Report 2022
Task 44

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Wind Farm Flow Control

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The purpose of IEA Wind Task 44 is to coordinate international research in the field of wind farm flow control.

The Task aims to provide guidance for the wind industry and researchers concerning current control algorithms, requirements, impediments to adoption, future directions, and expected benefits of wind farm flow control.

In 2022, IEA Wind Task 44 made significant progress toward its primary objectives. The team created a database of research results to disseminate research hosted on the Task 44 Wiki (https://ieawindtask44.tudelft.nl/). In addition, a series of lectures on wind farm control was organised and archived on the Task's YouTube channel (https://www.youtube.com/@ieawindtask44talks21/). Furthermore, two critical journal articles describing best practices in uncertainty quantification for wind farm flow control and wind farm flow control field validation have been put in motion. Work package participants met regularly throughout 2022. Notably, an in-person meeting was held in coordination with The Science of Making Torque from Wind Conference.

Introduction

Wind farm control is an active and growing field of research in which the control actions of individual turbines in a wind farm are coordinated to minimise wake interactions. These interactions are significant as each wind turbine produces a wake downstream. A wind turbine in the wake of another turbine experiences a wind field with a lower average wind speed and a higher turbulence intensity, causing significant power loss compared to turbines without wake interaction.

Task 44, Flow Farm Control, is dedicated to coordinating international research in this field and it can increase energy production in existing wind farms by reducing wake losses and encouraging energy entrainment into the farm. This has the benefits of optimising the layout and maximising the cost-effectiveness of new wind farms when incorporated into the design process. Additionally, it aims to optimise existing wind turbine control strategies, such as maintaining alignment to the flow.

The goal of Task 44 is to provide guidance for the wind energy industry and researchers on current control algorithms, requirements, impediments to adoption, future directions, and expected benefits of wind farm flow control.

The project is divided into the following four work packages (WPs):

- Work Package 1: Collection of Research Results, the State-of-the-Art, and Expert Consensus.
- Work Package 2: Uncertainty Quantification.
- Work Package 3: Overview of Control Technology and Algorithms.
- Work Package 4: Outreach and Collaboration with other Ongoing Wind Farm Control Research and Development Activities.

Table 1. Countries Participating in IEA Wind Task 44.

	COUNTRY/SPONSOR	INSTITUTION(S)
1	**United States**	National Renewable Energy Laboratory, Sandia National Laboratories, General Electric
2	**United Kingdom**	Strathclyde, DNV, ORE Catapult, Durham University
3	**Spain**	National Renewable Energy Centre, Naturgy
4	**Finland**	VTT
5	**Ireland**	Technical University Dublin, Trinity College
6	**Denmark**	Technical University of Denmark, Aarhus University, Aalborg University, DNV, Vestas, SGRE, Ørsted, Vattenfall
7	**Germany**	Technical University of Munich, Forwind, University of Oldenburg, Innogy, RWE, Stuttgart University, Flesburg University, Fraunhoffer
8	**Norway**	SINTEF, Equinor, Norwegian University of Science and Technology
9	**Japan**	New Energy and Industrial Technology Development Organization
10	**Netherlands**	Delft University of Technology, Shell

Progress and Achievements

IEA Wind Task 44 made important progress in 2022:

WP1
First, the database of research results (Figure 3) and nomenclature references were each successfully launched in 2022. The database will include the latest research results in wind farm flow control and is organised and cross-referenced by control type, details of validation campaigns, and other metrics.

The online speaker series continued, and a YouTube channel of the recorded talks is now available in association with the Task. These talks present the latest research findings from world-leading wind farm flow control researchers.

A new expert elicitation was conducted, with the article currently in development. Additionally, the WP1 team met regularly throughout 2022, for example, at an in-person general meeting in Delft, Netherlands, prior to the TORQUE conference and a research mini-symposium, which occurred at the Wind Energy Science Conference (WESC) in 2023.

WP2
Seven virtual meetings were held in 2022, in which participants refined the work package scope and coordinated activities. Invited presentations were hosted during two of the meetings. Accomplishments include:

- Creating a new literature review database**.** To prepare for establishing best practices, the work package contributed to the following on the Task 44 Wiki:

  *Database of field validation experiments (created in WP1).

  *Sources of uncertainty for forward UQ for wind farm control.

  *Model calibration and inverse UQ methods for wind farm control.

- Conducting invited presentations, such as:

  *Wind farm as a sensor: Improving FLORIS predictions by simultaneous tuning and learning with operational data, by Robert Braunbehrens, Technical University of Munich.

  *Results from a wake steering experiment at a commercial wind plant, by Eric Simley, National Renewable Energy Laboratory (NREL).

- Identifying best practice publications**.** The work package team decided to prioritise review and best practices journal articles on "Forward Uncertainty Quantification for Wind Farm Flow Control" and "Wind Farm Flow Control Field Validation." The publications will combine a review of previously published methods, recommendations by the Task 44 authors, and demonstrations of the recommended methods using open wind farm control data sets (e.g., the SMARTEOLE data set).

