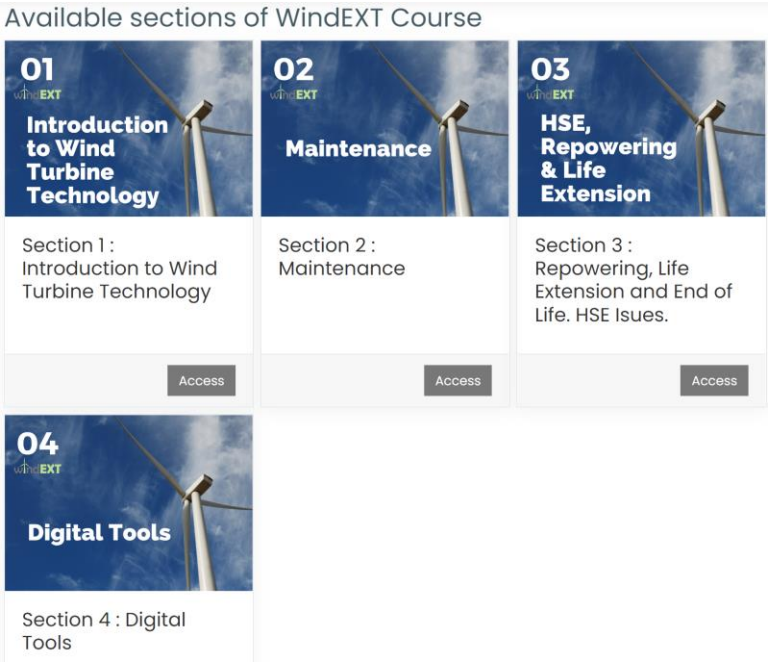
Project outputs

The project has produced a **standard training course based in a MOODLE platform** where all the contents are integrated as well as the different digital tools below presented. The purpose of the consortium is to promote the use of **either the course as a whole or some independent modules** or tools, serving always as practical basis of the theoretical teaching.

The course provides the training contents of the wind turbine technology (WTG) including the descriptions of the different components of a WTG and their function. It also deals with the maintenance of WTG and Wind Farms (WF) from both, general and specific point of view, as well as the main tasks for either extending the life of repowering the WF installations.

The structure of WindEXT is based on four sections and each section has different modules. The sections are:

1. Introduction to wind turbine technology
2. Maintenance
3. Life extension and repowering
4. Digital tools



Picture 1: overview of the course structure on Moodle

WindEXT has developed the following digital tools:

Through the WExSiM tool, various maintenance procedures have developed using a 3D simulation software.

The WExLaB shows the basic concepts and design of a wind turbine. Especially the design of wind turbines is explained with the help of MATLAB Simulink®.

From its side WExViR presents the various maintenance areas (preventive, corrective and predictive) of wind turbines through the H5P tool.

Finally, the CaDWEx "Failure Tree" software allows, through a mathematical function, a set of data is taken as input and as output we get the evolution over time of the damage of a machine component.

A new version of SIMULWIND, developed in a previous ERASMUS project has been also completed in this project

Additionally, different interactive videos extend the use of the digital tools to give a complete overview of different maintenance and operational tasks related to repower, life extension and recyclingAll the content of WindEXT project will be in the MOODLE platform, from the theoretical content to the digital tools, with the exception of WExSiM, which will be accessed externally.

Picture 2: structure of our WindEXT course

WindEXT . Digital tool: WExSiM

The simulation runs on the Oculus Quest 2. We have now completed 5 training procedures, which can be viewed on our homepage www.windext.com and on our YouTube®-channel WindEXT. The 5 training scenarios are:

- Maintenance and replacement of a yaw drive
- Blocking High speed shaft
- Evacuation from service lift
- Hydraulic torque wrench operation
- High voltage cabinet fuse replacement

WindEXT .Digital Tool: new version von SimulWind

WindEXT has developed a new version of the SimulWind that allows the software to be used in up to four VR Googles (Vive PRO, Vive Pro 2, Oculus Rift and Oculus Quest 2). That makes it possible, that 13 vocational training centers in Spain are using SimulWind as training tool now. The new version of SimulWind can be downloaded from the webpage www.simulwind.com after a short registration.

