PLECS

DEMO MODEL

Double Fed Induction Generator Wind Turbine

Last updated in PLECS 4.3.1

1 Overview

This demonstration shows a 2 MW wind power system with a doubly-fed induction generator (DFIG), where the interaction between the electrical circuit and the mechanical drivetrain during normal operation, as well as fault conditions, are investigated. The PLECS thermal and magnetic physical domains are integrated into the model as well.

Note This model contains model initialization commands that are accessible from:

PLECS Standalone: The menu **Simulation + Simulation Parameters... + Initializations**

PLECS Blockset: Right click in the **Simulink model window + Model Properties + Callbacks + InitFcn***

2 Model

2.1 Power circuit

The electrical power circuit consists of a DFIG, whose stator is directly connected to the grid via a transformer, while the rotor winding is connected via slip rings to a back-to-back converter. The grid-side of the converter is connected to the tertiary winding of the transformer, which feeds the generated power into the 10 kV medium voltage network through a 20 km long cable. The transmission line is modeled with a distributed parameter line component.

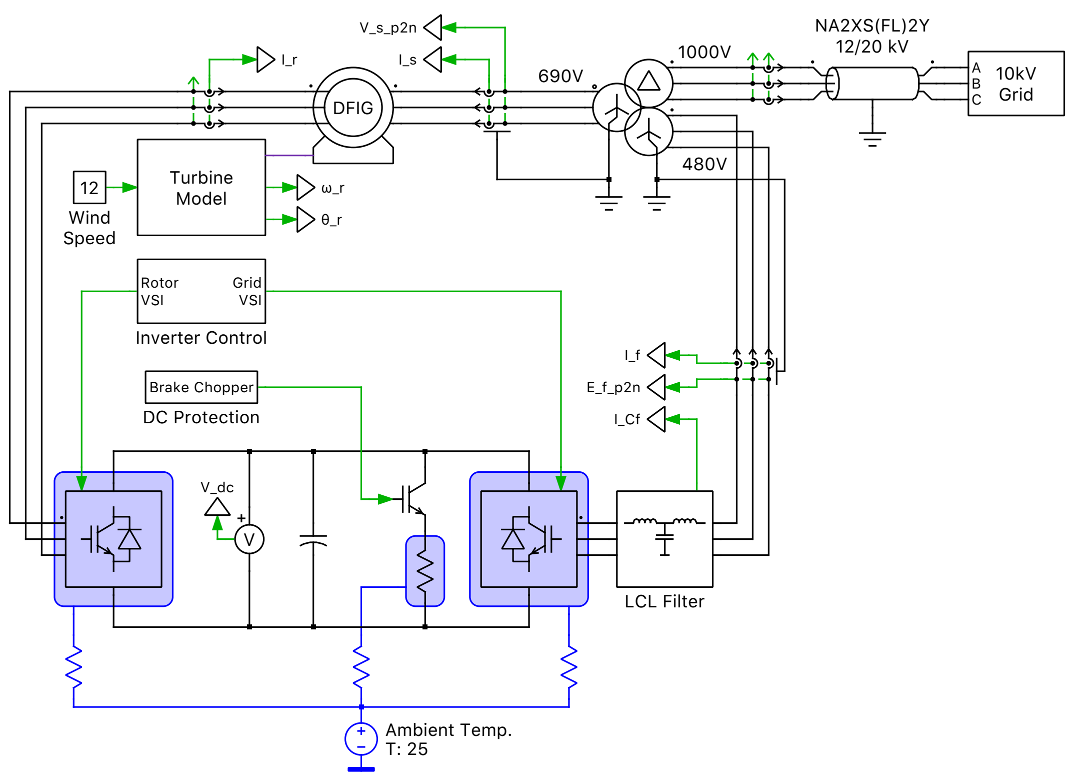

Figure 1: Power Circuit

2.2 Mechanical drivetrain

The machine's rotor, and the gearbox, hub and blades of the propeller together make up the mechanical part of the wind turbine. They are coupled elastically with each other, which introduces resonant oscillations into the system.

