High performance physical modeling and simulation

Predictive Model of Wind Turbine Helps Customer Design Effective Controller

The Challenge:

Wind power is a clean renewable energy source. As such, wind power generation represents one of the many important new green technologies that are being developed to address climate change in the 21st century.

A customer in the energy sector needs to develop predictive models of wind power generation systems. The models will be used to develop control strategies that will maintain a steady, predictable power output despite the highly variable and unpredictable changes in wind conditions. The system needs to adapt quickly to changes in wind speed and direction by changing the direction of the nacelle (the pod that contains the power generation components) and the angle of attack of the propeller blades with respect to the wind direction and speed.

A wind turbine power generation system is intrinsically multi-domain; it converts the mechanical energy of the propeller motion driven by the wind into electrical power for consumption. Among the challenges in modeling such a multi-domain system is the smooth integration between the different parts of the overall system. For instance, the wind profile, typically characterized by a table of speed and direction data measurements, needs to be applied to the dynamic model of the propeller blade through drag coefficients. In turn, the dynamic model of the mechanical component of the propeller needs to be coupled to the electric generator for power generation. Finally, a set of controllers needs to be designed and implemented to regulate the power output.

The Solution

MapleSim™, a modern, high-performance physical modeling tool, is particularly suitable for modeling a multi-domain system such as the wind turbine, where mechanical, signal blocks, controllers, and electrical components have to work smoothly side-by-side for proper operations. In MapleSim, it is straightforward to produce a mechanical model of the generator tower, propeller, nacelle, and a positional controller on the nacelle that responds to previously measured wind speed/direction data provided in an Excel® spreadsheet. The model is created by simply dragging and dropping the appropriate components into the drawing area and connecting them together.

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In this particular example, the mechanical model is designed using multibody components, with a revolute joint to represent the motion of the nacelle around the vertical axis. The direction the nacelle faces is controlled by an electric motor, connected first to a high-ratio gear, and then to the revolute joint. This control system reads the wind direction from the data file. This value is compared with the actual direction of the nacelle and the controller then applies the required voltage to the motor to align the nacelle to the wind direction. The torque applied at the blade by the wind is computed based on the wind profile data (speed and direction), as well as the relative angle between the wind direction and the propeller blade orientation. A second controller is used to regulate the propeller rotational speed by adjusting the blade pitch angle (the angle of attack). The goal is to keep the output power (proportional to the angular speed of the propeller) as steady as possible while under the influence of varying wind loading conditions.

To demonstrate how well a MapleSim model can be used to study the behavior of a wind turbine system, the result of a simulation of the system with a varying wind loading condition is shown below. From the results, it can be seen that the blade angle changes in response to changes in the wind speed and direction. This results in a relatively constant blade speed, which translates into a near-constant power output of 300kW as desired.

Because the wind turbine model is fully parameterized, it can be easily updated for different configurations and operating conditions. Furthermore, because the different components are modularized, individual component models can be adjusted easily and quickly independent of each other. Such flexibility represents enormous savings in time and cost for research and development.To demonstrate how well a MapleSim model can be used to study the behavior of a wind turbine system, the result of a simulation of the system with a varying wind loading condition is shown below. From the results, it can be seen that the blade angle changes in response to changes in the wind speed and direction. This results in a relatively constant blade speed, which translates into a near-constant power output of 300kW as desired.

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