X-shaped Radical Offshore Wind Turbine for Overall Cost of Energy Reduction

D1.3

WP1 Project Management Periodic Status Report 2

https://xrotor-project.eu

@XROTORProject

December 2022

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1	16/12/2022	Final Version	James Carroll	W. Leithead

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X-ROTOR Consortium

University of Strathclyde

Delft University of Technology

University College Cork – National University of Ireland, Cork

Fundacion Cener

General Electric Renovables España

Norwegian University of Science and Technology

https://xrotor-project.eu

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About X-ROTOR

X-ROTOR: “X-shaped Radical Offshore wind Turbine for Overall cost of energy Reduction” is a Horizon 2020 funded project which aims to develop a disruptive new offshore wind turbine concept.

The X-ROTOR project is led by University of Strathclyde (UK) in partnership with Norwegian University of Science and Technology (Norway), Delft University of Technology (Netherlands), University College Cork (Ireland), Fundacion Cener National Renewable Energy Centre (Spain) and GE Renovables España (Spain).

As the effects of climate change are becoming ever more visible, Europe has raised its target for the amount of energy it consumes from renewable sources from the previous goal of 27% to 32% by 2030. Offshore wind energy can play a key role in achieving the EU target and contribute to the required 40% reduction in CO_2 emissions. However, to achieve the previously mentioned targets the cost of offshore wind must be reduced. The X-ROTOR concept provides a direct route to drastically reducing both capital and operating costs of energy from offshore wind.

The project runs for three years from January 2021, during which time, the concept will be developed through a holistic consideration of technical, cost, environmental and socio-economic impact aspects.

If proven feasible, X-ROTOR will, as a disruptive new offshore wind turbine concept, create new opportunities for the European wind energy industry and play an important role maintaining the EU’s position as global technological leader in renewable energy, reducing greenhouse gas emissions and decarbonising the EU economy.

For more information see **https://xrotor-project.eu**

Executive Summary

Deliverable Description: This deliverable will comprise of a report detailing the progress from each work package in Year 2 of the XROTOR project. The deliverable will be considered successful once delivered to the project coordinator and/or the executive management group.

Responsible: University of Strathclyde

Outcome Summary: Based on input from all WP leaders a report detailing the XROTOR project progress in year 2 has been created. The report was presented to and signed off by the Project Coordinator. Based on the reasons outlined above, Deliverable 1.3 is successfully completed.

List of acronyms

DoA	Description of Action
O&M	Operation and Maintenance
OEM	Original Equipment Manufacturer
OREC	Ocean Renewable Energy Coalition
WESC	Wind Energy Science Conference
WP	Work Package
XRC	X-ROTOR concept
LCoE	Levelised Cost of Energy

1 Introduction

The following report details the Year 2 progress of each work package from the XROTOR project. Next steps for each work package are also included. Section 11 provides the deliverable conclusion and a note from the project coordinator on the XROTOR project year 2 progress.

2 WP 1 Report (Project Management)

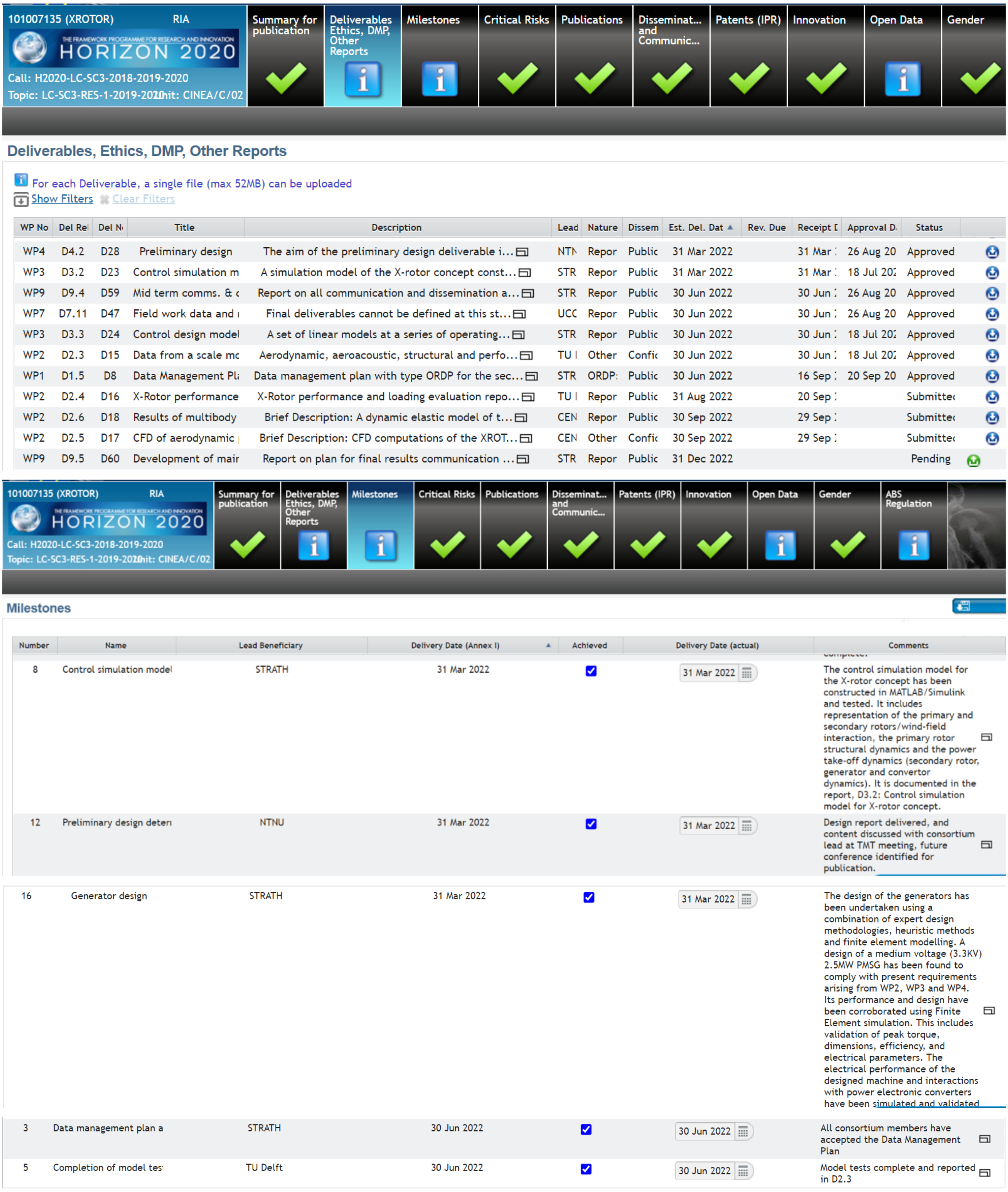
WP1 is currently being led by Professor Bill Leithead and Dr James Carroll. They have full time administration management from Nicola Baxter and Data Management from Dr Adam Stock as well as Nicola Baxter. Nicola was hired as the full time XROTOR administrator in Q1 2022.

Table 1 outlines the work package 1 deliverables and milestones that were successfully uploaded to the EU project portal and approved to date in WP1.

Project Month Di	Deliverable or Milestor	Work Package Numbe	Task Number 1	Responsible Institute	Deliverable/Milestone Title
1	D	1	1.1	Strathclyde	Project Master Plan
1	M	1	MS1	Strathclyde	Kick-Off Meeting
6	D	1	1.4	Strathclyde	Data Management Plan 1
6	D	1	1.7	Strathclyde	Procedures and criteria for identifying and recruiting research particpants
6	D	1	1.8	UCC	Inform data subjects of the existence of profiling
12	D	1	1.2	Strathclyde	Periodic Status Report
12	D	1	1.9	Strathclyde	Environmental and H&S overview
18	M	1	MS3	Strathclyde	Data management plan agreed on by the consortium
18	D	1	1.5	Strathclyde	Data Management Plan 2

Table 1.1: WP 1 deliverables and milestones uploaded and approved

In the first two years, the XROTOR project management team have engaged with 3 EU POs and have had excellent engagement with each. The project management team has created and set up the project events and updated the project portal on a monthly basis with milestone and project deliverable uploads. Figure 2 shows a snapshot of the project portal and confirms that all deliverables up to month 24 have been successfully uploaded for the XROTOR project.


101007135 (XROTOR) RIA
HORIZON 2020
Call: H2020-LC-SC3-2018-2019-2020
Topic: LC-SC3-RES-1-2019-2020 Unit: CINEA/C/02

Summary for publication | Deliverables Ethics, DMP, Other Reports | Milestones | Critical Risks | Publications | Disseminat... and Communic... | Patents (IPR) | Innovation | Open Data | Gender

Deliverables, Ethics, DMP, Other Reports

For each Deliverable, a single file (max 52MB) can be uploaded
Show Filters Clear Filters