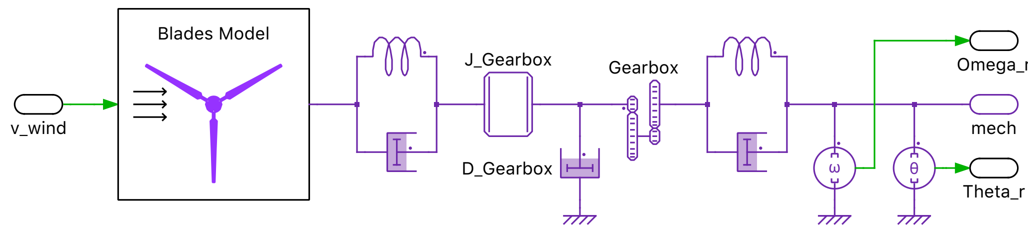

Figure 2: Mechanical drivetrain

The value of the wind torque applied on the turbine blades comes from a look-up table, where the value varies against the wind and shaft rotation speeds (transformed to the high-speed side of the gearbox).

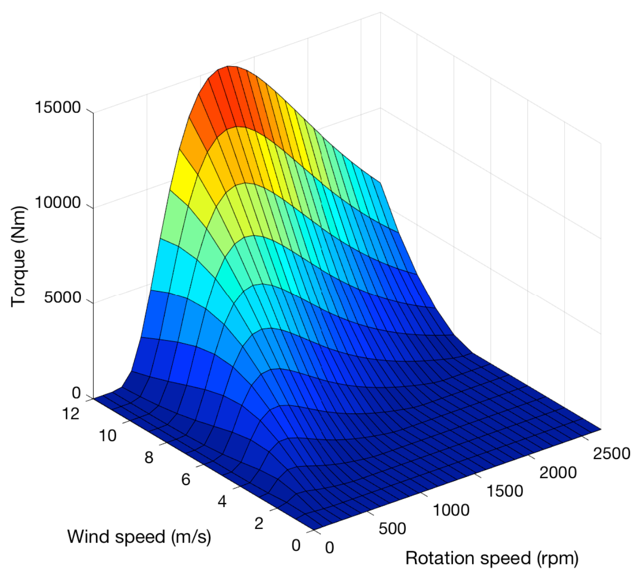

Figure 3: Wind turbine dynamics modeled as a torque surface

2.3 Magnetic transformer circuit

The three-winding transformer is built up with primitive components from the PLECS Magnetic component library. Compared to a conventional model using a purely electrical equivalent circuit, the layout of the core structure is more intuitive to understand and it is possible to model complex non-linear effects like saturation and hysteresis in the three-leg core.

2.4 Control

The back-to-back converter comprises separate machine-side and grid-side portions, which are connected with each other via a DC-link capacitor.

The machine-side converter regulates the torque of the DFIG and thus the rotational speed with a double loop structure, where the outer speed loop generates the reference signal for the inner current