WindEXT. Section 1: Introduction to wind turbine technology. Digital tool:

WExLaB

Section one of MOODLE, “Introduction to Wind Turbine Technology” is divided into seven modules:

- Introduction to the Wind Turbine Components
- Design of a Wind Turbine Rotor
- Load Analysis of a Wind Turbine
- Operation and Control of a Wind Turbine
- Wind Farm Component Layout and Design Criteria
- Reliability, Failures, Faults and Fault Tree Analysis
- Contractual Models

The purpose of these sections is to familiarise course participants with different technological aspects and challenges related to the wind turbine. The course aims to answer the main questions that people are going to face when starting out in the wind turbine operations and maintenance field.

The digital tool associated with this section is WExLaB. This software integrates OpenFAST source code with a standalone MATLAB application as a graphical user interface. We have developed 4 parts of software, which were described in the previous newsletters four and five:

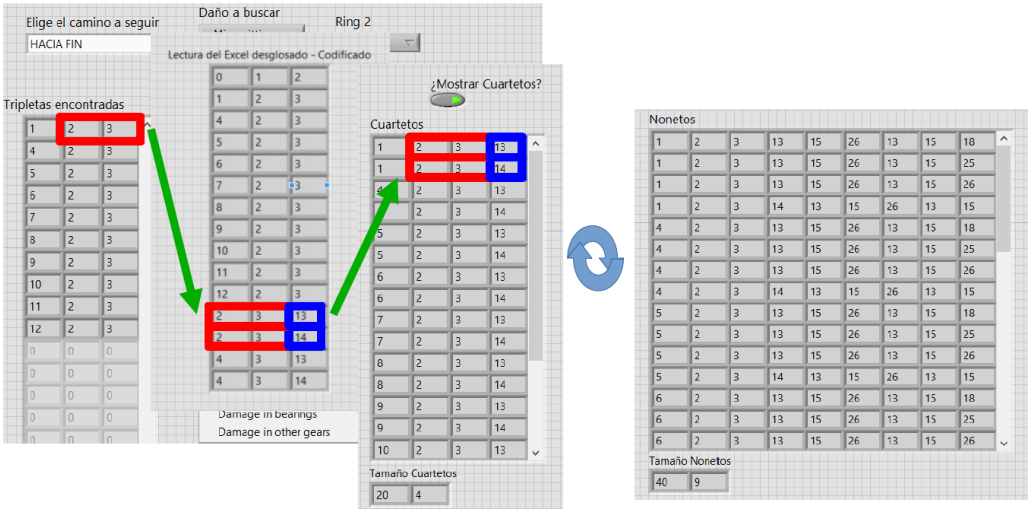
- System level analysis
- Modal analysis
- Load analysis
- Operation and control of the wind turbine

WindEXT. Digital tool: Failure Tree CaDWEx

CaDWEx (Cascade Damage Explorer) is a software that allows the students to explore the chains of damage of a specified component in the area of fault tree analysis. Each chain of damage is a time ordered list of damages that affect a component, as a damage evolves over the time and creates different damage. Within the WindEXT project, CaDWEx focused on the gearbox of a wind turbine, as this component is one of the most critical in the wind industry.

All possible faults of the wind turbine gearbox were analysed and listed with the help of experts. The experts also indicated the previous and subsequent faults for each individual fault, this is, the pasts damages that could causes the present damage, and the future damages that the present damage can cause.

