TRAINing School on EnTRAINment in Offshore WIND Power

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D2.2 Database of Modelling Results

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Preface

This deliverable presents the preliminary assessment of the modelling results obtained in Train²Wind. It provides a background of the modelling approaches implemented per ESR project and forms the basis of the open-access, FAIR database published as the outcome of the last Train²Wind Training School on FAIR data publication (through Train²Wind community in zenodo and/or DTU data).

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Table of Contents

1. EllipSys 3D LES: Fellow DTU.1

1.1. Background

Wind turbine outputs from Large Eddy Simulations of a single wind turbine operating under three different atmospheric inflow conditions: conventional neutral boundary layer (inflow velocity approximately 8.5m/s, 5.5% turbulence intensity); stable boundary layer (inflow velocity approximately 8.6m/s, 3.3% turbulence intensity); convective boundary layer (inflow velocity approximately 8.4m/s,14.6% turbulence intensity). Total simulation length of 2 hours, data from the last 1 hour. Grid resolution of 16 cells/radius, and the turbine is modelled with an actuator disc method, using the EllipSys3D-Flex5 coupling[1] to compute turbine power and loads.

1.2. Contents of the Database

Folders are different atmospheric inflow, turbine yaw and modelling combinations: e.g., 'CNBL_AD00': conventionally neutral boundary layer inflow, actuator disc turbine modelling, 0 degrees yaw. Files uploaded are in .nc format containing the three velocity components, split into mean and fluctuating parts, over three planes. The planes are 3 diameters wide and 2.5 diameters tall, normal to the streamwise direction. Position 1 (files named pos01) is 2 diameters infront of turbine; position 2 is 2 diameters behind the turbine; position 3 is 6 diameters behind the turbine. The files also contain the mean velocity and mean turbulence intensity at hub height, rotor radius, and x,y,z coordinates of the planes relative to the turbine location. READme file contains further details including variable definitions.

Files are in .nc format and contain U0: mean inflow velocity at hub height, TI0: mean turbulence intensity at hub height, R: rotor radius, x0, y0, z0: rotor position in x,y,z dimensions, x, y, z: coordinates of the planes relative to turbine location, u, v, w: velocity components (either mean or fluctuations depending on file), t: time vector for fluctuating components.

More data, such as 10- and 30-degrees yaw for all cases, planes at every 1D downstream, and some turbine outputs, are available for all simulations. Please contact emlh@dtu.dk if you are interested in further details.

1.3. Database Link

Hodgson, Emily Louise (2023): LES of Wind Turbine in Yaw with ABL Inflows. Technical University of Denmark. Dataset. https://doi.org/10.11583/DTU.22740029.v1

[1] Hodgson, E. L., Andersen, S. J., Troldborg, N., Forsting, A. M., Mikkelsen, R. F., & Sørensen, J. N. (2021). A Quantitative Comparison of Aeroelastic Computations using Flex5 and Actuator Methods in LES. Journal of Physics - Conference Series, 1934, [012014]. https://doi.org/10.1088/1742-6596/1934/1/012014

2. Explicit Wake Parameterization (EWP) in WRF: Fellow DTU.2

2.1. Background

The modelling uses the Weather research and forecasting[2] (WRF) model using a wind farm parametrisation[3] (EWP). Two modelling approaches are used: an ideal isolated case (one specific wind direction and wind speed) and real cases (two grid spacing) that cover the simulation of a full year (2016). The simulation aimed to compare methodologies for modelling very large offshore clusters and calculate their Annual Energy Production (AEP).

2.2. Contents of the Database

The dataset contains model outputs and necessary files to replicate the simulations from the article by van der Laan et al., titled "Simulating wake losses of the Danish Energy Island wind farm cluster"[4].

