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NEWSLETTER

Understanding of the Physics of Wind Turbine and Rotor Dynamics through an Integrated Simulation Framework

UPWARDS

A Horizon 2020 project funded by the European Union

UPWARDS project aims to make the development of bigger and better designed wind turbines possible, thus increasing the capacity of societies all over Europe and the rest of the world to harness wind-energy.

UPWARDS gathers a consortium of 11 partners (companies, research institutes and universities) across 8 countries and 2 continents.

UPWARDS is an European Commission (EC) backed project that promises to make achieving ambitious sustainability goals a reality.

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Our last results

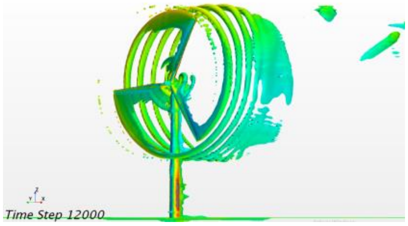
WP2 - Atmospheric model

The wake from the wind turbines affects power, structural response and noise propagation. **In UPWARDS, we have been developing wind turbine models based on actuator line approach.** Using these high-fidelity wind turbine models, we have performed simulation of Hog-Jæren park, Lillegrund park and UPWARDS 15MW wind turbine park. Here are the results you can get from these simulations :

- **OpenFoam case files of the Hog-Jæren and Lillgrund park.** This will be useful for researchers who want to analyse their park model with Hog-Jæren and Lillgrund.
- **OpenFoam wind turbine model of UPWARDS 15MW.**
- **Park simulations data mainly power, thrust, and other data.** These results will be useful for the researchers who wants to benchmark their approach.

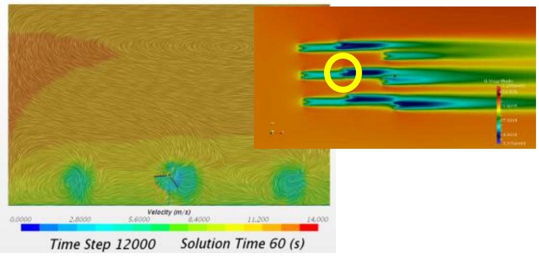
WP3 - Wind – Structure – Mechanisms - Control Interactions

In WP3, the usability of our simulations tools has been demonstrated. Simcenter Samcef with BEM elements for real time simulations and Simcenter STAR-CCM+/Samcef Mecano coupling for high fidelity simulations is now used to simulate the dynamic behavior of very large wind turbine in various wind conditions. This allow considering wind turbine in their global environment.

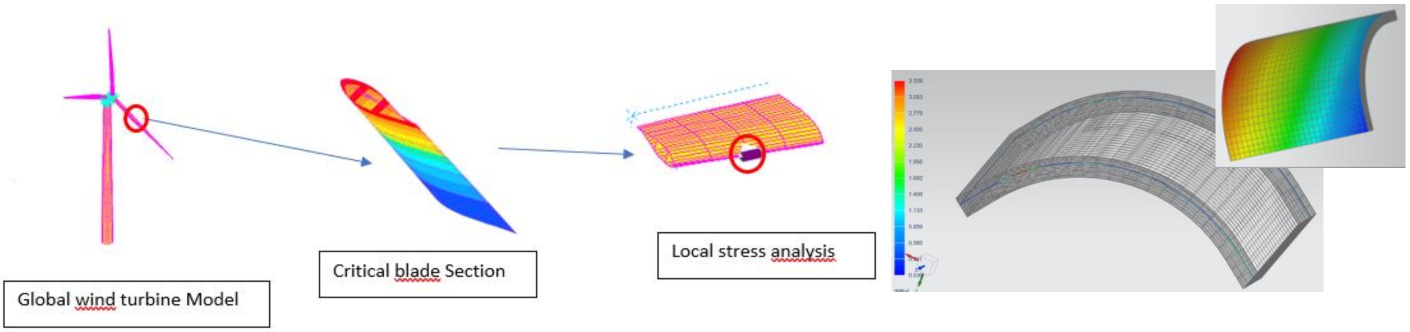


Several features have been developed and added :

- BNREL tool to generate WT mechanical models
- Procedures to make detailed stress analysis w/composite damage in connection to FSI analysis.
- Wind input coming from simulation of a WT park.