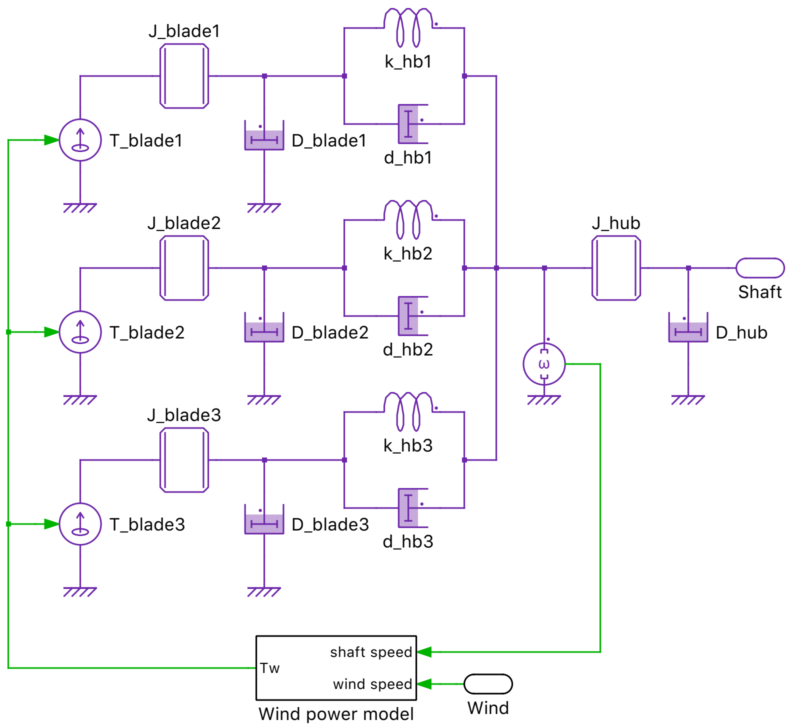

Figure 4: Mechanical model of the three turbine blades

loop. The current control is carried out in rotational framework (d-q) with stator flux orientation. In addition, the machine-side converter also regulates the reactive power injection of the DFIG.

The grid-side converter transfers the active power from the machine-side converter into the grid through an LCL filter, and maintains the DC-link voltage at 950 VDC. The methods of active damping, feed forward as well as integrator anti-windup are adopted for the PI controllers, and the converters operate using space-vector pulse-width modulation (SVPWM).

2.5 Thermal

The converter model can be simulated in either an "Averaged model" or a "Switched model with thermal" configuration. With the averaged converter model there are no harmonic components in the switching frequency present. In the switched model the conduction losses and switching losses of the IGBTs, as well as the effect of the cooling system, can be investigated. Thermal models for the "5SNA 1600N170100" and "5SND 800M170100" IGBT and anti parallel diode packages, both manufactured by ABB, are used for the machine-side and grid-side converters, respectively. Included with the look-up tables for power losses is the thermal impedance chain information from the device junction to the case, which was also supplied by the data sheets. These descriptions can be viewed and edited by double-clicking on the component and selecting **Edit...** from the drop-down menu of the **Thermal description** parameter.

The thermal descriptions for the IGBTs are stored in a private thermal library in the directory `/double_fed_induction_generator_wind_turbine_plecs`.

3 Simulation

As the simulation starts up the DFIG operates at synchronous speed. At $t = 3\,\mathrm{s}$, the speed reference signal jumps from 157 rad/s to 175 rad/s (-10% slip rate) to track the peak power output of 2 MW. Then, shortly after the system enters the new balanced state, a voltage sag occurs on the 10 kV stiff network