To perform the simulations with WRF, input files are attached as zip files for real (modelfiles_real_*km) and ideal (modelfiles_ideal_1km) simulations. This zip file contains the namelist.input*, namelist.wps, and input_souding necessary to run the models on both modes and for the specified grid spacing (1 or 2 kilometres). For the real simulations, boundary conditions (ERA5 reanalysis) are needed and can be downloaded from ftp://ftp.ecmwf.int/pub/wrf. For ideal scenarios, the input_soundig file is the only requirement. The files EnergyO.ideal, EnergyO.real, and GEN-15-236.turbine are provided to simulate the wind farms. The cluster comprises ten wind farms with 1 GW capacity. Each wind farm is simulated with 67 15 MW wind turbines. EnergyO.ideal, EnergyO.real are the locations for the ideal and real cases, respectively, and the thrust and power curves are given in GEN-15-236.turbine.

The model's output is in NetCDF format (*.nc) and contains the wind speed ("WS") field and the power production (''POWER") generated by the wind farms. Quantities are expressed as temporal averages over 1 hour and 1 year (2016) for the ideal and real cases, respectively.

2.3. Database Link

Garcia-Santiago, Oscar M. (2023). Supporting WRF dataset for the article "Simulating wake losses of the Danish Energy Island wind farm cluster". Technical University of Denmark. Dataset. https://doi.org/10.11583/DTU.22740071

[2] https://github.com/wrf-model/WRF

[3] Volker, P. J. H., Badger, J., Hahmann, A. N., and Ott, S.: The Explicit Wake Parametrisation V1.0: a wind farm parametrisation in the mesoscale model WRF, Geosci. Model Dev., 8, 3715–3731, 2015.

[4] van der Laan MP, García-Santiago O, Sørensen NN, Troldborg N, Criado Risco J, Badger J. Simulating wake losses of the Danish Energy Island wind farm cluster. In Wake Conference 2023, 20/06/2023 - 22/06/2023, Visby, Sweden. Vol. 2505. IOP Publishing. 2023. 012015. (Journal of Physics: Conference Series; No. 1)

3. EPFL WIRE LES: Fellow EPFL.1

3.1. Background

At EPFL, the WIRE-LES code, a well-established Large-Eddy Simulation (LES) code[5,6,7], is implemented to understand the flow physics better inside and in the wake of the Rødsand II wind farm. The LES simulation of this wind farm would provide important insights to the field measurement team. Time and space-averaged results help determine the most interesting locations for taking measurements.

3.2. Contents of the Database

The modelled wind-farm case considers prevalent offshore conditions in Denmark. A conventionally neutral boundary layer (CNBL) and a weak free atmosphere stratification level fixed at Gamma=1K/km are simulated. Rødsand II consists of 90 turbines manufactured by Siemens, SWT-2.3-93 of 2.3MW with a diameter D=93m and a hub height of z_h=68.5m [4-6]. The surface roughness is set to z_0=0.001m. The flow is driven by a geostrophic wind G=9.5m/s and the Coriolis parameter is equivalent to the latitude of the Rødsand II location, which is f_c=1.185e-4rad/s. The case is initialized with a constant streamwise velocity of 9.5m/s. The inflow to the windfarm is characterized by an 8.5m/s velocity and a 7% streamwise turbulence intensity at hub height. It is worth noting that the wind direction is West.

