Report 2023

Task 37

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Wind Energy Systems Engineering: Integrated Research, Design, Development and Operation

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The purpose of Task 37 is to apply a holistic, systems-engineering approach across the entire wind energy system and to improve the practice and application of systems engineering to wind energy research, development, and demonstration (RD&D).

The Task comprises four interrelated and complementary work packages (WP):

- WP 1: Definition and implementation of guidelines for a common framework for integrated RD&D at different fidelity levels.
- WP 2: Design, release, and maintenance of reference wind energy systems (both turbines and plants).
- WP 3: Benchmarking multidisciplinary design, analysis, and optimisation (MDAO) activities at different system levels (both turbines and plants).
- WP 4: Expert workshops on advanced MDAO topics.

Task 37 concluded its activities in

2023. During this last year, a team started the conceptual design of a new 22 MW reference offshore wind turbine [1]. The team was led by researchers at the Technical University of Denmark (DTU) and the National Renewable Energy Laboratory. Furthermore, a 740 MW reference offshore wind farm was designed collaboratively among participants from Germany, The Netherlands, Denmark, and the United States [2]. Both activities have actively involved industrial partners and received countless input from the broader wind energy community. Task 37 has now concluded, but these two designs will be continued by the newly approved Task 55: Reference Wind Turbines and Wind Farms (REFWIND).

Introduction

Over the last few decades, wind energy has evolved into an international industry involving major players in its manufacturing, construction, and utility sectors. Significant progress in technological innovation has resulted in larger turbines and wind plants while lowering the cost of wind-generated energy. However, the increasing importance of wind energy's role within the electricity sector also creates further requirements for the performance, reliability, and cost of the technology.

To meet these expectations, the industry has sought to improve the performance, reliability, and cost of turbine and plant design. However, trade-offs among these competing goals highlight the need for a more integrated approach. This strategy is necessary to fully assess the impact of a new design parameter on a myriad of objectives in system performance and cost. The application of integrated systems research, design, and development (RD&D), which can be applied to both tools and methods, makes it possible to improve system performance and reduce the levelized cost of energy. Despite its potential, developing such an approach poses significant challenges, both within organisations and across the industry.

Table 1. Countries that Participated in Task 37.

COUNTRY/SPONSOR	INSTITUTION(S)
The United States	National Renewable Energy Laboratory (NREL); Sandia National Laboratories (SNL); Brigham Young University (BYU); Siemens Gamesa Renewable Energy; Envision Energy; GE Global Research; University of Massachusetts Amherst
Denmark	DTU Wind and Energy Systems (DTU); LM Wind Power; Vestas Wind Systems
Norway	SINTEF Energy Research; CMR (NORCOWE)
Germany	TU Munich (TUM); Fraunhofer IWES; Nordex
The Netherlands	TU Delft
Spain	CENER
The United Kingdom	DNV; BVG Associates
China	Goldwind

Progress and Achievements

Task 37 concluded in the summer of 2023 and passed its work on to the newly approved Task 55. In its last year, the team focused on finalising its ongoing work and scoped activities for the continuation of some projects. The progress and achievements of each work package in 2023 are detailed in the following subsections.

Work Package 1: Guidelines for a common framework for integrated RD&D at different fidelity levels

Task 37 has developed windIO, which is freely available online at GitHub [3] and consists of rigorous wind turbine and wind plant ontologies. The two ontologies allow for a common definition of wind energy systems and are implemented in YAML format. In 2023, the usage of windIO spread across research organisations and attracted the interest of major industry players. The development team of windIO has identified a long list of improvements to be released in the next version of windIO. The improvements are scheduled to be implemented in 2024 within Task 55 REFWIND.