WP No	Del Rel	Del No	Title	Description	Lead	Nature	Dissem	Est. Del. Dat	Rev. Due	Receipt D	Approval D.	Status
WP4	D4.2	D28	Preliminary design	The aim of the preliminary design deliverable i...	NTN	Repor	Public	31 Mar 2022		31 Mar	26 Aug 20	Approved
WP3	D3.2	D23	Control simulation m	A simulation model of the X-rotor concept const...	STR	Repor	Public	31 Mar 2022		31 Mar	18 Jul 20	Approved
WP9	D9.4	D59	Mid term comms. & c	Report on all communication and dissemination a...	STR	Repor	Public	30 Jun 2022		30 Jun	26 Aug 20	Approved
WP7	D7.11	D47	Field work data and	Final deliverables cannot be defined at this st...	UCC	Repor	Public	30 Jun 2022		30 Jun	26 Aug 20	Approved
WP3	D3.3	D24	Control design model	A set of linear models at a series of operating...	STR	Repor	Public	30 Jun 2022		30 Jun	18 Jul 20	Approved
WP2	D2.3	D15	Data from a scale mc	Aerodynamic, aeroacoustic, structural and perfo...	TU	Other	Confic	30 Jun 2022		30 Jun	18 Jul 20	Approved
WP1	D1.5	D8	Data Management Pl	Data management plan with type ORDP for the sec...	STR	ORDP:	Public	30 Jun 2022		16 Sep	20 Sep 20	Approved
WP2	D2.4	D16	X-Rotor performance	X-Rotor performance and loading evaluation repo...	TU	Repor	Public	31 Aug 2022		20 Sep		Submitte
WP2	D2.6	D18	Results of multibody	Brief Description: A dynamic elastic model of t...	CEN	Repor	Public	30 Sep 2022		29 Sep		Submitte
WP2	D2.5	D17	CFD of aerodynamic	Brief Description: CFD computations of the XROT...	CEN	Other	Confic	30 Sep 2022		29 Sep		Submitte
WP9	D9.5	D60	Development of mair	Report on plan for final results communication ...	STR	Repor	Public	31 Dec 2022				Pending

101007135 (XROTOR) RIA
HORIZON 2020
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Milestones

Number	Name	Lead Beneficiary	Delivery Date (Annex I)	Achieved	Delivery Date (actual)	Comments
8	Control simulation model	STRATH	31 Mar 2022	☑	31 Mar 2022	The control simulation model for the X-rotor concept has been constructed in MATLAB/Simulink and tested. It includes representation of the primary and secondary rotors/wind-field interaction, the primary rotor structural dynamics and the power take-off dynamics (secondary rotor, generator and convertor dynamics). It is documented in the report, D3.2: Control simulation model for X-rotor concept.
12	Preliminary design deter	NTNU	31 Mar 2022	☑	31 Mar 2022	Design report delivered, and content discussed with consortium lead at TMT meeting, future conference identified for publication.
16	Generator design	STRATH	31 Mar 2022	☑	31 Mar 2022	The design of the generators has been undertaken using a combination of expert design methodologies, heuristic methods and finite element modelling. A design of a medium voltage (3.3KV) 2.5MW PMSG has been found to comply with present requirements arising from WP2, WP3 and WP4. Its performance and design have been corroborated using Finite Element simulation. This includes validation of peak torque, dimensions, efficiency, and electrical parameters. The electrical performance of the designed machine and interactions with power electronic converters have been simulated and validated
3	Data management plan a	STRATH	30 Jun 2022	☑	30 Jun 2022	All consortium members have accepted the Data Management Plan
5	Completion of model tes	TU Delft	30 Jun 2022	☑	30 Jun 2022	Model tests complete and reported in D2.3

Figure 1.1: XROTOR deliverables and milestones to M12 uploaded and approved

Figure 1.2 shows the XROTOR milestones and deliverables that the project management team will upload by the end of Dec 2022. No issues in meeting the project management requirements from year 2 are expected.

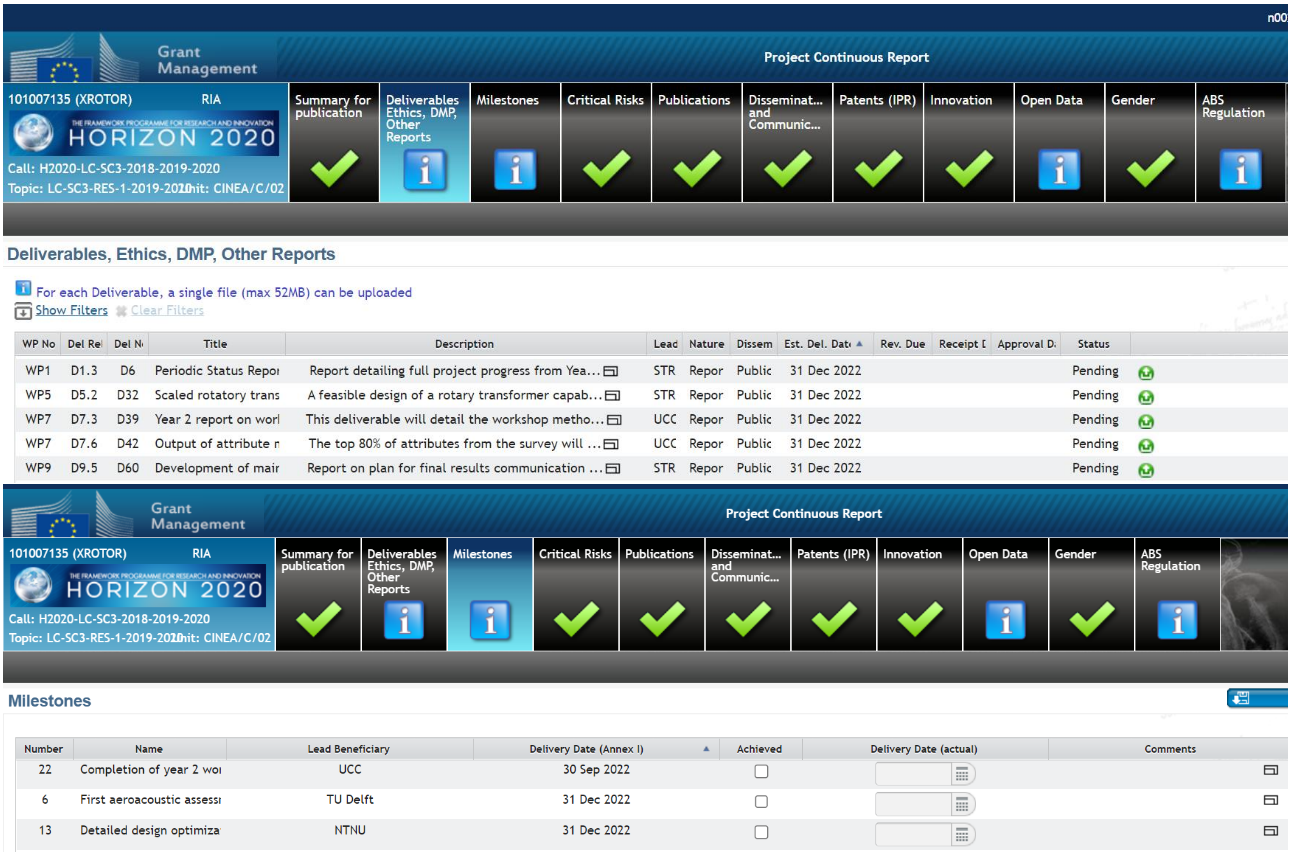

Figure 1.2: XROTOR deliverables and milestones to be uploaded by the end of M12

3 WP 2 Report (WP2: Aeroelastic Code Development and Performance)

3.1 WP2 Overview

The following section provides input from Work Package 2 regarding the work developed in the second year of the project

Work Package 2 is entitled Aero-elastic code development and performance. The objectives are: to create an aero-elastic dynamic model of the X-Rotor concept; to create a CFD prediction tool to validate the aeroelastic computations; to create and test a small-scale X-Rotor concept in a wind tunnel; to evaluate the loading and performance of a full-scale X-Rotor concept; to predict noise emissions from the X-Rotor concept by CFD simulations; to complete Multibody analysis of the X-Rotor Concept.

In the second year, the following deliverables and milestones were scheduled and developed.

D2.3: Performance from a scale model test (M18, TUDelft)

D2.4: Report evaluating the performance and loading of a number of hypothetical full-scale machines (M20, TUDelft)

D2.5. Report and CFD simulation data for the performance, thrust and power of the X-Rotor including validation analysis of the aerodynamic computations. (M21, CENER)

D2.6: Report and data related to the multibody analysis of the X-Rotor configuration. (M21, CENER)

M2.2: Completion of model tests (M18, TUDelft)

M2.3: First aeroacoustic assessment (M24, TUDelft)

According to the project plan, all deliverables and milestones were accomplished and delivered on schedule. The definition of Deliverable 2.3 was revised since the project plan had wrongly indicated that it would contain noise data, which was not in accordance with the project plan. The execution of this update was coordinated with the EU project officer.

All deliverables and milestones are backed by the publishing of reports and/or data. The scheduled experimental model testing was completed in the second year; nevertheless, the results revealed such novel, intriguing, and valuable research topics that more experiments will be conducted in 2023.

In addition to the planned events, the partners have established a beneficial benchmarking exercise. This benchmark is the result of simulations demonstrating that the X-Rotor will generate more power than originally projected. For the purpose of validating and confirming this conclusion, a benchmark of all employed models has been conducted to further investigate operating circumstances. TU Delft and UOS (hosted by TU Delft) collaborated for many weeks in the same office to accomplish this standard.

It is anticipated that the scheduled deliverables and milestones for 2023 will be met on time. These are the expected deliverables:

D2.7: Report and CFD simulation data for noise generated at subcomponent level (M28)

D2.8: Comparison of CFD computations and experimental results (M32)

D2.9: 3D CFD simulations of noise from a full X-Rotor concept (M34)

M2.4 Final X-Rotor concept (M24)

3.2 WP2 Dissemination, Milestones and Deliverables

WP2 has produced a number of scientific articles, which are mentioned in the list of publications. Additionally, other works have been approved for 2023 conferences. Journal publications are anticipated to emerge in 2023.

Reports and databases associated with the deliverables and milestones:

In the next pages, we include the summary of the reports of the deliverables submitted in WP2 during the second year of the project.

D2.3: Performance from a scale model test (M18, TUDelft)

The report executive summary states:

> The current progress on the D2.3: Data from a scale model test (M18) is presented in this report. The report contains the following:
>
> • An overview of the experimental results for the Generation 1 turbine so far. This includes an experimental validation of the proof of concept and an analysis of the flow field with and without the presence of actuator mesh disks as tip rotors. The experimental setup and methodology are described in D2.2.

