EARS4WindEnergy

Ensemble-based Approach utilizing a Refined SODAR for Wind Energy Applications

Review and resulting Applications from the EARS4WindEnergy Project – EU Eurostar III Program -

The Aim

The aim of the project EARS4Windenergy – Ensemble-based Approach utilizing a Refined SODAR for Wind Energy Applications – was to:

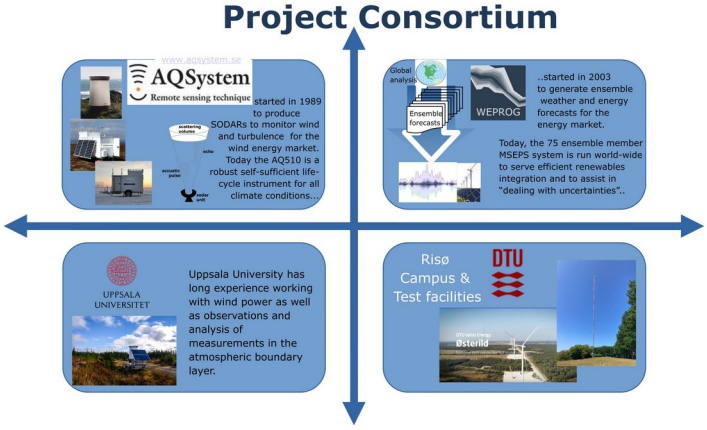
(1) provide the wind industry with new products for the accurate quantification of pre-construction wind conditions

(2) enable major productivity improvements in existing wind farms regarding operation and maintenance, the integration of wind power into the electric grid, trading and balancing of wind power.

The plan foresees through a new partnership between a manufacturer of ground-based remote sensing instruments and another SME which supplying ensemble-based meteorological simulations and the support of two universities, to be able to invent, innovate and validate these new developments for their purpose in real-world applications.

The necessity of dedicated research and development on this topic springs out of an urgent need to find a replacement for the expensive meteorological towers, which are traditionally used to determine the relevant wind conditions for both wind farm operations and wind turbine siting. Apart from the cost, the permit process for installing meteorological masts usually involve long waiting times and delays the time-to-market for new wind projects. The combination of a measurement height up to 300m, unit mobility, cost, durability and immunity to environmental conditions makes the product we want to develop ideal for the transition. Turbulence measurements and data availability, covered in this project, are the remaining barriers.

Project Consortium



Impact

The project created impact in three areas:

1. Advancements in Remote Sensing

Precision in Turbulence Measurement: Enhanced algorithms will provide accurate turbulence assessments, critical for turbine safety and efficiency. Precipitation Detection: Improved capabilities to measure hail and precipitation intensity will aid in assessing potential erosion risks to turbine blades.

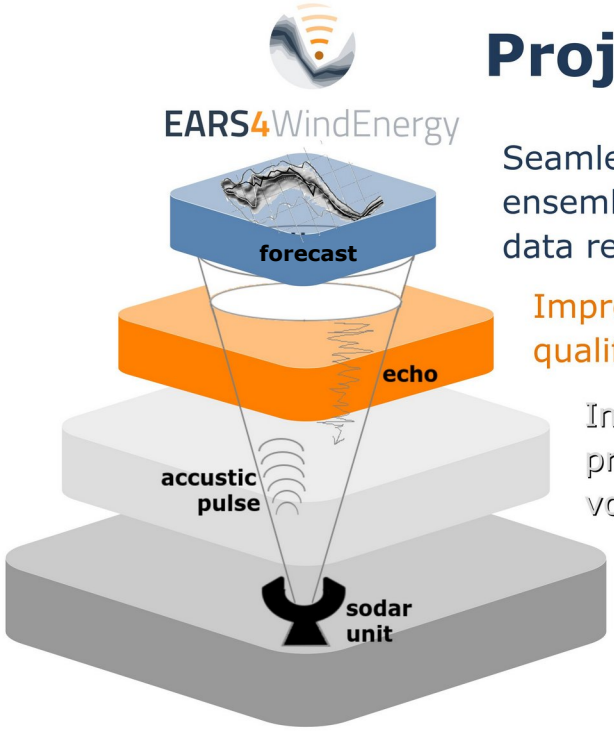
2. Enhanced Local Forecasting

Local Calibration and Precision: The integration of on-site SODAR data into WEPROG's forecasts will refine local weather predictions, ensuring operators can anticipate wind events accurately. Reduction of Bias in Datasets: By integrating high-reliability data for full yearly cycles, the risk of biased datasets in wind farm siting will be minimized.

