A Dynamic Wind Farm Wake Model Implemented in OpenFAST

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A very important research topic in the field of wind energy is the optimization of wind farms, in terms of layout and control system, in order to maximize the electrical power produced. In this field, models are needed in order to predict how upstream turbines influence the flow impacting downstream machines and how loads and power production are affected by this phenomenon. At present, the most accurate models used to evaluate flow characteristics in a wind farm are the ones coupling computational fluid dynamics (CFD) with an actuator line model (ALM). Despite being the approach that most closely reproduces reality, it cannot be used for control purposes on real machines as it requires extensive computational power. This is the reason why control-oriented algorithms, that make use of simplified analytical models efficient enough to run in real-time, are used to estimate the generated power and loads acting on the blades with sufficient accuracy.

Figure 1: G1 Turbine in Polimi Wind Tunnel (GVPM)

Among these models, there is the steady flow Gaussian Wake Model (GWM) proposed by Bastankhah and Portè-Agel (2014; 2016). It can be considered a state-of-the-art analytical model since it is able to capture the wake characteristics for a wide range of operating conditions as shown in the work performed by Campagnolo et al. (2019). For a long period of time, the most used tool to develop and analyze control algorithms has been NREL's FLORIS which uses pre- tabulated values of Ct – TSR in order to predict the velocity deficit and orientation of the wake. In Cioffi et al. (2020) the authors proposed a modified version of the GWM; the wake model has been coupled with the aeroservo-elastic wind turbine simulator OpenFAST.

This leads to higher accuracy because the dynamics of the wind turbine is taken into account. The purpose of the present work is to further investigate and improve this GWM model. In the first part of the work an OpenFAST model of a scaled wind turbine will be validated. Within the CL-Windcon project, a large amount of experimental data on a scaled wind turbine (the image below pictures it in GVPM), tested at the Galleria del vento Polimi (GVPM), has been gathered. Experiments have been conducted for both the single turbine case and two turbines in a row configuration. At first, the focus will be on replicating the experimental setup in OpenFAST and compare the results obtained by simulation against the experimental data. The validation will be firstly done on a single turbine working in smooth flow conditions which will be tested for different yaw angles (results of the simulations will be compared with averaged figures extracted from experimental data). Finally turbulence and more than one wind turbines will also be considered. Then, the focus will be shifted on tuning the GWM parameters implemented in OpenFAST by comparing the velocity deficit predicted by the numerical simulation with measurements of the velocity taken with hot-wire measurements downstream of G1 turbines.
Finally, the GWM implemented in OpenFAST will be changed in order to take into account the dynamics of the flow as proposed by Becker (2020). The goal is to obtain a model that is able to take into account spatially and time-wise heterogeneous field conditions, leading to a computationally cheap model that includes the dynamic effects of both the turbine and the flow.

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