- The progress on the development of the Generation 2 numerical twin turbine. This includes results using the 2D Actuator Cylinder model, a modal analysis, and blade deflections considering coupled aeroelastic effects.

Below is one of the results extracted from the report including original caption, as an example of the work.

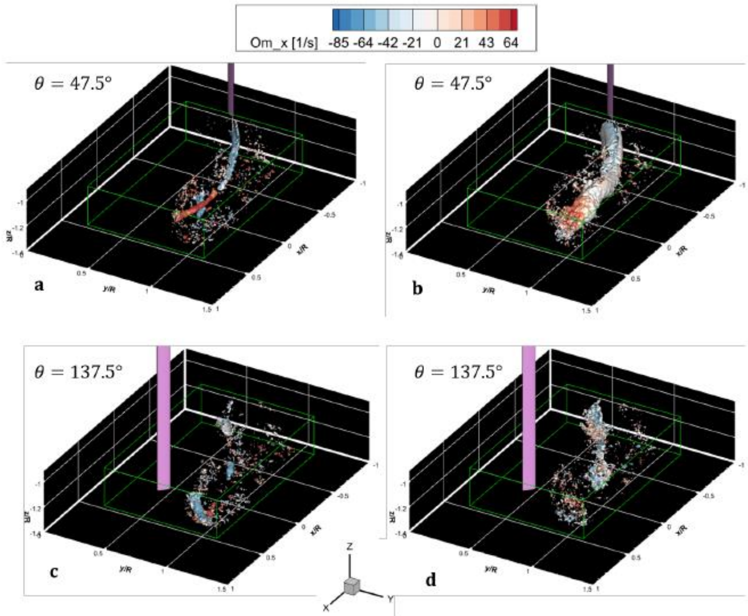

Figure 6: Instantaneous iso-surfaces of vorticity magnitude at (a,b) $\theta = 45.5°$ and (c,d) $\theta = 137.5°$ with $|\vec{\omega}| = 63\,s^{-1}$ and flooded by the vorticity in the X-direction $\vec{\omega}_x$. Green edges represent the stitched measurement volume and the blade is colored pink. A comparison between (a,c) a clean case (no tip-rotor) and (b,d) with mesh disk at $\beta = 0.8$ is made for a constant tip-speed ratio of $\lambda = 4.0$.

The data is available in the project repository "Data sharing/WP2/Deliverable 2.3/Data from experiments" in ".csv" file format.

D2.4: Report evaluating the performance and loading of a number of hypothetical full-scale machines (M20, TUDelft)

The report executive summary states:

The current progress on the D2.4: X-Rotor performance and loading evaluation report (M20) is presented in this report. The report contains the following: Performance and loading summary of the two-bladed X-Rotor configuration. This includes power and thrust results with collective pitch control as well as blade loading for operating and standstill/parked conditions with varying freestream velocity; Complimentary blade loading results for the three-bladed X-Rotor configuration.

The simulation data is shared in the data repository of the consortium. The data is stored in the folders in Data Sharing/WP2/Deliverable 2.4. The source code will be made available upon request for the duration of the X-Rotor project, and made available in an open repository upon conclusion of the project. The current models can support the X-Rotor project's immediate planned activities. As described in Task 2.1, the model will be further developed in the project, both as part of Task 2.1 and in conjunction with other tasks.

Below is one of the results extracted from the report including original caption, as an example of the work.

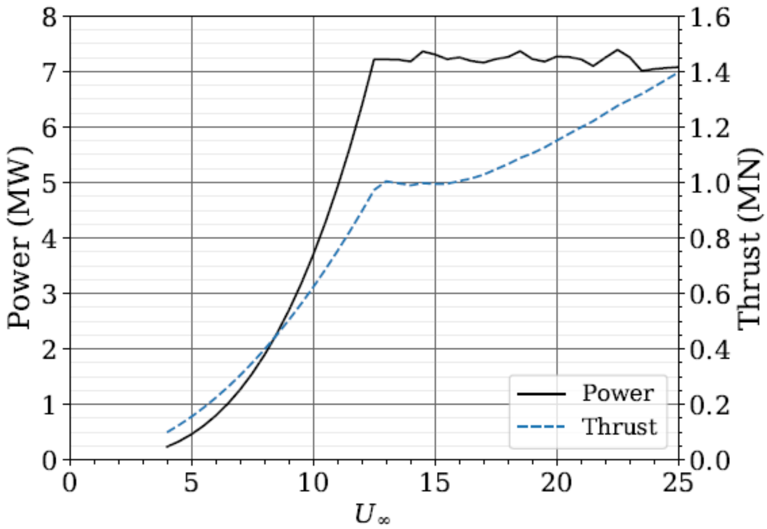

Figure 2: Two-blade configuration aerodynamic Power and Thrust as function of wind speed U_∞, with collective pitch control, accounting for tip losses.

The data associated with the report is available in the project repository "Data sharing/WP2/Deliverable 2.4/Simulation results" in the folders "2-bladed results" and "3-bladed results" in ".xls" file format, in the sub-folders for the cases of "Loads Operational Curve" and "Loads standstill".

D2.5. Report and CFD simulation data for the performance, thrust and power of the X-Rotor including validation analysis of the aerodynamic computations. (M21, CENER)

The report executive summary states:

This deliverable report supports deliverable D2.5 "CFD of Aerodynamic performance", and details the CFD simulations that have been performed to evaluate the aerodynamic performance of the XROTOR concept. First, CFD simulations of the primary rotor are shown, followed by the simulation of the secondary rotors. Both simulations have been performed separately to understand the flow physics of each part of the concept. Subsequently the CFD simulations of the full concept are performed and the the first results are shown in this deliverable. The CFD code used to perform the XROTOR aerodynamic simulations is openFOAM v8. The CFD simulations presented in this deliverable will give more insight into the flow physics complementing the studies performed by TUDelft with the design of an aeroelastic code suitable for non-conventional wind turbine components. These results were presented in D2.4. With CFD magnitudes as the blade vorticity, wakes interaction and flow separation can be deeply studies.

Below is one of the results extracted from the report including original caption, as an example of the work.

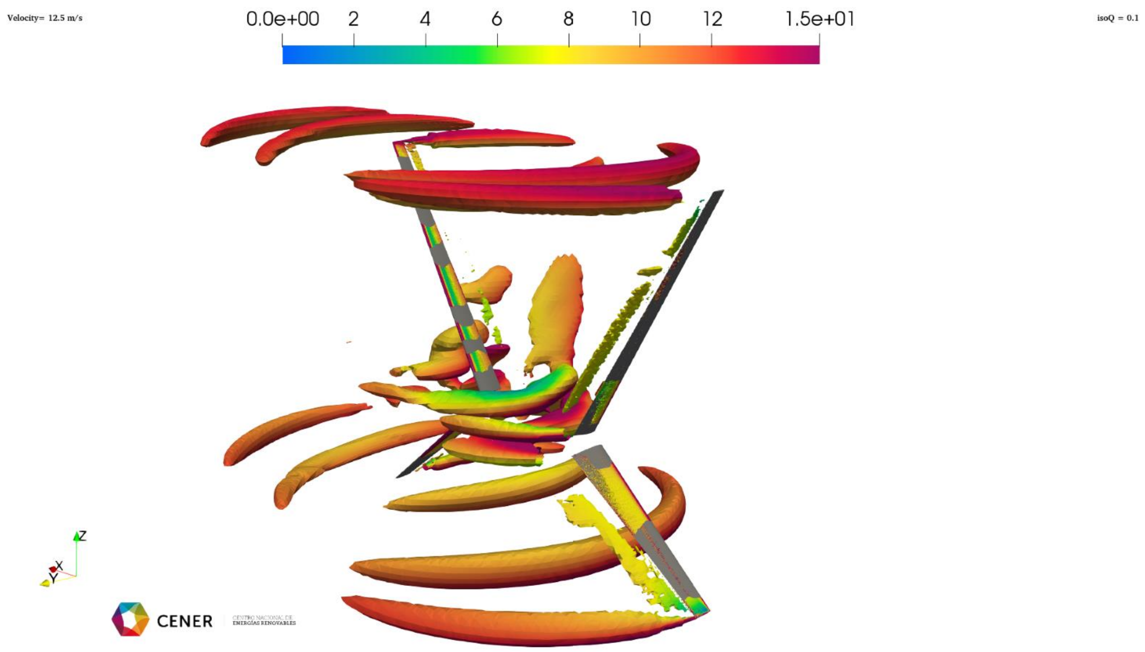

Figure 10 Primary rotor wake

D2.6: Report and data related to the multibody analysis of the X-Rotor configuration. (M21, CENER)

The report executive summary states:

> This deliverable report supports deliverable D2.6 "Validation of the X-ROTOR concept using Multibody Analysis" and details the results of the study performed over the X-Rotor Primary rotor. Wind turbine loads have been obtained from the Aeroelastic Dynamic model output from Task 2.1 and the load cases evaluated in Task 2.4.
>
> Below is one of the results extracted from the report including original caption, as an example of the work.