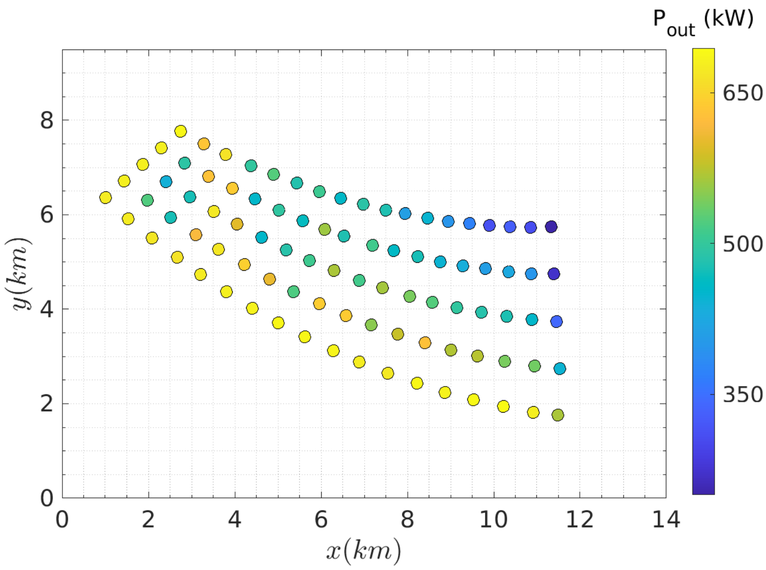

Figure 1: Rødsand II wind farm layout. The colour indicates the time-averaged power output of each turbine, which can be found in the 5x18 matrix attached (Rodsand2_avg_turb_power.mat) in the dataset.

[5] Albertson, J.D., Parlange, M.B.: Surface length scales and shear stress: Implications for land-atmosphere interaction over complex terrain. Water Resources Research 35, 2121–2132 (1999).
[6] Porté-Agel, F., Meneveau, C., Parlange, M.B.: A scale-dependent dynamic model for large-eddy simulation: application to a neutral atmospheric boundary layer. Journal of Fluid Mechanics 415(1), 261–284 (jul 2000).
[7] Wu, Y.T., Porté-Agel, F.: Large-Eddy Simulation of Wind-Turbine Wakes: Evaluation of Turbine Parametrisations. Boundary-Layer Meteorology 138, 345–366 (2011).

Within the dataset, the .nc files contain the generated instantaneous flow field data every 1.2 seconds of the CNBL case over 10mins of real-time simulation, extracted in standard NetCDF format. The data is taken at three horizontal xy-planes: the hub height, top tip and lower tip height, where 'hub, 'top' and 'bottom' are the corresponding labels for each that can be found at the end of each .nc file. The streamwise velocity component 'u' is recorded. The naming convention would be: t_ts_u_top/hub/bottom.nc

The geometry used to model the wind farm, and which is helpful to read the flow fields, is also attached as a text file where the x and y coordinates used in the LES model are listed in two columns (x/y).

3.3. Database Link

Souaiby, Marwa; Porté-Agel, Fernando (2023): Rødsand II wind-farm instantaneous LES flow field datasets and averaged power output. Technical University of Denmark. Dataset. https://doi.org/10.11583/DTU.22739831

4. EPFL WIRE Wind Tunnel: Fellow EPFL.2

4.1. Background

In EPFL WiRE boundary layer wind tunnel, a three-bladed horizontal axis wind turbine (HAWT) model with a rotor diameter of 15 cm and hub height of 12.5 cm is used for studying wakes. The rotor of the test turbine is paired with a direct current machine, which acts as the nacelle, to perform power measurements.