Work Package 2: Reference wind energy systems (both turbines and plants)

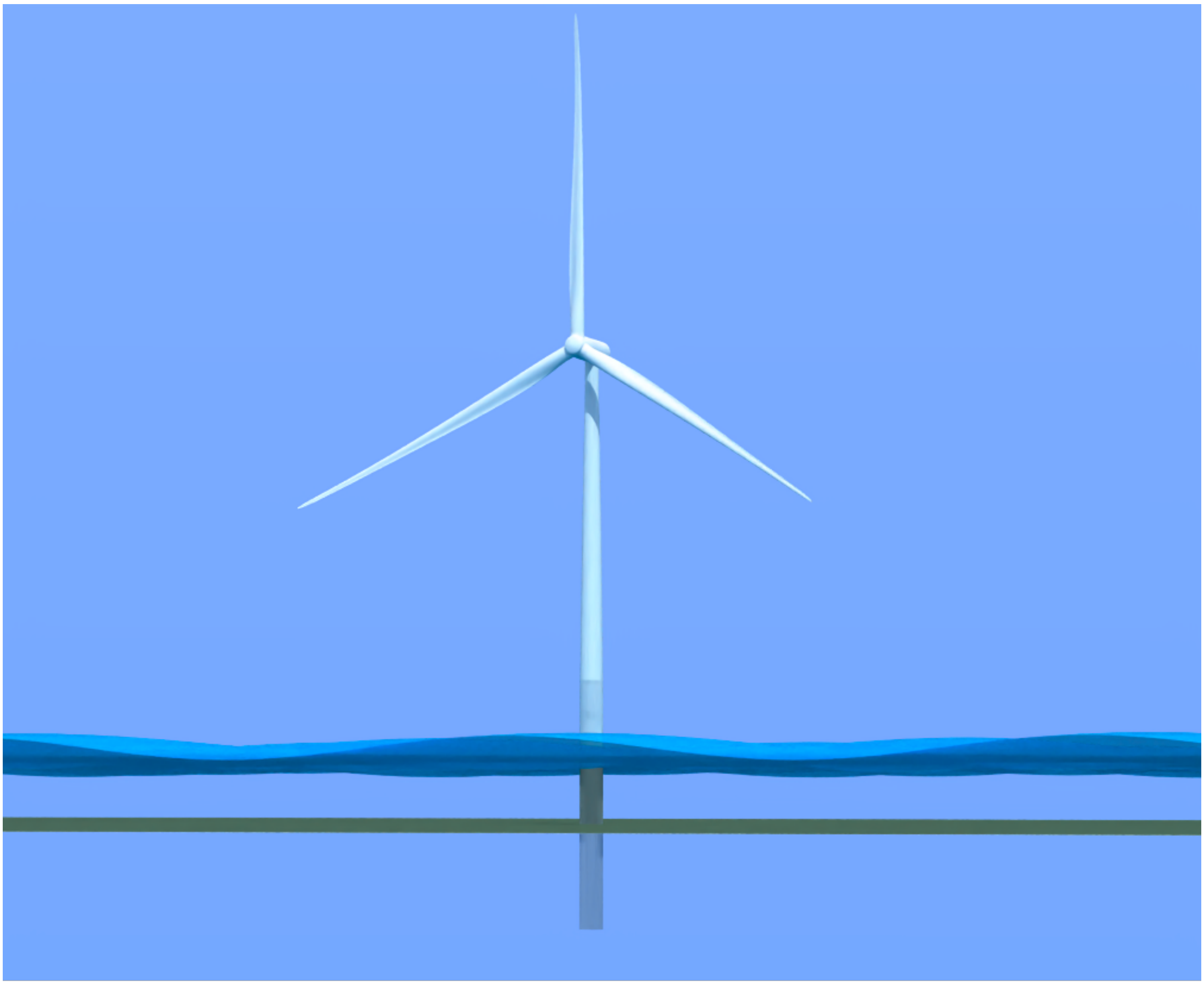

Figure 1. Render of the IEA 22 MW offshore reference wind turbine mounted on its fixed bottom monopile. *Image from Frederik Zahle, DTU.*

Work package 2 progressed the most through the design of the new 22-MW reference offshore wind turbine [1] and the design of the new 740 MW reference offshore wind farm [2]. Both designs are described in technical reports published at the beginning of 2024 and have already attracted significant interest.