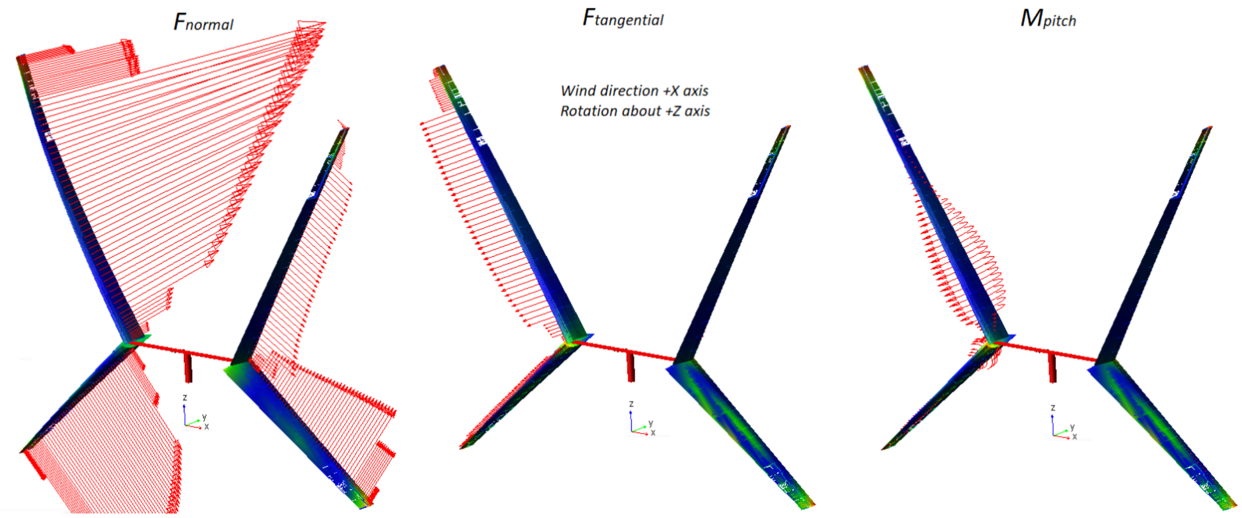

Figure 15 Direction of aerodynamic loads on blades. X-Rotor position on 90°/270° azimuth plane

M2.2: Completion of model tests (M18, TUDelft)

1) See deliverable D2.3
2) Additionally, data associated with the first experimental campaign is available in the project repository *"Data sharing/WP2/Experimental campaign 1"*. Data of the latest experimental campaigns are still being processed, with performance data already made available (D2.3).

M2.3: First aeroacoustic assessment (M24, TUDelft)

This milestone has the same date as the 2nd year report. For the milestone, a report has been developed which, although complete, is still pending final approval. The

The abstract of the report states:

> A preliminary aeroacoustics analysis on the X-Rotor Offshore Wind Turbine baseline concept is presented in this report. X-Rotor is a hybrid offshore wind turbine consisting of a large-scale vertical axis wind turbine (VAWT)and two small-scale horizontal axis wind turbines (HAWT)to reduce offshore wind energy costs. In order to evaluate the noise emitted from the X-Rotor concept, a high-fidelity computation fluid dynamics (CFD) simulation was performed using the commercial CFD software SIMULIA PowerFLOW. The results from the numerical simulation were used to predict the far-field sound pressure using the Ffowcs-Williams & Hawkings (FW-H) acoustic analogy implemented in the SIMULIA PowerACOUSTICS® and Opty∂b®software.
>
> Below is one of the results extracted from the report including original caption, as an example of the work.

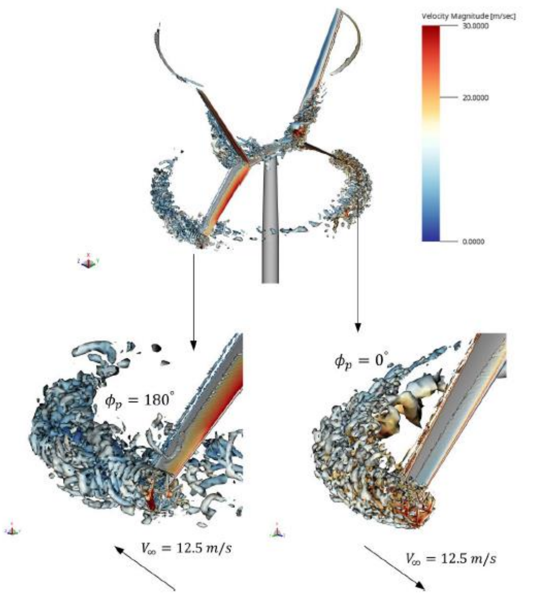

Figure 8. Instantaneous turbulence structure visualization with iso-surface using lambda-2 criterion ($\lambda_2 = -2.5\ s^{-2}$), the color contoured with the velocity magnitude.

> The report is accompanied by a database of noise results in ".txt" format. Due to "draft" status, the location in the repository is still temporary and a definite folder label will be allocated in the future.

3.3 Additional information based on the questions on the 18-month report

- Provide explanations for tasks not fully implemented, critical objectives not fully achieved, deliverables being changed and/or not being on schedule. Explain alsothe impact on other tasks on the available resources and the planning
- All tasks have been implemented as expected from the project plan and have been re- ported according to schedule. Future tasks and available resources will have no impact
- Include explanations on deviations of the use of resources between actual and planned use of resources in Annex 1

  No significant deviation of resources.
- Has any unforeseen subcontracting occurred in the first 18 months of the project?

  No.
- Have there been any unforeseen in-kind contribution from a 3rd party in the first 18months of the project?

  No.

4 WP 3 Report (Control and Operational Strategy)

4.1 Task 3.1. Specification of operational strategy

D3.1. Definition of operational strategy (M34)

Progress

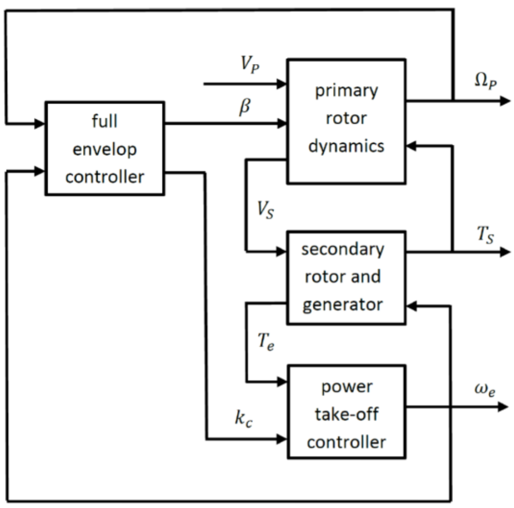

Figure 3.1: Controller schematic diagram

The most appropriate control vectors, i.e. the actions through which control is achieved, have been determined, namely varying the secondary rotors' tip speed ratios and the pitch angle of the primary rotor's upper blades. To realise the first control vector, an auxiliary controller for each power take-off unit, i.e. secondary rotor and generator, is required such that in response to an input, k_c, the relationship $Q_S = k_c \Omega_S^2$ or $T_e = k_c \omega_e^2 / p^2$ is maintained, where Ω_s is secondary rotor rotational speed, Q_S secondary rotor aerodynamic torque, ω_e frequency of the AC connection to generator, p

the number of generator pole pairs and T_e generator reaction torque. The corresponding structure for the control system with, for simplicity, only one secondary rotor is shown in Figure 3.1, where V_P is ambient wind speed acting on the primary rotor, Ω_P primary rotor rotational speed, β pitch angle of the primary rotor upper blades, V_S wind speed on the secondary rotors induced by rotation of the primary rotor and T_S secondary rotor thrust.

The baseline operational strategy has been defined. It consists of 4 modes as described below:

- *Mode 1 – Below rated, low wind speed, constant speed*: The average of the secondary rotor speeds is held constant with each varying with angle of rotation of the primary rotor. The primary rotor tip speed ratio adjusts to match primary rotor torque to secondary rotor thrust. The control action, k_c, is set by the feedback loop depicted in Figure 3.2, where Ω_{S1} and Ω_{S2} are the rotational speed for secondary rotor 1 and 2, respectively, and $\overline{\Omega}_0$ is the set point for the average secondary rotor speed.

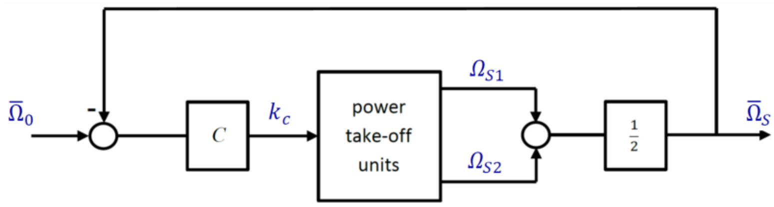

Figure 3.2: Secondary constant speed controller

- *Mode 2 – Below rated, maximum energy capture*: The secondary rotors operate at constant tip speed ratio corresponding to maximum C_P. The primary rotor does likewise. The control action, k_c, is set to k_{opt}.
- *Mode 3 – Below rated, pre-emptive pitching*: The primary rotor pitch angle is adjusted by a small offset. Secondary rotors tip speed ratio increases to their thrust to primary rotor. The control action, k_c, and β are set to appropriate functions of $\overline{\Omega}_S$ and Ω_P, respectively.
- *Mode 4 – Above rated, primary rotor speed and torque constant*: The secondary rotors maintains constant tip speed ratio. The primary rotor pitches to maintain constant primary rotor speed. The control action, k_c, is set to k_{AR} and β is set by a feedback loop acting on Ω_P in a similar manner to Figure 3.2.

An equivalent to the torque/speed plane diagram for the conventional HAWTs, namely the torque-thrust/speed plane, has been developed and used to establish the viability and resilience of the baseline operational strategy. A software package has been developed that enables the full specification of an operational strategy to be obtained from the aerodynamic characteristics of the primary and secondary rotors.

Next Steps

The next steps for Task 3.1 are as below:

1. Investigate the effectiveness of pre-emptive pitching to increase energy capture and reduce actuator pitch activity and turbine loads.
2. Investigate whether positive or negative pitching in above rated wind speed is preferable.

3. Investigate the impact of a combination of fixed pitch offset plus sinusoidal varying pitch offset on range and rate of change of pitch requirements

4.2 Task 3.2. Construct control simulation model of X-rotor concept

D3.2. Control simulation model of X-rotor concept (M15)

Progress

The deliverable, D3.2, was completed on time.

The control simulation model for the X-rotor concept has been constructed. Its schematic diagram is depicted in Figure 3.3. It consists of four sub-systems, namely, the wind model, the primary rotor aerodynamic and structural models, the secondary rotor aerodynamic and power take-off dynamics and the controller. The controller is typically incorporated into the control simulation model as a dll and so is not described here. Details of the other dynamics sub-systems are provided below.