3. Strengthened Research Collaboration

Innovative Data Treatment: Uppsala University's methodologies will enhance the accuracy of measurements, while DTU's validation processes will reinforce trust in the SODAR technology, solidifying its industry application

Project Goals



Seamless hybrid products for SODAR and ensemble forecast data for improved measurement data reliability & forecasting processes

Improved signal processing of SODAR to qualify as life-cycle instrument for wind farms

Improved Ensemble Forecasts, assimilation, presentation & accessibility of large data volumes

Improved experimental procedures and processes for efficient product development

Figure: High-level overview of the project goals

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Challenge

The project has brought already mature technologies together. AQ-systems and WEPROG have been serving different wind energy markets with unique solutions and specific benefits. The idea to merge the technologies came from DTU-Risø and University of Uppsala and their knowledge as research institution of both companies and their unique area of expertise.

At the end of the project, both, AQ-systems and WEPROG will remain active coompetitors in their respective markets – nevertheless, the project developments and demonstrations have brought the partners in a position, where a combined solution can deliver a solution as soon as there is an "EARS" related business opportunity. The ambitious deliverables of the project have led to a close collaboration and a good understanding of the challenges in each market.

We need to admit that some of the demonstrations of the project developed to test bed environments due to abnormal and extreme weather. The WINSENT demonstration in Germany was such an example, where neither the AQ510 SODAR nor the MSEPS performed as expected. The original objective was to produce a pure gap-fill application for 10-minute time resolution, but the demonstrations revealed that the weather at wind power relevant sites is extremely variable and causes significant uncertainty in the range 150-300m above ground. There are also important weather changes below the 10-minute time scale.

The natural step – and a requirement for the certification in Ireland – was to step up to a 1-minute resolution, which implies only 11 vertical scans per minute of the AQ510 SODAR. The means increased risk of both realistic and unrealistic extreme values. Gap-filling had no longer a single objective, but required an additional quality control prior to gap-filling on minute scale. The result has become an Ensemble-based integrated Analysis of Remote Sensing data, which we refer to as the EARS-Approach..

Solutions

The following items outline the solutions we have developed in the form of new applications that we call "the EARS-Approach"

Project Output 1 — **EARS-Approach**. We developed the Ensemble-based integrated Analysis of Remote Sensing data and validated it using the AQ510 SODAR and the MSEPS ensemble data from five demonstration sites. It performs a meteorologically consistent analysis of the raw minute-scale data from the SODAR and the MSEPS ensemble. The out put is a complete time series of the wind profile in 5m vertical resolution in minute-scale of very high accuracy.

Project Output 2 — **Early detection of extreme events.** The EARS-Approach led to an important warning of a critical event. An event, a nacelle anemometer is unlikely to detect before it is too late, even though it is a critical event for the wind farm.

Project Output 3 — **Wind Turbine Control Alternative**. Nacelle measured wind is an estimate around a single height above ground, whereas the SODAR provides a wind profile and covers the entire swept area of wind turbines. We have demonstrated in this project that the EARS-Approach provides a serious wind turbine control alternative to state-of-the-art.

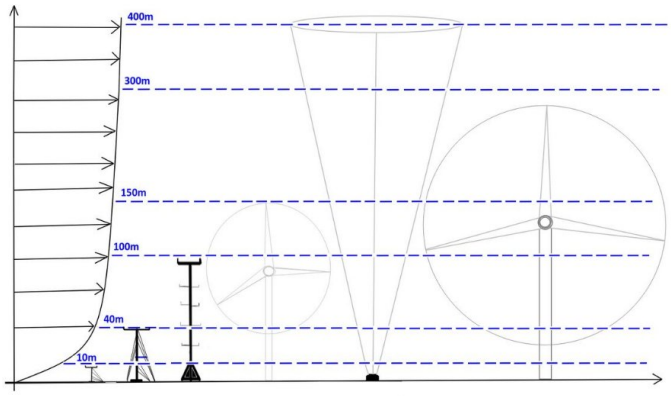


Figure: Development of wind turbines and measurement equipment requirements

Project Output 4 — **Forecast Reliability for increased peak wind power feed-in**. The reliability of wind speed forecasts above 15m/s cannot be increased to a satisfactory level without onsite wind speed measurements and a forecasting system that can make use of such measurements. The EARS-Approach can deliver the required additional accuracy needed to increase the peak wind penetration.

Project Output 5 — **Skill-score Framework with dynamic phase-error tolerance**. The developed dynamic phase-error tolerance tests within a skill-score framework procedure is valuable for (1) verification, critical for (2) quantifying improvements over the low-resolution forecast and for (3) identifying which features – captured only at higher resolution —- contribute meaningfully to the specific prediction task.

Project Output 6 — **Enhanced cross-correlation-based Gap-filling.** Combined with quality control via WEPROG's ensemble forecast it is possible to

(1) produce significantly more reliable wind speeds inclusive a quality measure of each reported value
(2) produce consistent multi-year time series based on a few months of onsite measurements, and
(3) the enhanced cross-correlated (EnKF) gap-filled time series are 4-5 times more accurate than the substitution with native NWP forecast values.



Figure: Map of the project's demonstration sites in different climates and topography

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