Report 2021

Task 37

Photo: Omkar Jadhav

Systems Engineering

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The purpose of IEA Wind TCP 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 RD&D.

THE TASK COMPRISES three interrelated and complementary work packages (WP):

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

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

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

WP 4: Expert workshops on advanced MDAO topics

Key results from 2021 included the publication of a technical report on system modelling frameworks/ontologies for wind turbines and plants and progress on the development of reference wind energy systems (turbines and plants).

Table 1. Countries Participating in Task 37

	COUNTRY	INSTITUTION(S)
1	**The United States of America**	National Renewable Energy Laboratory (NREL) Sandia National Laboratories (SNL) Brigham Young University (BYU) Siemens Gamesa Renewable Energy (SGRE) Envision Energy GE Global Research University of Massachusetts Amherst
2	**Denmark**	DTU Wind Energy (DTU) LM Wind Power Vestas Wind Systems
3	**Norway**	SINTEF Energy Research CMR (NORCOWE)
4	**Germany**	TU München (TUM) Fraunhofer IWES Nordex
5	**The Netherlands**	TU Delft
6	**Spain**	CENER
7	**The United Kingdom**	DNV GL BVG Associates
8	**China**	Goldwind

1.0 Introduction

Over the last few decades, wind energy has evolved into an international industry involving major players in the manufacturing, construction, and utility sectors. Significant technological innovation has resulted in larger turbines and wind plants with lower costs of energy. However, the increasing importance of wind energy's role within the electricity sector also imposes more requirements on the performance, reliability, and cost of the technology.

To meet these requirements, the industry has sought to improve the performance, reliability, and cost of the turbine and plant design. However, trade-offs among competing goals require a more integrated approach (see Figure on complex wind systems). An integrated approach is needed to fully assess how a change or uncertainty in a design parameter affects the myriad objectives in system performance and cost. Integrated systems research, design, and development (RD&D), which can be applied to both tools and methods, can improve system performance, and reduce the levelized cost of energy. Nevertheless, developing such an approach poses significant challenges, both within and across organizations.

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Progress and Achievements

In 2021, Task 37 continued with its four work packages in its second 3-year phase.

In WP 1, the Task extended the wind turbine ontology, or common parameterization, to include the floating substructure and mooring system. Additional work is ongoing to also parameterize the drivetrain and its many architecture variations. 2021 also saw significant progress in developing