From those high fidelity models of the whole turbine, we can extract loads for very detailed damage simulation at composite level and so assess the life duration of the turbine. The whole being integrated in Upwards simulation framework.



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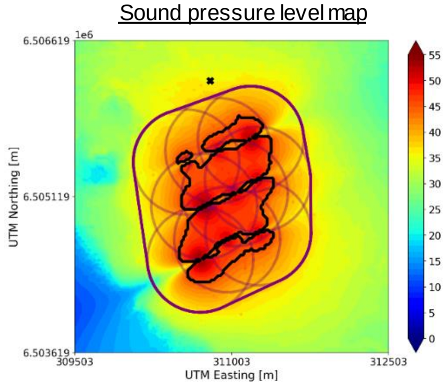
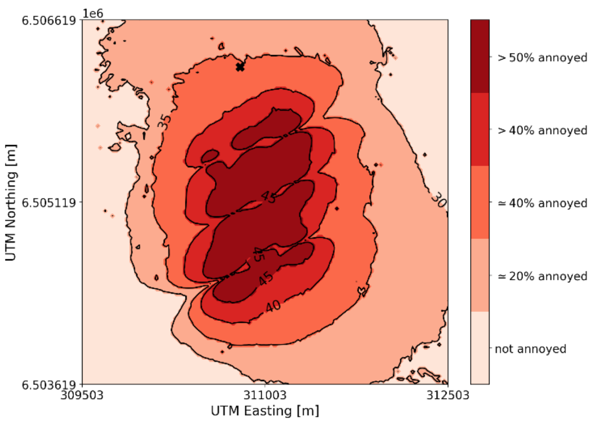
Sound pressure level map



WP4 - Flow and acoustic simulations

During the UPWARDS project, **Siemens Industry Software and the von Karman Institute for Fluid Dynamics developed a methodology in order to predict the noise footprint of wind farms** accounting for realistic atmospheric flow conditions.

An application of the noise methodology has been shown for a subset of 9 wind turbines of the Høgjaeren wind park in Norway. The noise computation takes as input the weather reforecast simulation of the 30th Dec., 2017 and the park simulation accounting for the wind turbines interactions. As an output, the overall sound pressure level map is provided on a listener grid around the wind farm overlayed with the set-back distance (circles around wind turbines) and noise threshold (black iso-contour) defining the noise regulations in Norway. Working together with Wageningen University, corresponding annoyance maps are computed showing the percentage of people likely to be annoyed by the wind turbine noise. The available noise methodology can be used to optimize the wind turbine layout and individual wind turbine operational parameters in order to minimize the noise footprint.

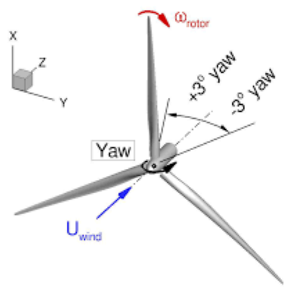


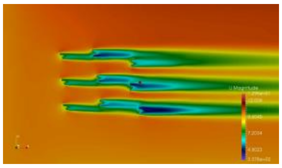
Annoyance map

WP6 - Integrated System Simulation and Knowledge Extraction

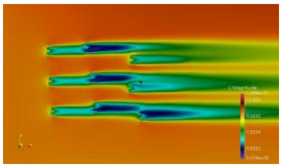
The last work done **for WP6 focused on improving some parameters by controlling the yaw at the level of a whole wind farm.** It has been shown that, by changing the yaw misalignment,

- The stress on blades caused by oscillating thrust forces can reduced for turbines standing behind.
- The first row of turbines can enhance flow conditions faced by turbines standing behind.