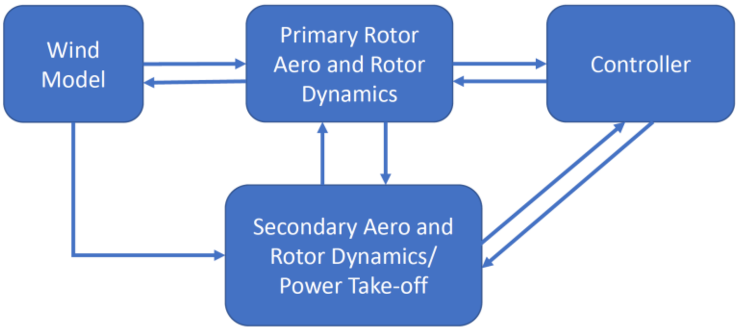

Figure 3.3: Schematic diagram of Control Simulation Model

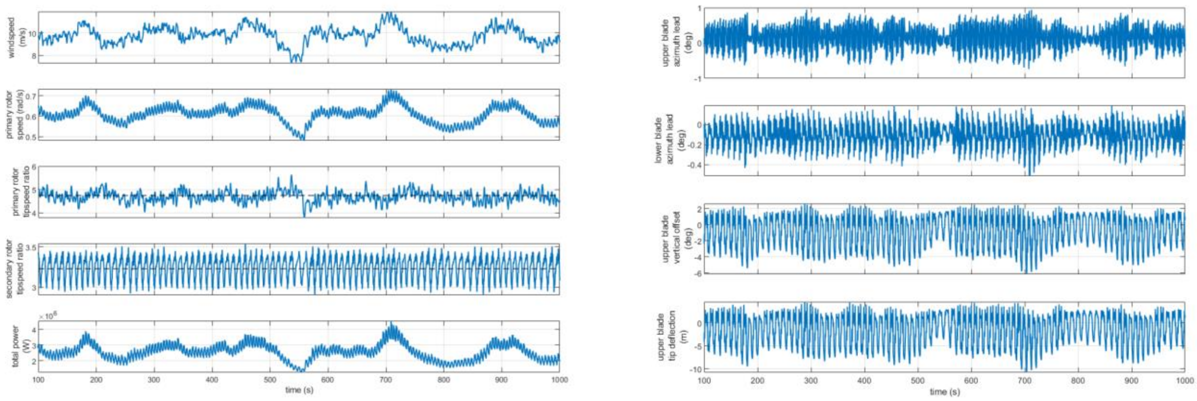

Figure 3.4: Illustrative control simulation model output

- *Wind model*: A three-dimensional effective wind-field model has been determined with values, $V(t, \phi_P, d)$. Effective wind speeds for each primary rotor upper and lower blade are derived from the effective wind-filed model by setting t to time, ϕ_P to the angular displacement of the blade, when projected onto a vertical plane perpendicular to the wind speed direction, and d is its positional displacement in the wind speed direction from the axis of rotation of the primary rotor. These effective wind speeds can be used to determine the forces and moments on each blade with representative correlations between them. An additional effective wind speed is derived for the secondary rotors with the correct correlation to those for the primary rotor blades.

- *Primary rotor aerodynamics and structural dynamics*: The forces and moments are obtained using appropriate aerodynamic coefficients and the above effective wind speeds. The structural model for the primary rotor consists of the first in-plane and first out-of-plane mode for each upper and each lower blade. For simplicity, the cross-arm is considered rigid.
- *Secondary rotor aerodynamic and power take-off dynamics*: The forces and moments are obtained using appropriate aerodynamic coefficients and the previously mentioned secondary rotor effective wind speed. The secondary rotor and generator dynamics are represented by a simple two lumped-inertia model.

The control simulation model has been implemented in Simulink with characteristic parameter values and tested. In Figure 3.4 some illustrative results are plotted.

Next Steps

This task is complete in that the model has been constructed.

4.3 Task 3.3. Construct control deigns model of X-rotor concept

D3.3. Control design models of X-rotor concept (M18)

Progress

The deliverable, D3.3 was completed on time.

Two control design models are required, namely, the power take-off system controller and the turbine full envelope controller, see Figure 3.1. Both have been constructed.

Full envelop control design model: The dynamics of the control simulation model are simplified; the variation of aerodynamic torques and moments with azimuthal angle is neglected, i.e. the aerodynamic coefficients are averaged over azimuthal angle; The lower blades, being very much stiffer and less flexible than the upper blades, are considered rigid; the upper blades are represented by a “single blade model” whereby only the lowest tangential and normal dynamic modes, with tangential displacement and normal displacement for each blade the same, are included; and the pitch angle for both blades are the same.

Power take-off system control design model: The power take-off system is treated as an actuator. Its dynamics are simplified: the azimuthal variation in wind speed experienced by the secondary rotor is neglected; and the electrical dynamics are considered to be at relatively high frequency. The schematic diagram for this model is shown in Figure 3.5. The relationship $T_e = k_c \omega_e^2 / p^2$ or its equivalent $Q_S = k_c \Omega_S^2$ is embedded in the “strategy” block.

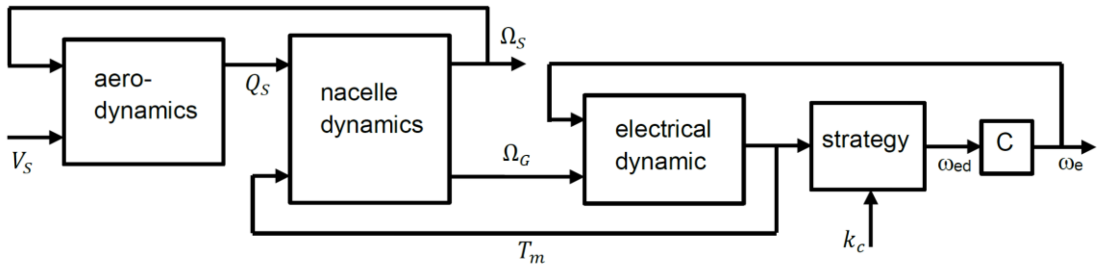

Figure 3.5: Schematic diagram for power take-off system controller design model

- Full envelop control design model: The dynamics of the control simulation model are simplified; the variation of aerodynamic torques and moments with azimuthal angle is neglected, i.e. the aerodynamic coefficients are averaged over azimuthal angle; The lower blades, being very much stiffer and less flexible than the upper blades, are considered rigid; the upper blades are represented by a "single blade model" whereby only the lowest tangential and normal dynamic modes, with tangential displacement and normal displacement for each blade the same, are included; and the pitch angle for both blades are the same.

Both control design models have been implemented in Simulink with characteristic parameter values and tested.

Next Steps

This task is complete in that the models have been constructed.

4.4 Task 3.4. Design controller to realise operational strategy

The design of the controller to realise the baseline operating strategy has started. A full specification of all parameter values and aerodynamic coefficients are required. WP3 is working with all other Work Packages to determine this specification.

Next Steps

The next steps for Task 3.4 are as below:

1. For the baseline operational strategy, build the control simulation and control models by inputting the full set of parameter values once obtained.
2. Design both the full envelop and power take-off controllers.
3. Test and evaluate performance using the control simulation model.

5 WP 4 Report (Design of mechanical structure & Analysis)

5.1 Work carried out during M13-M24

The main objectives of WP4 are to determine an efficient structural design of the Xrotor machine, and in particular to design a suitable tower and jacket support structure. In the previous project period the design basis and preliminary load analysis model were established. In this period of the project the model was tested, refined, and an automated workflow was established.

A first feasible design was attempted based on some strengthening of the OC4 reference jacket. However, very large cycles in the rotor loads meant that it was difficult to obtain a realistic support structure. Through discussions with WP2 and WP3 it was realized that the rotor loads are quite sensitive to the control strategy used. Loads obtained by Strathclyde in the preliminary project and used in WP3 assumed a different control strategy and differed substantially, therefore, from the loads provided by WP2. This prompted a comparison and validation study between the loads and structural analysis performed in the preliminary project and WP4 that is on-going. Regarding the loads it has been concluded recently that the loads from WP2 are mostly consistent with loads obtained from e.g. the multiple streamtube model used at Strathclyde, and can therefore be relied upon.

However, some significant differences between the earlier quasi-static analysis (during the pre-project) and the current dynamic analysis were seen that were suspected to be due to the effect of neglected higher harmonics. This issue was discussed during the mid-term project review, then investigated, and although indeed a few higher harmonics were found for the loads, these were seen to be not actually relevant for the very stiff designs considered. Eventually it was found that initial transients in the simulations were not removed for long enough time. This has been fixed. There still remains the general issue that the cyclic loading from the rotor is very large, so it is really important to perform computer aided structural optimization to determine how heavy the support structure actually needs to be, before the damage constraint precludes further cost savings.

The blade design has been independently checked by performing computations with the Precomp tool. Although the design could mostly be confirmed, some deviations in the mass were found between the blades used in the pre-project and the current blade design that have not been accounted for yet. These deviations are currently being checked with the original ANSYS model at hand.

The structural model was improved. The local beam coordinate systems were consistently orientated. The design checks were updated to include the latest changes, e.g. how to treat the superposition of stresses in tubular joints in the latest DNV-RP-C203 guideline. An efficient workflow was established that relies on the Fedem COM API, which allows Julia/Python code to interact directly with the multibody solver, e.g. to change element or model properties.

A sensitivity study has been performed to determine how the mass (and thereby cost) of the support structure will change under various reductions of the aerodynamic loads (potentially achievable through different control strategies). First results are available that indicate significant potential for a lighter structure, albeit under potentially reduced power production. The study is currently being finalized, and has been accepted for oral presentation at the EERA DeepWind 2023 conference, with an accompanying paper to be published in 2023.