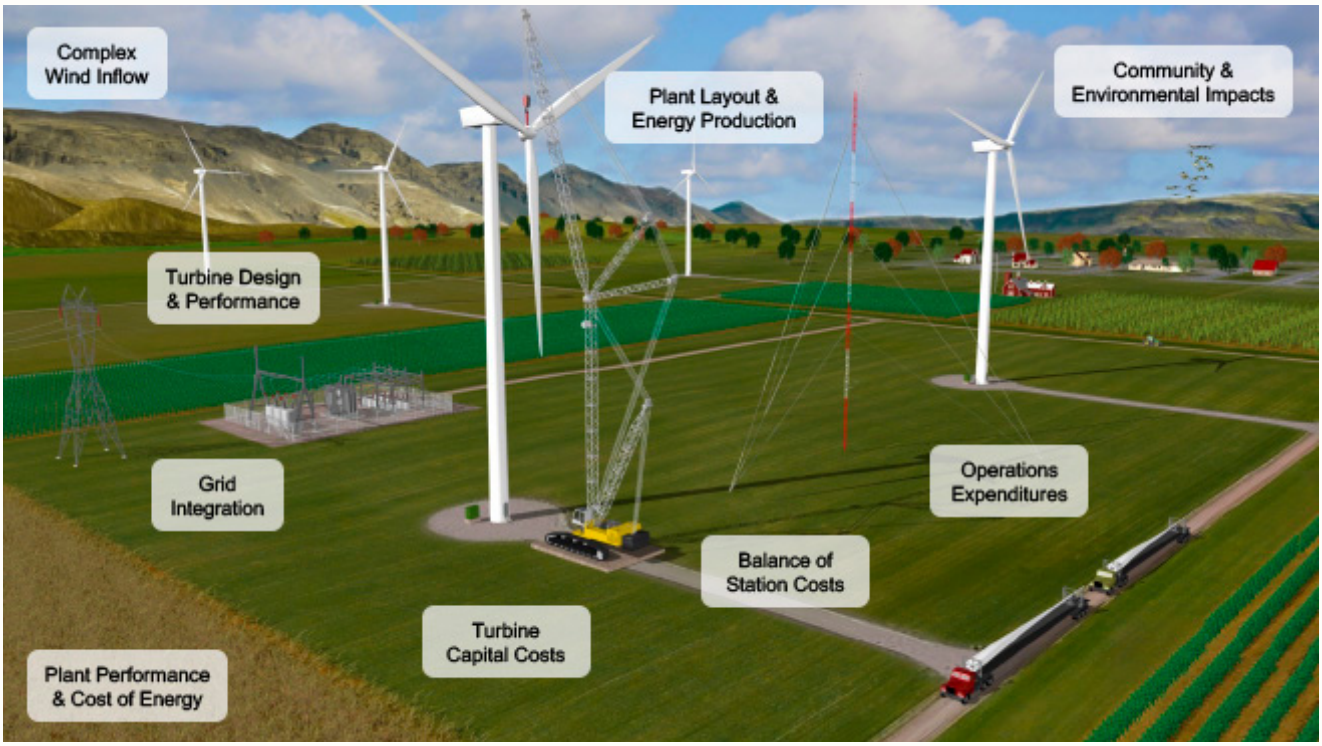

Figure 1: An example of a wind plant: a complex and highly interconnected system
(Graphic: Alfred Hicks, National Renewable Energy Laboratory)

the plant ontology to support layout optimization – now released. All of the ontology implementations are based on json schema in the WindIO project. The main accomplishment in 2021 was the publication of the technical report (see chapter highlight) on both the turbine and plant ontology with full documentation of the formulations [1].

For WP 2, the Task continued to support the development and use of the fixed-bottom and floating variants of the new offshore 15-MW reference wind turbine**,** developed through a collaboration between NREL, DTU Wind Energy, and the University of Maine [2,3]. On the plant side, a series of offshore reference wind farms for a range of depths, layout types, and turbine sizes are under development. Two papers were presented at the Science of Making Torque from Wind, related to energy production analysis and monopile sizing of reference offshore wind farms [4, 5]. Task 37 also plans to coordinate on floating wind farm design with the new floating arrays in Task 49.
For WP 3, on benchmarking MDAO activities, the Task facilitated a detailed comparison of optimization methods on an array layout optimization with real-world constraints (concave boundaries and multiple discontinuous regions). A journal paper describing the lessons learned is in the draft and will be submitted in 2022.

For WP 4, three workshops were held for which proceedings are in development and will be published in 2022:

Low-wind / Low-specific power wind turbines (co-hosted by CENER/DTU and held in conjunction with an EERA workshop and the online Task annual meeting)

Reliability and load surrogates for wind farm design and operation (online co-hosted by NREL/DTU)
MBSE and MDAO – synergies for wind energy applications (online co-hosted by Aachen/DTU)

In 2021, the Task persevered despite the COVID disruptions to the normal work habits and rhythms of all participants. The annual meeting was held online across two separate days in September in conjunction with the EERA annual event. The online format succeeded in engaging 40 participants across a broad swath of geography and industry.

Highlight(s)

A constant challenge in multi-disciplinary research and technology development is the exchange of design information between and within organizations as well as between models of different disciplines and fidelity levels. A core activity in Task 37, during phases I and II, has been the development of an ontology for system modelling of wind turbines and farms. In 2021, the team is happy to report the publication finally of the technical report that serves as the core reference for the effort [1].