Work Package 3: Benchmarking Multidisciplinary Design, Analysis, and Optimization (MDAO) activities at different system levels (both turbines and plants)

No new benchmark studies were completed in 2023. The lack of new comparisons was not driven by a lack of interest or scientific relevance, but rather by the awareness of the complication and associated workload involved with this type of comparison. The recommendation for future work consists of scoping MDAO benchmark studies by leveraging existing verification efforts, such as the ones ongoing within the turbine-focused Task 47: TURBulent INflow Innovative Aerodynamics (TURBINIA).

Work Package 4: Expert workshops on advanced MDAO topics

After the success of the sixth edition of the Wind Energy Systems Engineering workshop, held in Boulder, Colorado, in early autumn 2022, the team is now busy scoping and preparing the seventh edition, which will be held in Copenhagen, Denmark, in December 2024. The organising team has been meeting regularly in 2023 to prepare the new workshop.

Highlight(s)

The two major highlights of 2023 for Task 37 were the design of the 22 MW reference offshore wind turbine [1] and the design of the new 740 MW reference offshore wind farm [2]. After the success of the 15 MW reference offshore wind turbine, which technical report has received hundreds of citations since 2020, the 22 MW represents the next generation of offshore wind turbines that are expected to be installed between 2025 and 2030. A publication about a detailed aero-servo-elastic code-to-code verification has been submitted to the international conference, The Science of Making TORQUE from Wind, which will be held in Florence, Italy, in May 2024 [4]. The publication compares predictions among the popular solvers Bladed, HAWC2, HAWCStab2, OpenFAST, and QBlade and discusses the differences in numerical predictions. A rendering of the turbine in its fixed-bottom foundation is shown in Figure 1.

The 740 MW reference offshore wind farm is made of seventy-four 10 MW offshore wind turbines and aims to represent existing offshore installations [2]. Two variations, one with a regular layout and one with an irregular layout, see Figure 2, are described in the technical report, which was led by Samuel Kainz at the Technical University of Munich in Germany. The designs are based on the Borssele III and IV offshore wind plant projects. The associated wind resource, allotted territory, and bathymetry measurements are used to define the site characteristics. These reference wind plants have been described using the windIO ontology and have been made available through an open-source repository on GitHub.

Outcomes and Significance

Wind turbines and wind farms are increasingly complex systems where a myriad of competing objectives and constraints drive the designs. Over the past eight years, Task 37 has successfully spread knowledge, common definitions, reference designs, and benchmark studies across the broad wind energy community. In addition, Task 37 has conducted multiple in-person and virtual workshops, which were attended by dozens, if not hundreds, of experts from academia and industry, educators, and, more importantly, students. The publications from Task 37 have been downloaded thousands of times and cited hundreds of times. Additionally, the GitHub repositories where numerical models are stored receive a steady flow of comments, requests, suggestions, and recommendations.

Task 37 completed its activities in the summer of 2023, but Task 55 has picked up some of its goals. Importantly, its mission to share good reference wind energy systems across the wind energy community will continue.

Next Steps

Task 55 on Reference Wind Turbines and Wind Farms has been working to finalise and release the newly designed 22 MW reference offshore wind turbine and the 740 MW reference offshore wind farm. Once these activities are concluded, Task 55 will focus on a new reference offshore wind farm made of 22 MW wind turbines, which aims to represent future offshore installations. Next, Task 55 will continue the design for one or more new reference land-based wind turbines, possibly at both high and low specific power levels. Meanwhile, Task 55 will keep improving the windIO ontologies for wind turbines and wind farms.