WP4
The team established a project catalogue on the Task Wiki page, a continuously growing database of finalised, ongoing, and newly started wind farm control activities in academia and industry. It is divided into five main categories:

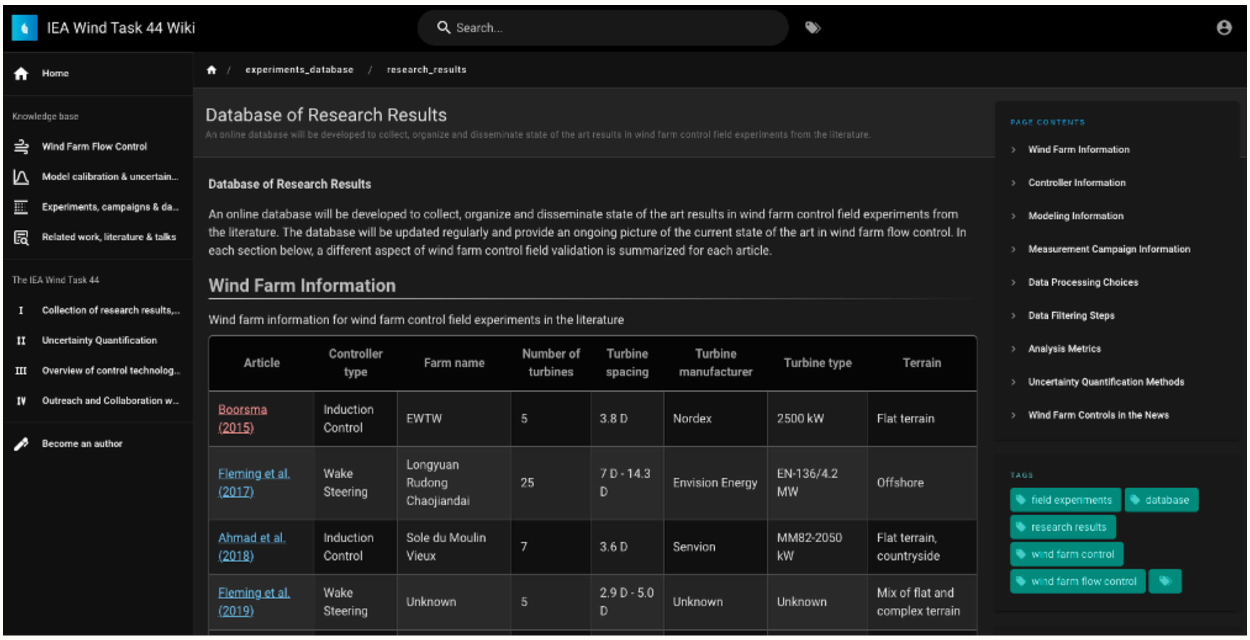

Figure 3. IEA Wind Task 44 database of research results.

1. Other IEA Wind Tasks of relevance (e.g., Task 37 System Engineering, Task 43 Digitalisation).

2. Relevant European-Union-funded projects (e.g., CL-Windcon, FarmConners).

3. Relevant nationally funded projects (e.g., SMARTEOLE).

4. Other national and international activities of relevance (e.g., Joint industry projects, American WAKE ExperimeNt [AWAKEN]).

5. Commercial activities/products (e.g., Siemens Gamesa's Wake-Adapt).

The work package team also hosted a workshop providing an overview of WFFC activities, which can be watched here. The following invited speakers presented their work:

- Michael Howland, Massachusetts Institute of Technology Civil and Environmental Engineering, "Collective Wind Farm Operation Based on a Predictive Model Increases Utility-Scale Energy Production."

- Thomas Duc, ENGIE Green, "Overview of Wind Farm Control Field Test Results Obtained in the Scope of SMARTEOLE project."

- Irene Eguinoa Erdozain, National Renewable Energy Centre (CENER), "Highlights of CL-Windcon: Closed-Loop Wind Farm Control."

- Tuhfe Göçmen, Technical University of Denmark, "Wind and Energy Systems - Highlights of FarmConners."

Highlight(s)

In 2022, the team:

- Successfully launched an online database of research results.

- Developed an online speaker series sharing current research results from top research institutions (The talks can be viewed via IEA Wind Task 44's YouTube channel at https://www.youtube.com/@ieawind-task44talks21/)

- Organised a symposium with four sessions at one of the major international research conferences (WESC 2023).

Outcomes and Significance

IEA Wind Task 44 brings together the international research community in wind farm flow control via regular meetings and discussions. Through coordination with external projects, it acts as a central hub for knowledge and information in the field. The online database will serve as a public knowledge centre of current findings and the latest research results. The team will identify best practices in implementing wind farm flow control through discussion and coordination and disseminate this knowledge through presentations, database updates and partner meetings.

Next Steps

In 2023, there is a general meeting for the IEA Wind Task 44 held in conjunction with WESC, as well as a mini-symposium of research results. The database of research results will continue to be developed actively, and so will the online speaker series.

The following two papers are currently under preparation in WP2 and are expected to be submitted in 2023:

- "Review and Best Practices for Forward Uncertainty Quantification for Wind Farm Flow Control."

- "Review and Best Practices for Wind Farm Flow Control Field Validation."

In the fall of Fiscal Year 2023, the WP4 team will organise online presentations of newly granted projects.

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WIND FARM
FLOW CONTROL
IEA Wind Task 44

Figure 1. Task 44 Logo

Figure 2. Under dedicated meteorological conditions, the wakes are visible within a wind energy farm. Photo taken on 12 February 2008 at the offshore Horns Rev 1 wind farm, which has a minimum spacing of 7.5 rotor diameters. *Graphic courtesy of Vattenfall.*