Report 2021

Task 47

Inauguration of TIADE turbine, one of the aerodynamic measurement test facilities.

Social Science of Wind Energy Acceptance (SoSWEA)

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In 2021 the IEA Task 47 TURBINIA (TURBulent INflow Innovative Aerodynamics) started for a period of 4 years.

THE TASK AIMS to cooperate in the field of high-quality, detailed aerodynamic measurements for MW scale turbines in the atmospheric flow. Such measurements are extremely difficult to do, and the only public example until now is the Danish DanAero experiment, which was used in the final phase of IEA Task 29.

Recently several other countries initiated new experiments for turbines up to a scale of 8MW, and they now all have to go through a similar learning process on these new measurement techniques. Sharing experiences is then a very fruitful way to steepen the learning curves.

Moreover, a sound scientific approach requires a cross fertilization between

Table 1. Task 47 Participants in 2021

	MEMBER/SPONSOR	PARTICIPATING ORGANIZATIONS
1	**Denmark**	Technical University of Denmark (DTU), Siemens- Gamesa Renewable Energy
2	**France**	ECN, ONERA, IFP Energies Nouvelles
3	**Germany**	Forwind/Fraunhofer IWES, University of Stuttgart (IAG), Kiel University of Applied Sciences, WINDnovation, German Aerospace Center DLR, Enercon, UAS Emden/Leer
4	**Italy**	CNR-INM, PoliMi, University of Rome "La Sapienza" University of Rome "Roma Tre" - University of Florence, Politecnico di Bari
5	**Netherlands**	Netherlands Organisation for Applied Scientific Research (TNO), CWI, Delft University of Technology, Suzlon Blade Technology (SBT), Det Norske Veritas (DNV), LM, University of Twente,
6	**Sweden**	Uppsala University Campus Gotland
7	**Switzerland**	Eastern Switzerland University of Applied Sciences (OST)
8	**United States**	National Renewable Energy Laboratory (NREL)

measurements and theory where experiments feed theory and vice versa. Therefore, the new (and existing) aerodynamic measures are analysed and simulated by a large group of research institutes and industries.

In parallel, simulations are carried out on a 15 MW Reference Wind Turbine as designed in IEA Task 37.

In 2021, the Task has started with designing experiments and the organization of workshops around on several subjects which are relevant for detailed aerodynamic measurements. First data are collected already. Moreover, several calculational cases have been defined and started.

Introduction

The best strategy to improve aerodynamic knowledge is to perform experiments that are specifically devoted to the measurement of aerodynamic blade properties. To that it should be realised that conventional wind turbine measurements of, e.g. power and blade root bending moment lack sufficient detail, so that very special rotor aerodynamic experiments are needed (often denoted as detailed aerodynamic experiments). In these detailed aerodynamic experiments, pressure distributions at different locations along the rotor blades are measured anyhow where measurements of, e.g. local blade inflow and boundary layer properties are very nice to know.

Such measurements are in particular needed for multi-MW scale turbines due to the fact that the aerodynamic modelling challenges increase with the size of the wind turbines. At the same time, such measurements are very specialized and difficult to do, and the only public example on the MW scale until now is the Danish DanAero experiment that was used in the final phase of IEA Task 29.

Recently, several other countries initiated new experiments for turbines up to a scale of 8 MW, and they now all have to go through a similar learning process on how to do these aerodynamic measurements; for this reason a new Task is defined TURBINIA: TURBulent INflow Innovative Aerodynamics. The first aim of TURBINIA is to share experiences on these measurement techniques so that the learning curves can be steepened. Moreover, a sound scientific approach requires a cross fertilization between measurements and theory where experiments feed theory and vice versa. Therefore, the DanAero experiment (and possibly other experiments) are used as validation material for many design codes based on a large variety of different aerodynamic models. In parallel, simulations are carried out on a 15-MW Reference Wind Turbine as designed in IEA Task 37. From these simulations, aerodynamic knowledge gaps for the design of 15-MW scale turbines are identified. The synergy between experiments and theory will enhance the aerodynamic knowledge level, which eventually leads to better aerodynamic design models and more competitive designs for 15-MW wind turbines.

Progress and Achievements

In 2021 several countries starting to define detailed aerodynamic measurement programs and several new aerodynamic measurement technologies are developed and applied, e.g. MEMS based pressure sensors, fibre optic pressure sensors and pressure belts and some first data are collected already.

Pressure distributions around a blade section of a 3.6-MW turbine at different wind speeds from the TIADE experiment

The cooperation in Turbinia on this specialized field of aerodynamic measurements is facilitated by the WeDoWind collaboration and knowledge sharing platform developed by the Eastern Switzerland University of Applied Sciences (OST). With this platform it is possible to share knowledge, data and code on issues related to aerodynamic measurements and simulations. Thereto several "discussion challenges" have been defined which are considered relevant subjects for further discussions in Task 47. Examples of challenges are: How to find the angle of attack in aerodynamic field experiments, how to compare (turbulent) simulations and measurements, how to do standstill measurements etc. Moderated workshops are organized for each challenge. These workshops are recorded and documented in a structured way on the WeDoWind platform so that they can form reference material for future users.

Moreover a calculational case is defined around the DanAero experiment where the comparison is done on the basis of time series. It should be noted that a 'conventional' comparison of statistical properties depends heavily on the random seed which is needed for the turbulent wind field generation. A comparison based on a time series basis is, however, very challenging since the timing of results from lifting line codes, CFD codes, and measurements all need to be synchronized. In 2021, some first steps were made where turbulent winds are generated and prescribed based on measurements at the meteorological mast.

Moreover, a first preparatory case is defined for the IEA 15-MW Reference Wind Turbine, which aims to check the correct aerodynamic and aero-elastic input so that trivial input errors are eliminated in the follow-up calculational rounds. Thereto, aerodynamic simulations are carried out under relatively simple conditions, with uniform steady inflow. The activities on the 15-MW Reference Wind Turbine are coordinated with IEA Task 37.

Highlights

The figure below shows pressure distributions around a blade section at different wind speeds as measured on a 3.6 MW turbine.

Such detailed aerodynamic measurements on an MW scale turbine are extremely rare.

Outcomes and Significance

The most important outcomes include:

- Innovative aerodynamic measurement technologies applied to large scale wind turbines
- Best practices on how to do detailed aerodynamic measurements that are currently being carried out at several places around the globe.
- Documented databases of detailed aerodynamic measurements on various wind turbines
- Improved and validated aerodynamic (and related aero-elastic) models to design large scale wind turbines (up to 15 MW). Model improvements include (but are not limited to):
  - Aerodynamics at turbulent and non-homogeneous inflow, including wakes, yaw and veer for large scale wind turbines
  - Boundary layer transition for large scale wind turbines in turbulent inflow
  - 3D effects for large scale wind turbines
- Dissemination of the generated wind turbine aerodynamic knowledge through publications, presentations, and other activities where the Wind Energy Human Capital Agenda is supported by employing many students and Ph.D.'s in TURBINIA. These students will find positions in the wind industry after graduation. In this way, they spread the Task 47 knowledge in the industry.

Next Steps

The next steps include more detailed aerodynamic measurements on several facilities. Moreover, calculations of several design codes are compared with measurements on the DanAero turbine on a time series basis. In addition, a mutual comparison of calculations from a large variety of codes will be carried out on the 15-MW turbine.

References

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