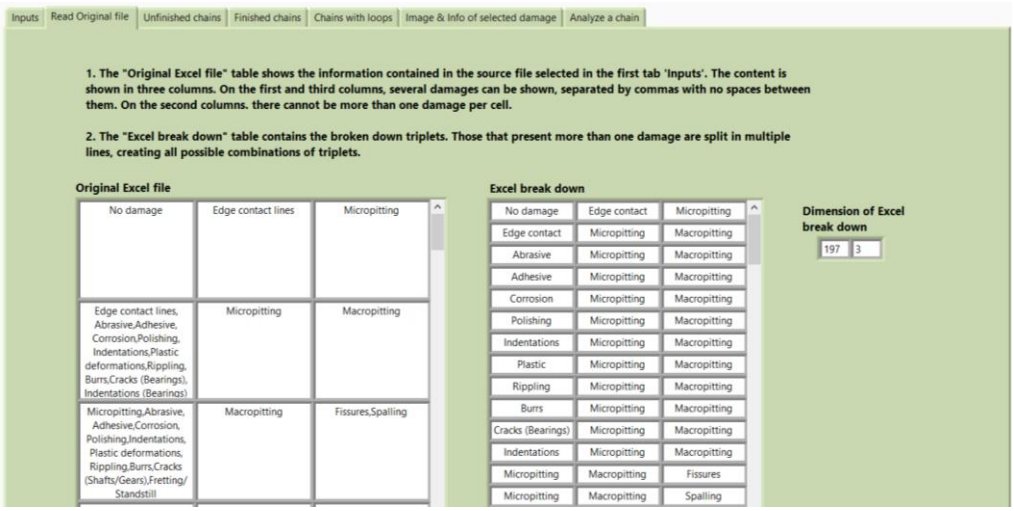
The software takes this information and builds the degradation chains from a specific failure (damage). To do this, CaDWEx converts the information into numbers and builds the numbers into chains by comparison (see Picture 3), so that a complete fault tree can be created by the student.



Picture 3: fault tree analysis

Using this fault tree, the students can now learn about the faults, and how the individual faults develop in the gearbox of a wind turbine along time. The learning material also shows the student when and how to react correctly to the respective faults.

The software easily adapts, and with little modifications, to other components if the information of the fault development is provided by experts on the components.



Picture 4: Design of CaDWEx

WindEXT. Section 2: Maintenance: Digital tool: Virtual Reality WExViR

In the second section of the course, students are taught the different approaches to maintenance strategies. This includes preventive, corrective and predictive maintenance. The theoretical teaching material for each section is available on the Moodle platform.

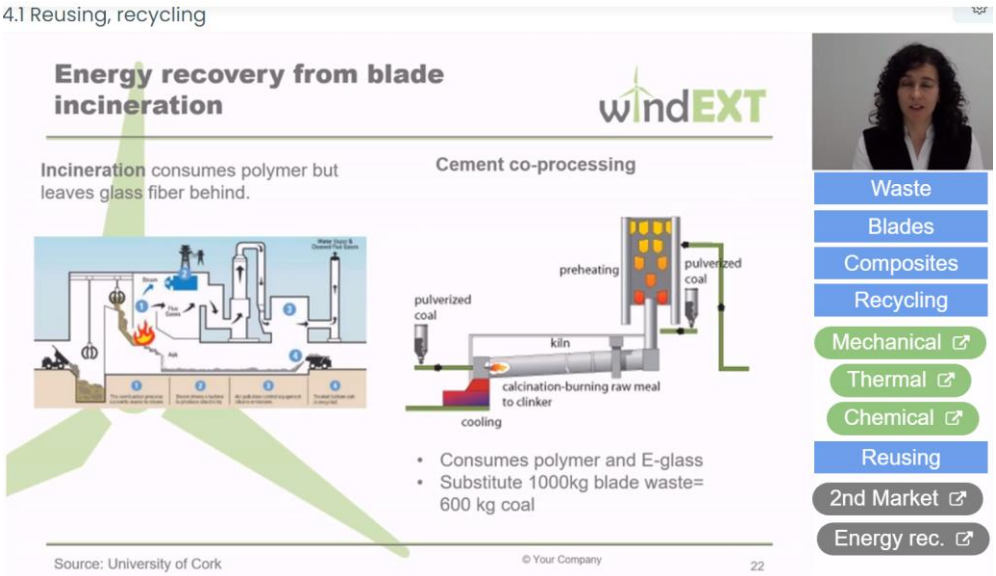
Through the WExViR digital tool, the theoretical concepts of this section can be better assimilated using interactive contents that allow for a friendlier approach than the traditional written material, developed in H5P as a *Guided Tool*. Besides, virtual tours have been developed through a wind turbine with 360° images using the H5P tool as well, in this case as a *Move-around Tool* that allows for a more independent use, for the students to have a complete overview of the different maintenance procedures.

