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Transfer of small scales space-time fluctuations of wind fields to wind turbines torque computation

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Wind fields are known to be extremely variable in space and time over a wide range of scales. Universal Multifractals (UM) are a common tool used to model and simulate such features. This parsimonious framework is based only on 3 parameters (α, C_1 and H) with physical interpretation, while the 4th, the power a of a conservative flux, is absorbed by the empirical estimation of the mean singularity over a non-conservative field. Obviously, in the context of wind power production, these properties are transferred to wind turbine torque and ultimately power.

Here, we investigate this transfer through modelling of wind turbine torque. For this purpose, 2 different modelling chains have been developed. The first one takes into account the spatial distribution of the wind velocities and the rotation of the blade considering an integral torque along the blades, this is in contrast with traditional approach which uses the average wind speed at hub height and blade radius to compute the torque. The second one is based on TurbSim for wind input computation, and OpenFAST for torque computation, which are tools developed by National Renewable Energy Laboratory (NREL). The main challenge is to input a space-time varying wind because, although it is possible to know the wind data at isolated points, where high resolution anemometers can be located, obtaining the wind speed in all points over a given area is rather complex. Using uniform wind fields in space creates too strong artificial correlations.

In this work, we suggest the reconstruction of wind fields from a point measurement by relying on well established scaling laws. More precisely, the wind field at any location is obtained by adding to the data at the available anemometer point, the product of a prefactor, a random UM field and distance increment raised to power av and Hv respectively. The exponents are obtained in the literature using purely dimensional arguments. Data from 2 high resolution 3D sonic anemometers located on a meteorological mast in a wind farm situated approximately 110 km south-east of Paris, with approx. 33 m vertical distance, are used to tune parameters of UM field and the prefactor according to the event. Data is collected in the framework of the RW-Turb measurement campaign (https://hmco.enpc.fr/portfolio-archive/rw-turb/); which is supported by the French National Research Agency (ANR-19-CE05-0022)

UM analysis over numerous events (more than 1-year data is available) was carried out to confirm good agreement between UM parameters retrieved on anemometer data and simulation data. A comparison between torque obtained with the traditional approach and both modelling chains using simulated fields and UM analysis of the outputs was also performed to observe the differences focusing on the small scales.