Figure 1 (taken from the report) illustrates the challenge when it

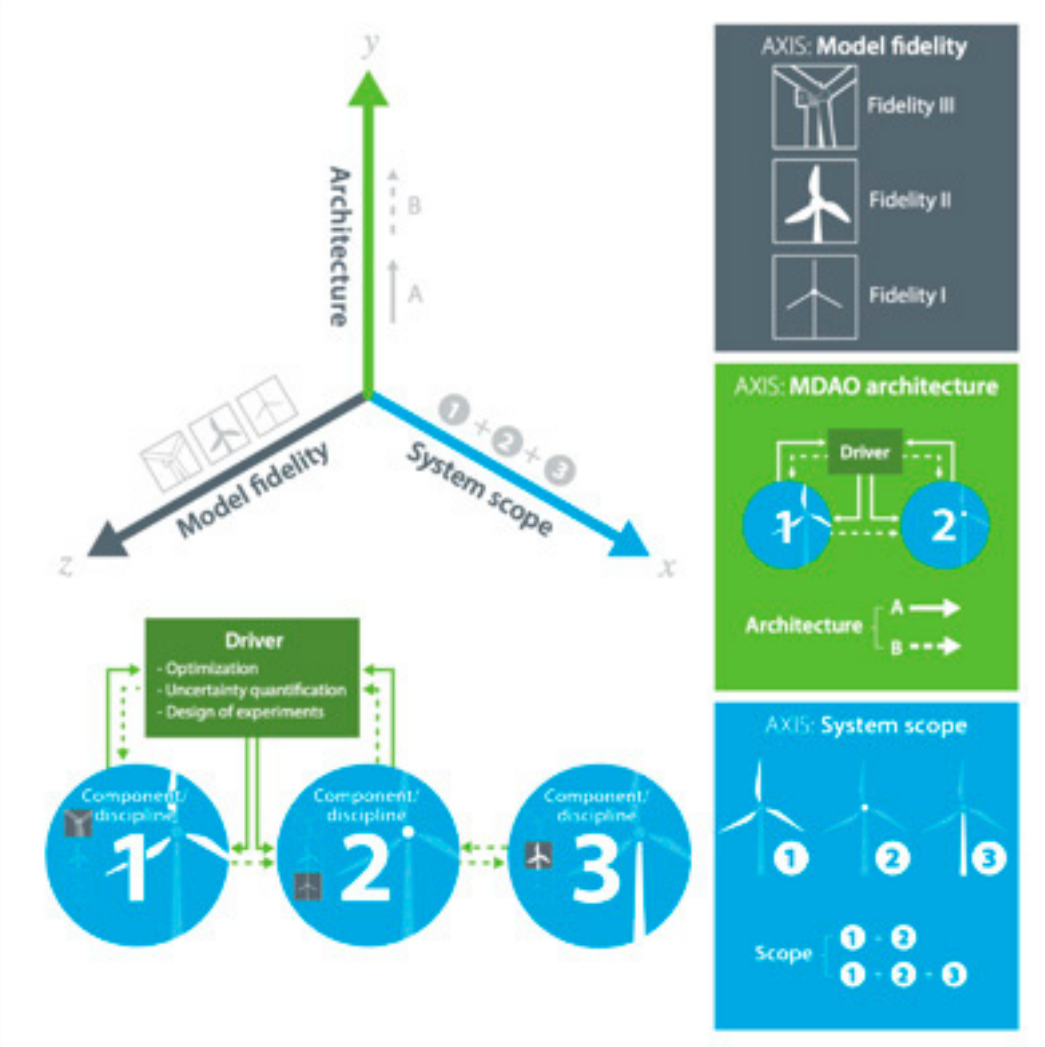

Figure 2: Dimensions of MDAO that include the system scope (disciplines), model fidelity, and workflow architecture [1]

comes to the design of complex technical systems with large scope (many components and subsystems, disciplines, etc.) and many different stakeholders involved. In the ontology, the main disciplines, and fidelities for MDAO of wind turbines and farms were first identified. Then, data formats that standardize model representations for those commonly used disciplined and fidelities were developed – adding more scope once the first discipline-fidelity ontologies were developed. Over time additional scope to translate between disciplines and across fidelities levels can be added. The ontology is now in use by several Task 37 organization members and is used to represent the reference systems developed by the Task in WP2, as well as to aid in the comparison of data collection and results from analysis for case studies in WP3. All of the ontology implementations are based on json schema in the WindIO project.

Outcomes and Significance

Task 37 participants and others are using the series of IEA Wind Task 37 reference turbines for follow-on studies ranging from novel approaches to load mitigation in wind turbine blades, new materials for wind turbine blade design, tall-tower applications for land-based technologies, code-to-code load comparison, floating wind support structure design, and more. In WP1, the ongoing work to extend the ontology to floating substructures and drivetrains has engaged a new community of users. Furthermore, the release of the ontology at the farm level and the technical report have further broadened the impact.

Next Steps

In 2022, the focus will be on continuing Phase II work including:

WP 1: Extension of plant ontology and webinars to support use and uptake.

WP 2: Publication of reference wind farm series for offshore wind and on-

going updates to reference turbines ("maintenance").

WP 3: Publication of the case studies III/IV for wind farm optimization.

WP 4: Next annual meeting and holding of the 5th Wind Energy Systems Engineering Workshop at NREL in the fall of 2022.

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