Loads for a 3-bladed rotor were supplied by WP2 and have been set up for use in dynamic structural analysis. However, no results are available yet, as the focus has been on completing the sensitivity study and other tasks first.

In reaction to concerns from GE during the mid-term project meeting the amount of inertial loading (e.g. centrifugal and gyroscopic loads) has been studied and will be reported soon, to complement the above-mentioned sensitivity study. As part of this investigation also (simplified) thrust forces from the secondary rotors have been included in the structural model.

A general methodology for pile design for large offshore vertical axis wind turbines (which includes the Xrotor machine) has been developed and will be used to size the piles. The approach will be presented during the EERA DeepWind 2023 conference, with an accompanying paper to be published in 2023.

Some ideas for a lock-down mechanism have been established, that could potentially lead to a lighter structure by reducing vibrations and stresses during storms. However, the added cost and complexity seem unfavourable, so this idea has not been pursued further. In the case that a master student can be interested, this will still be studied on the side.

The detailed optimization problem has been defined and the most promising solution approach has been established. Due to the stiff nature of the support structure, the response will be mostly quasi-static and it is expected that the local optimization approach (pioneered by the group at NTNU) will be an effective solution strategy. As the design is getting closer to the load eigenfrequencies and their harmonics, however, the convergence speed might decrease. Therefore it has been decided to extend the meta-model for fatigue damage prediction used to also include non-local effects. This will be the main scientific research objective for WP4 in the next period.

Of note, a master student was found who will implement and test design sensitivity analysis of the Xrotor support structure, using the quasi-static approach pioneered by Oest et al., and who aims to also study changes in the footprint of the jacket, in the next project period.

5.2 Overview of results towards objectives (deliverables, milestones, exploitation)

All milestones were reached, and all deliverables were submitted on time.

Deliverable 4.2: Preliminary design (M15): This report documents a first attempt at obtaining a preliminary design. Its main conclusion is that, given the currently used loads, the design would be somewhat unfavourable.

Milestone M4.3: Preliminary design determined and feasible (M15). This is the accompanying milestone, which has been reached.

Milestone M4.4: Detailed optimization problem defined (M24). This milestone has just been reached, with the definition of the optimization problem and the solution strategies. The work will now proceed with implementation of this approach and using it to obtain a detailed support structure design in the next project period.

Regarding dissemination and exploitation, two conference papers have been accepted and will be presented at EERA DeepWind 2023 conference in January. Journal publications have been planned that will be finalized and submitted in the next period. Work carried out towards objectives. The work in WP4 contributes to objective O1 (To determine the performance, by designing the mechanical structure, operational strategy, and carrying out a performance assessment), in particular to objective O1c (Turbine mechanical structure design).

The work prepares for minimizing the structural costs while satisfying all relevant constraints (e.g. on safety). However, the goal to obtain a structural mass less than a current commercial machine has not been reached yet 1. Indeed, the jacket mass of the preliminary design is still significantly more than what is obtained for a comparable conventional wind turbine. A study on the sensitivity of this mass with respect to potential reductions in the aerodynamic loads (obtainable through different control strategies) has been initiated and is close to being finalized. In general, the outcome is that reductions in rotor loads indeed lead to relatively large reductions in structural cost. Therefore an optimum balance needs to be found, which will be part of the overall system optimization work in the next project period. There also remains further cost saving potential through more detailed design and more advanced, computer-aided optimization, which is being investigated now.

WP4 also contributes to objective O3 (To determine the reduction in LCOE) by quantifying the capital expenditure necessary to build the tower and support structure. First estimates of the mass are available, but to address the objective fully more points on this Pareto-curve should be established, and the accuracy needs to be improved (by performing fully automated structural optimization).

5.3 Explanations for deviations in tasks, deliverables or schedule

There are no major deviations in the work, but a few minor adjustments have been made. In particular, due to Covid-19 and the resulting restrictions on traveling and entering the country, the recruitment of an experienced researcher (PostDoctoral fellow) has been delayed by more than six months. Since the contributions of this researcher were scheduled with some flexibility this has not affected deliverables and the overall work, but means that e.g. planned scientific publications are somewhat delayed from this project period into the next period.

Task 4.1 (Parameterization of design space) has been performed for the preliminary design, but not fully implemented for the detailed design yet. For example, the soil pile has not been fully parameterized so far, and the detailed design contains additional design parameters. This is not a deviation, but due to more work on the validation and load model and the blades in the meantime.
Task 4.2 (Establishment of a design basis) has been performed without deviation.

Task 4.3 (Development of load simulation models of full wind turbine system) has been partially performed, without deviation. However, since no fast-aerodynamic load model is available, a coupling analysis could not be performed yet.

Task 4.4 (Preliminary design) has been only partly performed. A minor deviation is that it was decided in the consortium that optimization of the number of blades and the geometry of the turbine shall not be done; instead, more effort will be spent on optimizing the operational parameters of the current design. The preliminary design was also not fully optimized, since it was seen that it was sensitive to the control strategy. Therefore it was decided to wait until an improved control strategy would be available later before attempting computer-aided optimization. This task is expected to be finished in early 2023.

Task 4.5 (Structural optimization) has been started and proceeds currently without deviation. The optimization problem has been defined, the most promising solution strategy has been determined, and work has begun to implement the optimization algorithm. [1]

Task 4.6 (Detailed structural design) has been started and proceeds slowly, currently without deviation. Most work is expected to be performed in Q2-Q3 of 2023. One minor deviation in WP4 is that the last milestones and deliverables have not had supporting publications in the scientific literature yet. This is mainly due to the case that a better control strategy should be in place first, but also due to delays in hiring the experienced researcher. This will be remedied soon. Indeed, two conference papers have already been accepted and will be published in the next project period, and journal publications have been planned.

5.4 Explanations on deviations of use of resources

- There has been no unforeseen subcontracting
- There have been no unforeseen in-kind contributions from a 3rd party

6 WP 5 Report (Power take off and conversion system design)

6.1 Year 2 update

The objectives of WP5 include the design of the power take-off and conversion system for the X-rotor turbine that delivers power, initially extracted by the secondary rotors as mechanical power, to the local power network connection point. This comprises the design of the electric generators for the secondary rotors, the wireless power transfer systems (rotary transformers) to transfer energy from the primary rotor to a fixed structure and the power electronic systems and controllers that drive all the energy conversion stages of the system. A key design input will be enabling the controller to realize the choice of turbine operating strategy.

The work during Year 2 focused on the design of a rotary transformer configuration (i.e. a wireless power transfer system) capable to handle the MW power transfer requirement of the XROTOR system. The work included the formulation of a design procedure of the rotatory transformer and parameter selection (such as operating frequencies, current density, windings area, air-gap length, and others). The work quantified the efficiency of the design using finite element simulation and numerical calculations. Furthermore, its thermal performance at rated power levels was analysed and quantified using finite element simulation.

The second part of the work during year 2 focused on the design and analysis of a suitable power electronic topology for the rotary transformer to manipulate the wireless power flow at the levels of efficiency required by the XROTOR project. The work included the analysis of the electrical operation and energy conversion losses simulation of a three-phase dual active bridge configuration suitable for high-power wireless power applications.

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[1] Note that this goal is not a necessary condition for a commercially attractive wind turbine, since a major part of the cost reduction is expected to arise through reduced maintenance costs.

Furthermore, the work in year 2 also improved the design of the secondary generators following recommendations from industrial advisors, this included thermal performance assessment (numerical, 2D and 3D) and airgap deformation due to centrifugal forces.

The results of this work include design an analysis of a RT system to transmit bidirectionally up to 1 MW of power using magnetic wireless power transfer. The design methodology was validated using FEA simulation and all relevant losses (electrical, magnetic, thermal) were quantified to determine efficiency. The engineering considerations to develop the RT system where also revised and compared against current magnetic design practices. In general terms the manufacture of the RT systems is doable, and the efficiency is enough to comply with the XROTOR project requirements (98.5%). Additionally, a power electronic topology capable to drive power bidirectionally through the RT windings was developed and validated. This topology (the three-phase dual active bridge) was analysed numerically, electrically, and thermically to quantify performance and efficiency. The simulation results indicate that bidirectional power control can be obtained at the desired switching frequency (2KHz) with overall efficiency of around 98% in the power electronic system. All these results and methodologies are presented in the deliverable 5.2.

Finally, new design of secondary generators was developed, and their thermal assessment was revised using numerical and finite element analysis simulation. The effects on airgap deformation due to centrifugal forces is still being investigated with the aid of mechanical engineers from the University of Strathclyde.

6.2 Overview of results towards objectives (deliverables, milestones, exploitation)

The milestone was reached, and the deliverable was submitted on time.

MS5.3 Rotatory transformer designs. The design, analysis and simulation of a rotary transformer (RT) system to transmit bidirectionally power up to 1 MW of power using magnetic wireless power transfer has been archived. The design methodology was validated using FEA simulation and all relevant losses (electrical, magnetic, thermal) were quantified to determine efficiency. The efficiency is enough to comply with the XROTOR project requirements (98.5%). Additionally, a power electronic topology capable to drive power bidirectionally through the RT windings was developed and validated. This topology (the three-phase dual active bridge) was analysed numerically, electrically, and thermically to quantify performance and efficiency. The simulation results indicate that bidirectional power control can be obtained at the desired switching frequency (2KHz) with overall efficiency of around 98%. The overall efficiency of the full rotary transformer system, including power electronic driving circuits turned to be 96.53%.

Deliverable 5.2 Is a written report that reviews the design of the rotary transformer system and its power electronic driving circuit. The reports present a design methodology for a 1MW wireless power system including electrical, magnetic, and thermal analysis. The combined efficiency of the system is calculated to be around 96.56%.