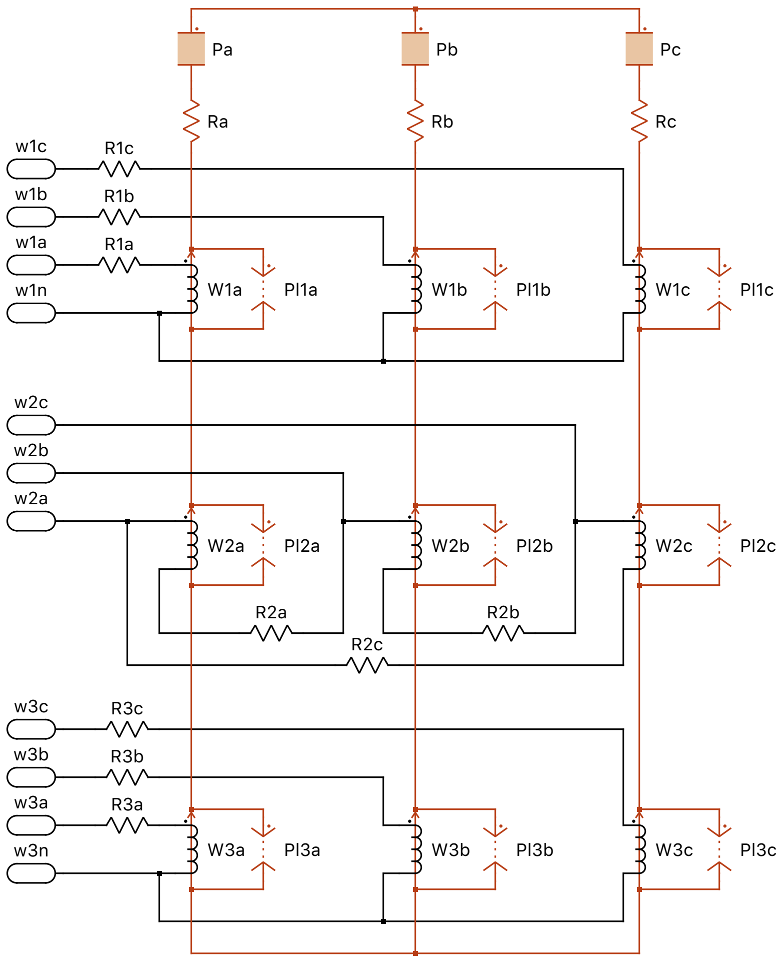

Figure 5: Magnetic circuit

at $t = 12\,\mathrm{s}$. This fault is modeled as the border line condition corresponding to the worse case scenario as defined by the Germany Grid Code of 2007. As a result of the fault, a transient with high frequency oscillation in both the electrical and mechanical systems can be observed. After the grid voltage recovers, the system returns to its steady state.

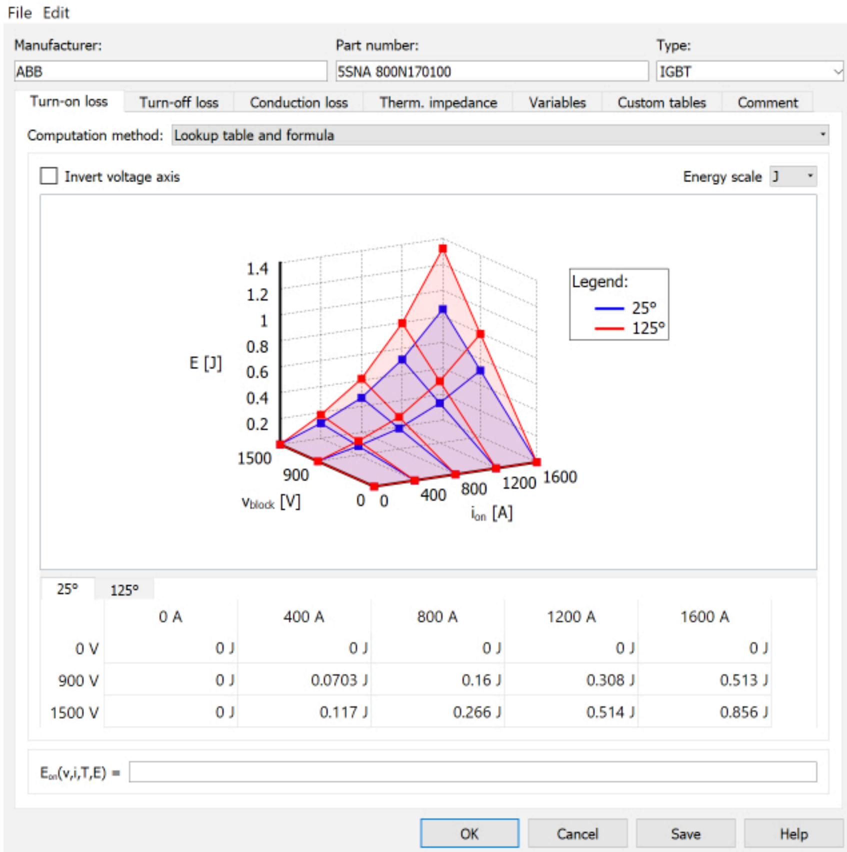

Figure 6: Thermal model for the 5SNA 1600N170100 IGBT

Revision History:

PLECS 4.3.1 First release

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