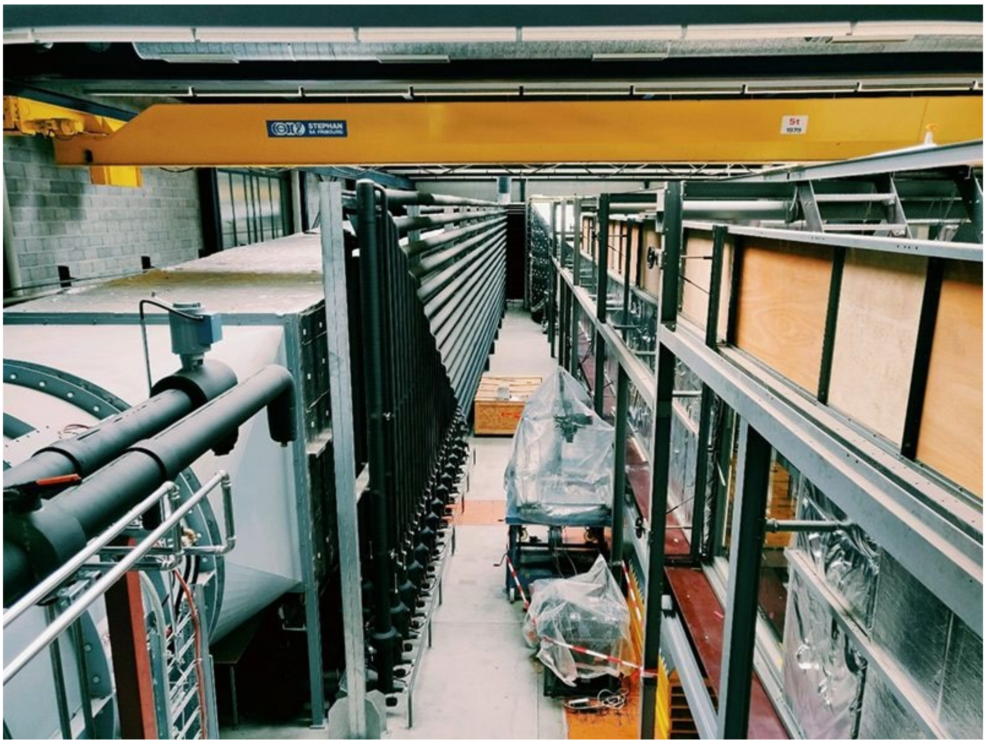

Figure 2: EPFL WiRE boundary layer wind tunnel

4.2. Contents of the Database

This dataset provides the power curve and the thrust curve data for the EPFL WiRE-01 miniature wind turbine (three-blade, horizontal-axis, developed in the WiRE Lab at EPFL Lausanne, Switzerland) immersed in a boundary layer, based on wind tunnel tests. In the data file, the first two columns give the test tip-speed ratio (TSR) and the corresponding power coefficient, respectively; and the 3rd and the 4th columns give the TSR and the corresponding thrust coefficient. The last three columns provide the dimension of the turbine rotor diameter, the turbine hub height and the inflow velocity at the hub height. The neutral inflow boundary layer has a turbulence intensity of 7% and a boundary layer height of 0.38m. Details of the turbine design can be found via Bastankhah et al.[8]

4.3. Database Link

Duan, Guiyue (2023): Power & Thrust data for the EPFL WiRE-01 miniature wind turbine. Technical University of Denmark. Dataset. https://doi.org/10.11583/DTU.22739750.v1

5. EPFL WIRE Wind Tunnel: Fellow EPFL.ra2

5.1. Contents of the Database

This dataset was created at the boundary layer wind tunnel of the WiRE Lab at EPFL (Figure 2) for the WIRE01 miniature wind turbine presented in the work of Bastankhah et al.[8] The data were collected at a constant wind tunnel fan speed of 6.5 Hz which corresponds to a 2.4 m/s free stream velocity.

A range of the tip speed rato of the miniature wind turbine was tested, leading to different power outputs of the turbine. The data include 2 types of files:

a) INFO.txt: This type of file contains an overview of the measurements for each tip speed ratio. In particular it has 8 different columns including:

(1) the file name of each of the measurements,
(2) the ambient pressure P0 (Pa),
(3) the ambient temperature T0(K),
(4) the free stream velocity U_ref(m/s),
(5) the diameter of the wind turbine D(m),
(6) the torque constant of the motor used TQ Cons(mNm/A),
(7) the sampling frequency Fs (Hz),
(8) the number of samples Ns,
(9) the yaw angle of the wind turbine,
(10) the mean rotational speed of the wind turbine (RPM), and
(11) the measured mean power (mW) corresponding to each measurement.

b) power_###.txt: This file contains the instantaneous values of each tip speed ratio. In particular each file has 4 columns:

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[8] Bastankhah, M.; Porté-Agel, F. A New Miniature Wind Turbine for Wind Tunnel Experiments. Part I: Design and Performance. Energies 2017, 10, 908. https://doi.org/10.3390/en10070908

(1) the free stream velocity (m/s),
(2) the rotational speed of the wind turbine (RPM),
(3) the current (mA),
(4) the power (mW).

5.2. Database Link

Kotsarinis, Konstantinos (2023): WIRE01_miniature_wind_turbine_power_measurement. Technical University of Denmark. Dataset. https://doi.org/10.11583/DTU.22739738