Picture 5: impressions of the WExViR tool

WindEXT. Section 3: Life extension, Refiting, Repowering: Interactive videos.

This section covers a reflexion about how the life of wind farms can be extended; it addresses the cost of repowering and presents wind turbine refitting as an alternative.

The content is presented through different training videos on the subject, with the special function of interactivity. The development has been done with the collaboration of different educators and teachers.



Picture 6: Interactive training video

Pilot tests

After completing the WindEXT platform and the digital tools produced during the project, pilot tests were organized by some of the partners to test them. For instance:

- **UCLM** carried out the pilot tests in the Faculty of Industrial Engineers, in Albacete, part of the University of Castilla-La Mancha (UCLM). The participants where students oof the Electrical Engineering Degree. The sessions were developed accessing the WindEXT Moodle platform and covered part of the WExViR tool and part of the WExSiM tool.

  In general, the students perceived the digital tools mentioned to experiment with close-to-real maintenance activities that are normally carried out at operating wind turbines.

- **TESICNOR** carried out the pilot tests in the CENIFER center (Centro de Referencia Nacional en Energías Renovables y Eficiencia Energética) in a session of three hours with 24 participants. The contents for these pilots where: Elevators: Safety use and evacuation procedures; Electrical works: Medium voltage switchgear; 360º Wind turbine tour; Identify bugs.

  The WExSiM simulator had a very positive balance. The students showed great interest in the courses received and the methodology adapted very well to their needs. Enthusiasm and proactivity would be the adjectives that best capture the essence of the Pilot Test. Every student executed the practices.

- **AEE** carried out several small Pilot Tests in different events where, the WindEXT project was presented and attendees were able to test the digital tool WExSiM.

  Those Pilot tests took place in Bilbao (WindEurope annual congress) and WindTalent (Madrid, event organized by AEE and the school of industrial organization (EOI). The participants had different backgrounds and profiles: workers of companies of the sector, university students, vocational training students. Many of them had never been inside a wind turbine, so the experience carried out through WExSiM was different parts of the nacelle so closely. They were happy to be able to put into practice the very rewarding for them. Among the comments they told us how real it was to be inside the elevator and see the maintenance tasks they have learned from their books in the classroom. Teachers also found it to be a perfect tool to complement their lessons.

- **INESTEC** carry out its own pilot test with the assistant of **AEE**'s technicians, a total of 15 students have the opportunity to test the different WindEXT tools. Similarly, a Pilot test was carried out in **TUDelft** facilities and at **RSC** with a similar scheme: a total of 20 students participate in that pilot test with the involvement of **AEE**`s staff too.

- **Dp2i** carried out 4 pilot tests to test the digital tools SIMULWIND/ WExSiM and CaDWEx in different cities from Spain; Valencia, Leon, Barcelona and Lleida.The professors are very enthusiastic about the possibilities, especially about WExSiM.

Finally, **AEE** tested the WExSiM with Moroccan students within the MOVE Green project addressed to extend the knowledge on RE energies to foster the creation of SME related to asset management sector in Morocco with the involvement of Spanish companies.