6.3 Work carried out towards objectives

The work in WP5 contributes directly to O2 which involves the design of the power take off, energy conversion systems and power electronic controllers to deliver the extracted power from the wind to the local power network. So far, the design methodology has incorporated the requirements, in terms of operating strategies of the Xrotor system. The goal to obtain a power transfer of 95% efficiency is the leading driver of the design efforts.

6.4 Explanations for deviations in tasks, deliverables or schedule

There are no mayor deviations in the work.

6.5 Explanations on deviations of use of resources

- There has been no unforeseen subcontracting
- There have been no unforeseen in-kind contributions from a 3rd party

6.6 Next steps in the WP work

Next year work will focus on the power take-off control systems for maximum power capture and provision of frequency support. This includes the coordination of the different control actions of generators, rotary transformers and power electronic converters. The performance of the power take-off controller will be evaluated using electromagnetic transient simulation software.

Additionally, work towards the drafting of three papers, (2 journal papers and 1 conference paper) has already started and will be completed in the following year.

7 WP 6 Report (Cost of Energy Reduction Analysis)

Work package 6 started in M15, year two of the XROTOR project.

7.1 Status update on WP6 tasks worked on in year 2 of our project

During Year 2 of the project, two of the 3 tasks from work package 6 were initiated:

- T6.1: Create O&M cost model to capture the unique characteristics of the X-Rotor and
- T6.2: Model O&M Costs for the X-Rotor

T6.1 started in 2022 and involved adjusting an existing benchmarked offshore wind O&M cost model for traditional offshore wind turbines. The adjusted model could then capture the unique characteristics of the XROTOR concept.

T6.2, modelling O&M Costs for the X-Rotor also started in 2022 and involved obtaining and systematically estimating the inputs required to model the O&M costs of the X-Rotor concept. Inputs included data such as failure rates, repair costs, repair times, number of technicians required for repair etc. Once the model was populated, it could be run and outputs such as availability, transport costs, staff costs, repair costs and total O&M costs could be obtained.

Both of the above tasks feed into the first deliverable from WP6 due in project month 25, January 2023. No issues with meeting the deliverable timeline are expected.

7.2 Overview of WP6 Deliverables/Milestones from year 2 of our project

There were no deliverables or milestones for WP6 due in Year 2 of the project. The following deliverables are due in Year 3 2023.

D6.1: O&M costs for X-Rotor modelled [Due in Month 25, Jan 2023]

This report will include an overview of the O&M cost model created for modelling X-Rotor O&M costs as well as detail the O&M cost results and assumptions. The deliverable will be considered complete once a report is produced detailing how an O&M model was adjusted to represent the unique configuration of the X-Rotor turbine and its O&M cost results compared to existing offshore turbines.

D6.2: CoE of X-Rotor Concept modelled [Month 31, July 2023]

A full cost of energy model of the XROTOR Technology will be delivered which will consider the full lifecycle cost of the technology along with lifetime generation capacity.

D6.3: CoE of existing turbines modelled and compared to X-Rotor CoE [Month 34, October 2023]

The full cost of energy of a the XROTOR Concept will be benchmarked against comparative values for at least 3 conventional horizontal axis wind turbines.

7.3 Overview of next steps for WP 6 in 2023

In 2023 the focus of WP6 will switch from T6.1 and T6.2 to T6.3. Task 6.3 includes modelling the LCoE for the X-Rotor and comparing that LCoE to existing turbines, this task will combine input from both UCC and the University of Strathclyde. The O&M cost modelling work form T6.1 and T6.2 will feed directly into the LCoE work in task 6.3.

All work package six deliverables will be submitted in 2023, the first being in January 2023 and the last being in October 2023. No issues are expected in terms of meeting the deliverable deadlines.

8 WP 7 Report (Environmental and Socio-Economic Impact)

Task 7.1: 'Complete Social Analysis' is led and realised by UCC, with support from University of Strathclyde (UoS) for the community engagement in Scotland. This task considers the social acceptability of the X-ROTOR concept. It involves liaising with two groups of stakeholders, the first are the host communities comprising members drawn from coastal populations, fisheries, environmental groups, etc. The second are those involved in the wider wind energy communities which includes members drawn from developers, academics, consultancies, standards bodies, operators, vessel companies, O&M providers, OEMs etc. As described in D7.3 (submitted in December 2022) there was an intensification of the engagement of the two sets of stakeholders during 2022, namely: societal and community stakeholders (group 1) and those from the wider wind sector (group 2). For group 1, a primary (prospective) host community was selected based on the criteria outlined in the first initial preparatory deliverable from WP7 viz. 'Methods to Identify and Convene Stakeholder Communities' (D7.1). Working through local gatekeepers and using the communication strategy envisaged in the aforementioned deliverable an in-person workshop focus group was organised and realised within this island community, where the project team engaged with a diverse group with a range of backgrounds to garner their perspectives and opinions to feed into the design process. In addition, contact was maintained and enhanced with a number of secondary (prospective) host communities which will be engaged extensively during 2023. Group 2 was engaged in 2022 through a combination of continuing remote data collection via surveys and through semi-structure in-person engagements during and around wind energy conferences and seminars. These engagements were useful proving some interesting insights, but moreover they form the basis of an intensification of such engagements about conference across Europe in 2023. For example, dedicated panel sessions (mini-symposiums) focused on the X-ROTOR project are already confirmed for the EERA DeepWind Conference, Norway (18-20 Jan 2023) and Wind Energy Science Conference (WESC), (UK 23-26 May 2023). Engagements during these sessions and importantly following on from these sessions will serve as an important route for engaged with Group 2 in 2023.

Task 7.2: 'Conduct an Economic Analysis', focusing on the wider, regional economic impact of the X-ROTOR, is led by UCC and supported by UoS. The task involves assessing the market potential of the technology using primary data from surveys of potential buyers and users of innovations drawn from stakeholder Group 2. The attribute matching task was conducted during the year, this involved considering both qualitative and quantitative data (from the group 2 engagement in T7.1) through a SWOT Analysis, followed by a sequencing exercise within a modified Delphi-panel engagement. These attributes identified from the collected stakeholder data were compared with the features of the X-ROTOR derived from an analysis of a foundational overview text, which first described the X-ROTOR concept. In this way an assessment was made of the extent to which the developing X-ROTOR design addresses those attributes which the industry stakeholders have deemed important to them. This work was reported in D7.6 'Output of Attribute Matching' (submitted in December 2022. While this report has been finalised, it is intended to prepare an updated iteration of the attribute matching over the first quarter of 2023, this will involve collected additional responses for the wider wind community, following which an analytic hierarchy process will be conducted and thereafter the sequencing exercise revised. This new iteration will be submitted with D7.7 report on economic impact. Additionally, initial scoping work has commenced on the Job Creation subtask and the UCC and UoS researchers involved have had a number of meetings already to discuss the task. The UoS staff are fully in place for this task, however UCC still have a staffing gap in respect of this work – but this should be resolved in the early part of 2023 when this work is due to be progressed.

Task 7.3: Undertake an Environmental Analysis led by UCC focuses on the (potential) environmental impact of the X-ROTOR concept, with some contribution from TUD on the assessment of environmental noise impact. Work in the period has continued to focus on the potential impact on marine mammals and sea birds. Field work was conducted to collect data on flight behaviour, sensitivity to disturbance and conservation status for 81 seabird species present in European waters before calculating Collision and Displacement Vulnerability Indices to assess the most at-risk species to wind turbines. These indices were combined with distributions of 12 commonly occurring seabird species in the North-East Atlantic based on surveys conducted between 1980 and 2018, to generate vulnerability maps for breeding, wintering and migration periods when risk is likely to vary. This was presented as D7.10 at the end of 2021. An overview of the methodological framework to be employed during the fieldwork (and that already employed) along with example data was presented as D7.11 in June 2022. A second strand of work in these tasks related to noise. An assessment is being made by TUD of the noise propagation expected for the full-scale X-Rotor concept proposed, based on measurements and modelling in WP2 and a propagation model assuming a flat sea surface. TUD and UCC researchers are liaising about this work and data is already being shared. This assessment to be reported as D7.13 in month 33 will be used in this work package to investigate the impact on sea birds and users of the marine environment. Additionally, this task will consider the whole life carbon implications of the design with this in mind, in association with Task 6.3 (on LCOE) due to commence in the new year, a full lifecycle carbon assessment will be prepared for both the X-ROTOR and standard horizontal axis turbine concepts using the industry standard tools (e.g., GaBi). This work will provide a benchmark for the impact of the X-Rotor concept and highlight opportunities to reduce environmental impacts at the design phase.

8.1 Specific objectives

WP7 address Objective 4 detailed in section 1.1 of the DoA, namely: To complete Socio-economic and environmental analyses. Based on a combination of field work, research and interviews, an assessment of the social, economic and environmental impact of the X-rotor concept and recommendations to mitigate them will be provided. Because of the disparate nature of the three aspects this objective is sub-divided into three tasks. (a) Social; (b) Economic; (c) Environmental. While now of the three aspects of this specific objective has been fully achieved yet, work has progressed well during 2022 towards meeting each of three aspects as described in T7.1, T7.2 & T7.3 above.

8.2 Deliverables

There were three deliverables prepared and submitted during 2022, these included:

- D7.3: Year 2 report on workshops design recommendations (UCC)
- D7.6: Outcome of Attribute Matching
- D7.11: Field work data and methodology

Milestone # 22 ‘Completion of year 2 workshop’ was moved with permission of PO to Dec 2022. This has been achieved as documented by the preparation of D7.3

8.2.1 Deviations on tasks:

There was been no significant deviations on tasks

8.2.2 Deviations on resources:

The nature of the engagement planned in this project means that there is a substantial around of effort in T7.1 & T7.2 which is backloaded for the final year of the project.

8.2.3 Sub-contracting:

There has been no unforeseen subcontracting during the report period.

8.2.4 Kind contribution:

There has been no unforeseen in-kind contribution during the report period.