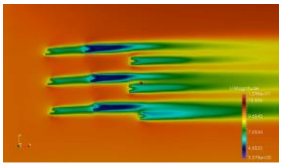




Yaw = -30

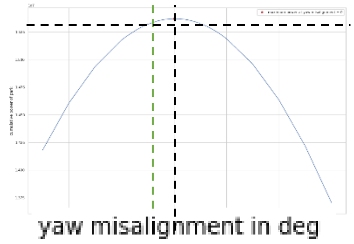


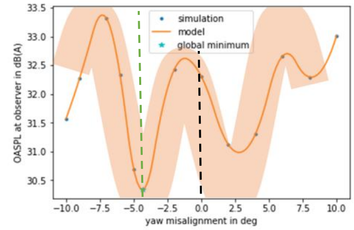
Yaw = 0



Yaw =25

- Adapting the yaw angle of the front row of turbines, noise reduction up to 3dB(A) has been obtained at a given observer position





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WP7 – D7.1 : Literature review on social and environmental issues and acceptance of wind turbines

Work package 7 worked on the social and environmental impact of wind turbines to increase acceptance. The starting point was to get a good overview of relevant social and environmental factors from the literature, including things like (financial) participation, resistance to wind turbines, bird strikes and other environmental factors.

Particularly, the deliverable D7.1 presents findings of literature review on social and environmental issues and acceptance of wind turbines in Europe as part of the UPWARDS project since opposition to wind energy developments is often framed as the main challenge and a major issue for governance. The report highlighted the fact that there are many concerns related to various topics such as societal concerns, landscape concerns or technological concerns.

See D7.1 available here: D7.1 - Literature review on social and environmental issues and acceptance of wind turbine and the open access publication: https://www.sciencedirect.com/science/article/pii/S2214629620304515

Next, the team at Wageningen University (WU) tried to match the factors from the literature to the more technical work done by other partners in the project, in order to enrich the modelling and try to integrate social and environmental factors into the simulation platform. The main factors that were included were existing government regulation and (predicted) noise annoyance.

See D7.2 available here: D7.2: Reports with data from on and offline panels

The final step was to actually execute the simulation platform and map the results and expected impacts on (noise) annoyance (see figure 1). Furthermore, analyses were done in collaboration with the Fraunhofer and Von Karman Institute to change the wind turbine configuration to reduce the amount of noise while minimising the impact on electric power production (see Figure 2 and 3) for an existing wind park in Hogjaeren (Norway).

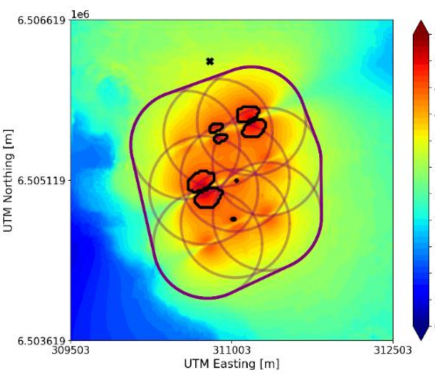

Figure 1. Colours show noise in DB and contours show the minimum distance from residential areas according to the regulations

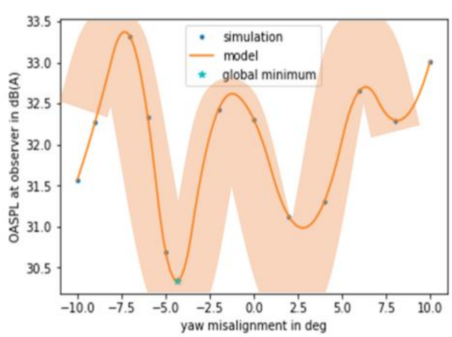

Figure 2. Graph of variation in noise (DB) as a result in changing the angle (yaw) of the wind turbine