Picture 7: Impressions from pilot tests

Project meetings

Fifth transnational meeting, October 13 and 14, 2022, Hamburg

Our fifth TPM took place on October 13th and 14th in Hamburg. All project partners were also able to attend this meeting in person. We are now two months before the end of the project, so that the outstanding points in particular were discussed. Above all, this included how and in what way the results of our project will be made available to the public. Furthermore, the results of the first pilot tests were discussed and the responsible project partners explained how the feedback was integrated into the individual modules. We are of the opinion that we have developed a finished product, which we will finally test in further pilot tests in the next few weeks.

At the end of the first day of the meeting, we had the opportunity to do a small city tour of Hamburg before we had dinner in a local brewery in the evening.

On the second day of our meeting, we made an excursion to a wind farm to give all project participants the opportunity to see a wind turbine in real life. Some project participants (with a valid "working at heights" certificate) were also able to take the elevator to the nacelle. We were also able to do exercise 2 from our WExSiM module "Emergency descent from an elevator" in a real elevator.

Finally, we visited the West Coast wind farm in the municipality of Kaiser-Wilhelm-Koog in Schleswig-Holstein. It was the first wind farm in Germany to go into operation in 1987 and thus

marks the beginning of the expansion of today's modern use of wind energy by wind turbines in wind farms in Germany.

Picture 8: Project consortium at the project meeting in Hamburg

Final conference in Madrid, December 15, 2022

On December 15, 2022, the final conference for our WindEXT project took place in Madrid. The final event aim to publish and disseminate the project results to a broad public. Our project coordinator AEE organized this event at the Spanish Institute for Diversification and Saving of Energy (IDAE). We were able to welcome more than 40 participants. After a short welcome by Juan Ramon Ayuso, director of the department of wind energy in IDAE, and Tomas Romagosa, technical directer of AEE, our WindEXT project was presented by various project participants (Alberto Cena (AEE), Elena Tylko (SGS), Victoria Campos (AEE) and Estefania Artigao (UCLM)). The conference participants actively participated in the subsequent discussion and evaluation of our project, as the development results aroused great interest. In addition to the project participants mentioned above, the consortium members from the Netherlands, France and Germany were also represented at the final conference.

Conclusions and strategical recommendations

The experience in the development of the Project has allowed to draw several conclusions:

- The importance and interest of creating links between university and vocational centres, not always simple. The firsts have difficulties in lowering the contents level and the for the second ones, it is not easy to understand the theoretical background to explain the failures and root causes.
- The difficulties of coordinating teams with different professional approach and different ways to approach the foreseen tasks of the project.
- However, working with such diverse entities has been truly motivating and has allowed mutual learning among the participants. In fact, the COVID pandemic has had a positive influence because it has allowed to have a more continuous contact through the telematics meetings.

- The importance of digital tools to approach the wind maintenance network, complex due to the multitude of technologies involved and the need to do it in so demanding physical conditions: work at heights and narrowed space.
- The pilot experiences and the first simulations have been welcomed by vocational training centers and they encourage to follow for this path in the future.

In this sense and in the line pointed out above, the possibility of giving continuity to the work carried out is being considered, with the partners' own means as well as with some possible public support. In this sense, the strategic approach for the future is based on the following points:

- Follow up of the impact of using the WindEXT tools in the vocational centers at worldwide level.
- Possible extension with new maintenance procedures.
- Evaluation of the possible updating of the tools to follow the hard and software advances on VR.
- Integration of new areas, taking into consideration the experience of other national and ERASMUS+ projects, as for instance off shore wind and PV maintenance.

Disseminations and Exploitation of project results

All results are published on the project website www.windext.com and are available for the next 5 years. If you have any questions or would like to have more information, you can still contact us at info@windext.com. In addition, you can of course also contact the individual consortium members directly.

Project Consortium

A consortium of European key players in the Wind Industry (entrepreneurial associations and maintenance companies), Universities and vocational training centres come together, to create the reference training course WindEXT. The presence of UTEC/CEFOMER from Uruguay is considered fundamental to adapt the contents to another sociological/legal scenario as the LATAM countries.

Projekt Leader:
Association Empresarial Eolica (AEE)

Projektpartner