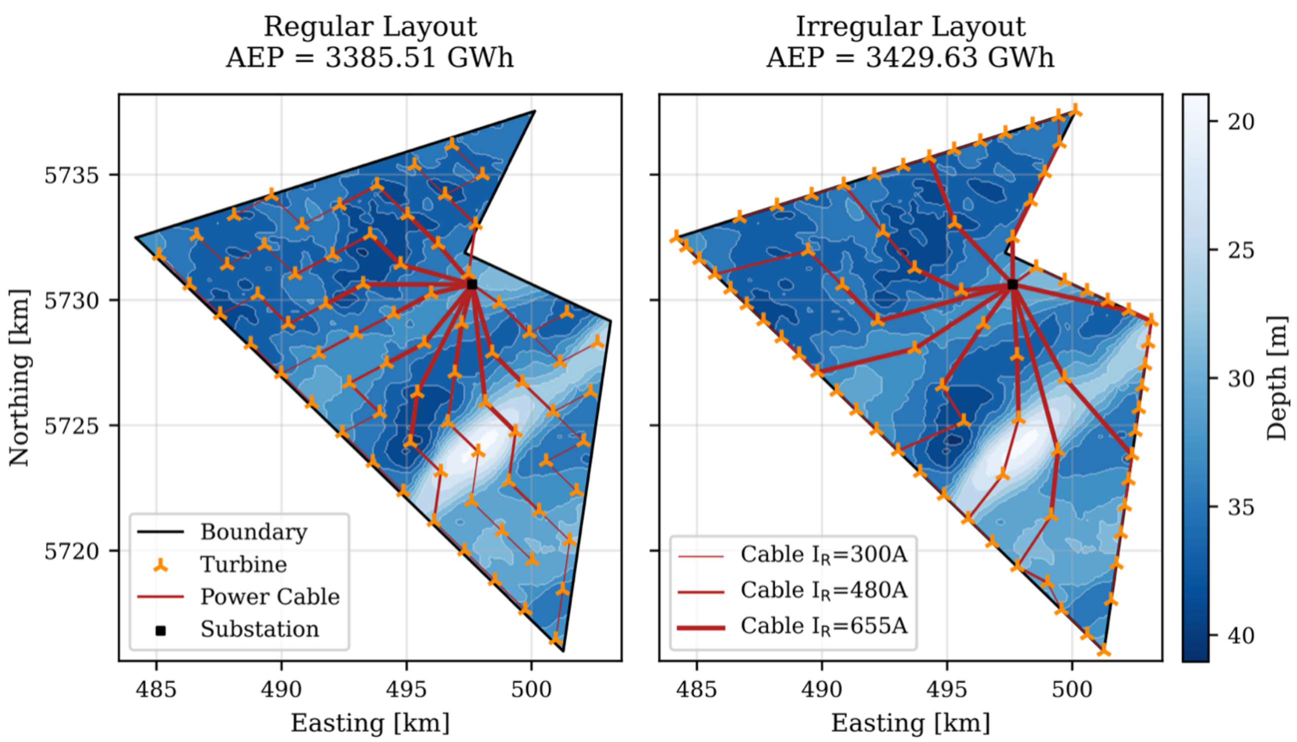

Figure 2. Regular and irregular layout of the 740 MW reference offshore wind farm designed and released within IEA Wind TCP Task 37 [2]. *Images from Kainz et al., 2024.*

References

[1] Zahle Frederik, Barlas Athanasios, Lønbæk Kenneth, Bortolotti Pietro, Zalkind Daniel, Wang Lu et al. 2024. Definition of the IEA Wind 22-Megawatt Offshore Reference Wind Turbine. Technical University of Denmark.
doi: 10.11581/DTU.00000317

[2] Kainz Samuel, Quick Julian, Souza de Alencar Mauricio, Sanchez Perez Moreno Sebastian, Dykes Katherine, Bay Christopher, Zaaijer Michiel B., and Bortolotti Pietro. IEA Wind TCP Task 55: The IEA Wind 740-10-MW Reference Offshore Wind Plants. 2024.
doi: 10.2172/2333634

[3]windIO:
https://github.com/IEAWindTask37/windIO

[4] Collier William, Ors Dilek, Barlas Athanasios, Zahle Frederik, Bortolotti Pietro, Marten David, Jensen CSL, Branlard Emmanuel, Zalkind Daniel, Lønbæk Kenneth. Aeroelastic code comparison using the IEA 22MW reference turbine. The Science of Making TORQUE from Wind 2024.

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