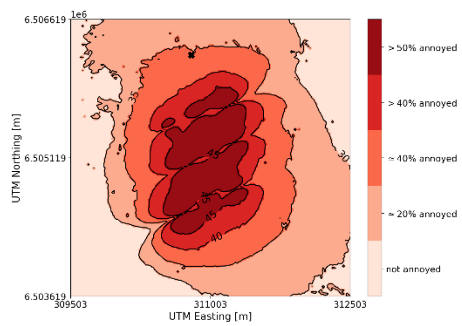

Figure 3. Map of expected annoyance

In addition, the team from WU has produced some extensive reflections on the simulation platform and the use of digital twins in environmental governance. The bottom line is that new (digital) tools and simulation platforms hold a lot of potential, but it is important to not only leave them in the realm of (technical) experts. Why? Because choices made during modelling inevitably lead to inclusion or exclusion of issues and factors, which ultimately impact people that have to live with wind turbines in their (close) surroundings.

For an extensive reflection on digital twins: https://www.sciencedirect.com/science/article/pii/S1462901121003130

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UPWARDS - a project represented in international events

- **WindEurope 2021 – Copenhagen (November) :**

UL Renewables, mainly represented by Roberto Chavez Arroyo, presented the results obtained from the Simulation of diurnal cycles in flat and complex terrain using the WRF-LES model. The main objectives here were to 1) Validate the WRF-LES (Large Eddy Simulation) model at 2 different sites and 2) Proceed to a sensitive analysis of relevant model's physics and numerical settings.

Option	Scheme, option ID
PBL Planetary Boundary Layer	Mellor-Yamada-Janjic (MYJ)
	MY-Nakanishi-Niino 2.5 (MYNN)
	Yonsei University (YSU)
SL Surface Layer	Monin-Obukhov (MO)
	MYNN
	MM5
SGS Subgrid scale	Deardorff (DEA)
	Non-linear Backscatter and Anisotropy (NBA)
Turb. Trig.*	No Perturbation (NP)
	Cell Perturbation Method (CPM)
	CPM based on PBLH (SCPM)

Option	Configuration ID		Size LES
Grid extent	Small (S): **61** points/side	**6 domains**: 9-3-1-0.3-0.1-0.037km	**2.5 x 2.5** km
	Medium (M): **111** points		**4.5 x 4.5** km
	Large (L): **241** points		**9.6 x 9.6** km
	Extra-large (XL): **241, 227, 215, 337 ,537** points/side on D1, D2, D3, D4, D5	**5 domains**: 9-3-1-0.2-0.04km	**21.5 x 21.5** km

Based on this table to carry out the sensitivity analysis, it has been found that :

- No dramatic difference found between **NBA** and **DEA SGS**. However, **DEA** provides better numerical stability.
- Domain's size, and turbulence triggering methods are key for the quality of the turbulence developed in LES. The scaling of the **SCPM** show very good skill in maintaining the adequate levels of mixing and **SGS TKE**.

- **WindEurope 2022 – Bilbao (5-7 April) :**

UL Renewables presented the results obtained from Large-Eddy Simulations of the Lillgrund wind farm with the WRF model and the Generalized Actuator Disk. The main objectives here were to 1) Verify the WRF-LES-GAD in a simplified environment, i.e., known scenario which allows us to compare it with existing wake modelling tools. 2) Demonstration case to show the usage of WRF (and HiFi models) as a wake modelling tool, its limitations, challenges and potential applications.

The conclusions from this presentation are the following :

WRF-GAD reproduced the trends of the power deficits, and compares fair with other wake models.

- It underestimates the deficits and Large uncertainty exists in the observations dataset (SCADA data processing) available.

Even in idealized mode, the model unveils complex dynamics of the interaction between ABL small scale turbulence and the turbine wakes.

- HiFi and multiscale tools doesn't intent to replace models designed for resource assessment, but rather to complement them. The design and operation of the future XL turbines and farms require many existing tools to operate outside their ranges of applicability.

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