9 WP 8 Report (Industry Ratification and Further Development Roadmap)

9.1 Task 8.1. Industry Ratification

Progress

The Technical Management Team meets on a monthly basis to ensure that GE is kept fully informed of WP progress. Depending on the status off each Work Package, a meeting is called between the Technical Management Team and the Work Package Leads. The GE member of the Technical Management Team participates in all these meetings. Guidance on methodology, results and next steps is, thereby, fed back by GE to Work Package Lead.

The following Technical Management Team meetings with all Work Package Leads present have been held on 22nd June 2022.

The following meetings of the Technical Management Team with individual Work Package Leads have been held:

- WP2 & WP4, 20th April 2022
- WP6, 21st April 2022
- WP7 & WP9, 27th April 2022
- WP5, 5th May 2022
- WP5, 5th May 2022
- WP3, 11th October 2022
- WP5, 13th October 2022
- WP2, WP3 & WP4, 21st October 2022
- WP4 & WP6, 24th October 2022
- WP7 & WP9, 9th November 2022
- WP3, 16th November 2022
- WP2, 23th November 2022

The Mid-Term Review Meeting was held at GE in Barcelona on 22 September 2022. Engineers from GE were present during the technical presentations. The feedback from them was very useful, particularly with regard to WP4 and WP5. The Technical Management Team engaged with the individual Work Package Leads concerned to ensure that the issues raised were addressed. In addition, a meeting was held with the WP2, WP3 and WP4 Leads to place additional Milestones to ensure information required to progress the work is available in a timely fashion.

Next Steps

1. As the project is now entering the stage when much tighter integration of the Work Packages is required, the TMT meetings with the Work Package leads will be monthly (over the first two years, if there is no requirement to meet, these have not occurred).
2. An Executive Management meeting is scheduled for 20th January 2023. On the Agenda is drawing up a timetable with milestones covering all of 2023.

9.2 Task 8.2: Further Development Roadmap

The following meetings of the full Independent Advisory Board have been held:

- CDG, ABL Board, CREADIS, SINTEF, Mainstream, GE, 9th August 2022
- CDG, ABL Board, CREADIS, Mainstream, 24th August 2022

The Independent Advisory Board requested access to information concerning the work done on the current and previous X-rotor projects. The relevant documents were placed on a SharePoint, created for The Independent Advisory Board.

The following individual meetings were held:

- CDG, 25th October 2022
- CREADIS, 1st November 2022
- Mainstream, 1st November 2022
- SINTEF, 3rd November 2022
- GE, 10th November 2022
- CREADIS, 30th November

The following questions were posed to each:

- What are the greatest barriers to entry for a new concept like the X-Rotor?
    - Who would be the early adopters of a concept like the X-Rotor?
    - How to overcome OEMs traditional focus on CAPEX rather than OPEX savings?
    - How to overcome OEMs sunk costs and skills foundation in traditional HAWT technology?
- What reduction in cost of energy would be needed to make an X-rotor turbine commercially attractive?
    - Is LCoE the only metric that matters?
    - How important is it to highlight other benefits to industry/funders (H&S improvement potential, lower requirement for limited resources, greater floating platform potential etc.)?
    - What would be the appropriate balance in reductions in OPEX and CAPEX costs?
    - Where would the greatest commercial opportunity be ~ fixed or floating?
- What is the minimum rating that would be attractive?
- What sites would be open to deployment of X-rotor turbines but not conventional turbines?
- What options are possible for financing a demonstration turbine?

All members of the Independent Advisory Board have engaged strongly and provided much useful insight.

Next Steps

1. Review transcripts of the all meetings and summarise in a single document, which will be circulated to the members of the Independent Advisory Board for their review and approval.
2. Compare to the outcomes from the Wider Wind Energy Community Stakeholder Group discussions, see WP7, and add ANNEX summarising additional useful points.

9.3 Task 8.3: Turbine Design Integration

Progress

The following consortium technical meetings with all Work Package Leads present have been held:

- Consortium Technical Meeting 4, 21st & 22nd June 2022
- Consortium Technical Meeting 5, 22nd September 2022

In addition, the following technical meetings have been held:

- WP2, WP3 & WP4, 19th May 2022
- WP2, WP3 & WP4, 6th July 2022
- WP2, WP3 & WP4, 28th September 2022

Frequent informal meetings have taken place between researchers on different Work Packages. Researcher have undertaken study visits to other partners to strengthen project cohesion.

Next Steps

Given the relaxation of travel restrictions imposed during COVID, it is important for consortium cohesion to hold a series of face-to-face meetings. The first of these will be held on 20th January 2023.

10 WP 9 Report (Communication and Dissemination)

Task 9.1: Corporate image of the project

This task is mostly in hiatus as the logos, templates etc. have been developed. However new material is produced as required (recent small examples include project icon for social media profiles, and a template for project meeting minutes).

Task 9.2: Set up and maintenance of XROTOR Website

In 2022, the website (https://xrotor-project.eu) was redeveloped and refined with a new welcoming design sensibility. The site includes modern publishing capabilities with the ability to display multi-media assets such as videos, images, infographics, and animation as required. It has tabs that will take the visitor to pages marked home, about, partners, outputs, news & events, and then a contact page. The website is being maintained, and content added regularly as the project progresses.

Task 9.3: Social media positioning (UCC)

This task led by UCC. Social media activity during the 2022 while still intentionally low-key was ramped up a little in anticipation of the final year where there will be a great deal of communication and dissemination associated with results and outputs. The project Twitter presence (@XRotorProject) was maintained and activity has been increasing as the project progresses, outputs emerge, and especially as public engagements and events take place.

Similarly, news items and posts are being shared through the personal LinkedIn accounts of the participating researchers. In addition to authors' sharing their works on LinkedIn, the project presence on the Zenado file repository has been maintained and developed (see https://zenodo.org/communities/x-rotor), with links from the project website to the outputs. Each of these project outputs have been given provides Digital Object Identifier (DOIs) for documents, which greatly improves their citability and enables far more effective promotion.

Task 9.4: Communication and dissemination materials (UOS)

This task led by UoS and supported by all partners is responsible for creating the communication and marketing materials and ensuring the proper dissemination of project results. Examples of dissemination outputs during 2022 include:

Peer-review papers

Morgan, L. and Leithead, W. (2022). 'Aerodynamic modelling of a novel vertical axis wind turbine concept' Journal of Physics: Conference Series. 2257: 012001 doi:10.1088/1742-6596/2257/1/012001.

McMorland, J., Flannigan, C., Carroll, J., Collu, M., McMillan, D., and Leithead, W.E., Coraddu, A. (2022) A review of operations and maintenance modelling with considerations for novel wind turbine concepts. Renewable and Sustainable Energy Reviews, 165. 112581. doi:10.1016/j.rser.2022.112581.

Flannigan, C., Carroll, J., Leithead, W.E (2022). 'Operations expenditure modelling of the X-Rotor offshore wind turbine concept'. Journal of Physics: Conference Series, 2265: 032054 doi:10.1088/1742-6596/2265/3/032054.

Conference oral presentations

Morgan, L. and Leithead, W.E. (2022). 'Aerodynamic modelling of a novel vertical axis wind turbine concept'. Wind Europe, Bilbao, Spain. 5-7 April. [subsequently published as a journal article]

Flannigan, C., et al., (2022). 'Operations expenditure modelling of the X-Rotor offshore wind turbine concept', The Science of Making Torque from Wind, Delft, Netherlands. 1-3 Jun [subsequently published as a journal article]

Conference posters

Bensason, D. (2022). 'A new player in the water: the X-Rotor turbine'. JM Burgers Symposium, Lunteren, Netherlands. 8 & 9 June.

Giri Ajay, A. (2022). 'The Future of Vertical-Axis Wind Turbines: X-Rotor.' JM Burgers Symposium, Lunteren, Netherlands. 8 & 9 June.

Deeney, P. and Dunphy N.P. (2022). 'Stakeholder Engagement for a New Offshore Wind Turbine', Wind Energy Ireland, Dublin. 13 & 14 April.

In addition, two dedicated panel sessions (min-symposiums have been organized for X-ROTOR at significant conferences in 2023: DeepWind and WESC.

10.1 Specific objectives:

Not applicable

10.2 Deliverables:

There were two deliverables prepared and submitted during 2022

- D9.4 Mid-term communications. & dissemination report (UoS)
- D9.5 Development of main results material (UoS)

Milestones: There were no milestones associated with this Work package in 2022

10.2.2 Deviations on tasks

All tasks have been implemented as envisaged from the project plan.

10.2.3 Deviations on resources

It was always intended for the majority of dissemination and communication activity to the backloaded towards the latter stages of the project – until the project had something to communicate. Within 2022 there was already an increase in communication and dissemination activity over 2021, which of course was impacted by the COVID-19 pandemic. Already the plans for the 2023 show this ramping up of activity continuing into the final year as would be expected (with for example two X-ROTOR panel sessions/mini symposiums already confirmed at major conferences)

10.2.4 Sub-contracting

There has been no unforeseen subcontracting during the report period.

10.2.5 In-kind contribution

There has been no unforeseen in-kind contribution during the report period.

11 Note from Project Coordinator and Conclusion

All deliverables and milestones have been met in year 2 of the XROTOR project. The project coordinator would like to thank consortium members for their contribution to this report as well as for their work in year 2 of the XROTOR project. Additionally the project coordinator would like to thank the EU PO for facilitating the XROTOR project in year 2.

To determine if this deliverable has been successfully completed, the deliverable description must be examined.

The deliverable description states: “Report detailing project progress from Year 2. Successful once delivered to the project coordinator and/or the executive management group.”

Dissecting that description, a report detailing full project progress from Year 2 has been created and delivered to the Project Coordinator.

The year 2 progress report has been reviewed by the Project Coordinator and has been approved. In conclusion, this deliverable has been successfully completed.