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Dynamic Modelling of Wind Turbine and Power System for Fault Ride-through Analysis

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ABSTRACT

This paper presents a Simulink model of a wind power system for the holistic analysis of wind turbine and power grid during grid faults, aiming to investigate wind turbine Fault Ride-Through performance. The model comprises a highly detailed dynamic model of a 2MW wind turbine and a generic electrical network model. The simulation result shows the behaviour of both wind turbine and power grid when grid faults occurs. The impact that a grid fault has on wind turbine components and grid transients is illustrated and discussed.

KEYWORDS

Wind turbine, DFIG, Fault Ride-Through

1 INTRODUCTION

As one of the most promising renewable energy, wind power is growing rapidly around the world. Grid Codes have been revised to cope with the high penetration level of wind power. The integration of large-scale wind turbines into power system needs to be investigated to meet the new requirements raised by power system operators. The challenge for wind power integration is focused on wind turbine Fault Ride-Through and grid support capability.

The objective of this paper is to present a detailed wind power system that allows analysing the wind turbine and power network in an integral way. The wind turbine model consists of the dynamic model and the control system of a 2 MW wind turbine. A doubly-fed induction generator model is attached to the wind turbine model because of its popularity in the wind energy industry. A generic power system model including a main system generator and a conventional power plant equipped with synchronous generator is developed to represent the electrical network dynamics.

This paper is organised as follows. First, the wind turbine model is briefly described. Then, the model of the DFIG using decoupled current-mode control is explained, followed by the

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description of the power system model. Simulations are carried out with grid faults applied and results are presented.

2 WIND TURBINE AND ITS CONTROL SYSTEM MODEL

2.1 Dynamic models

The dynamic model of a wind turbine consists of the aerodynamics and drive-train dynamics. When the wind turbine is running, the wind produces an aerodynamic torque on the rotor. The torque is

$$F_1 = \frac{1}{2} \cdot \frac{\rho \pi C_p(\lambda, \beta) R^2 v^2}{\lambda}$$

where the tip-speed ratio is $\lambda = \frac{R\Omega}{v}$, R is the rotor radius, Ω is the rotor speed, v is the effective wind speed, ρ is the air density, β is the pitch angle and Cp is the aerodynamic power coefficient. This implies the wind turbine can be controlled by regulating the rotor speed or adjusting the pitch angle.

The wind turbine drive-train is composed by rotor hub, low-speed shaft, gearbox, high-speed shaft and generator rotor. To study the interaction between the wind turbine and the power grid, the behaviour of the drive-train needs to be investigated as it is connected directly to the generator and affected by the power fluctuation in the grid. It should be noted that the drive-train of wind turbine is lightly damped therefore it is very sensitive to torque variations caused by grid faults. A two-mass drive-train model is used as a simpler model does not provide clear transients for wind turbine fault ride-through studies.

2.2 Wind turbine control system

The wind turbine is controlled by defining the relationship between the rotor speed of the wind turbine and the wind speed. The generator reaction torque is adopted to regulate the rotor speed in below-rated wind speed, while the blade pitch angle is varied to control the rotor speed in above-rated wind speed. Different controllers are used under different wind speeds. A controller switching method is implemented to guarantee the smooth switching between different control modes.

3 DFIG SYSTEM MODEL

A DFIG is basically a wound rotor induction generator coupled with the grid through power electronics. The DFIG controller developed in [3] is adopted. The generator torque and reactive power generation are controlled by d and q axis rotor currents respectively.

4 GENERIC NETWORK MODEL

The generic network model presented in [2] is used to represent the dynamics of the power system. The layout of the system is shown in Figure 1

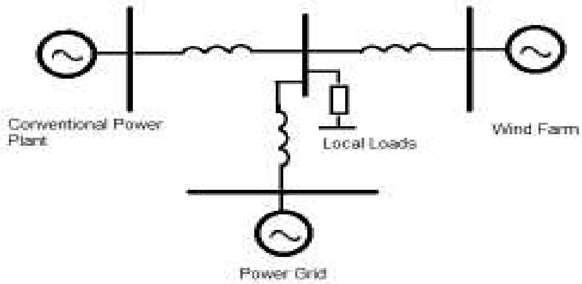

Figure 1: Generic network

The wind farm is represented by a DFIG wind turbine. The conventional power plant uses a synchronous generator with PSS and AVR installed. The power grid is modelled by a synchronous generator and a load. The generator represents the total generation on the grid and the load represents the aggregated loads in the power system. Grid faults are set at both the wind farm side and the power network side to test the fault response of the system.

5 SIMULATION RESULTS

A 3-phase symmetrical fault is applied near the wind farm. Figure 2 illustrates the generator torque during and after the fault. Due to the voltage drop in the grid, the DFIG loses magnetisation. Thus, the output torque drops significantly during grid fault.

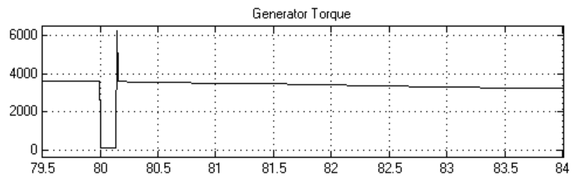

Figure 2: Generator torque

The generator speed keeps increasing during the fault because of the torque imbalance on the drive-train as shown in Figure 3. From the simulation result we can see the drive-train is very lightly damped.

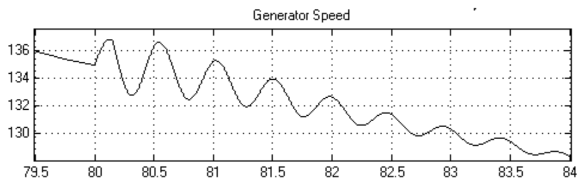

Figure 3: Generator speed

The torque drop is transferred through the drive-train and affects the wind turbine hub torque as shown in Figure 4. The hub torque oscillation increases wind turbine loads and therefore reduces turbine lifetime.

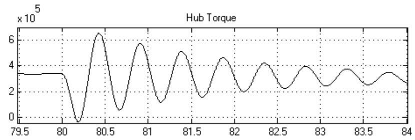

Figure 4: Hub torque

The grid voltage is illustrated in Figure 5. The DFIG output current rises during the grid fault trying to maintain the generator torque. The over current causes grid voltage sag.

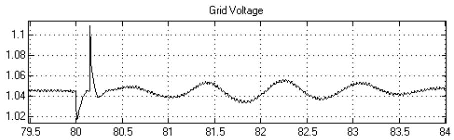

Figure 5: Grid Voltage

6 CONCLUSIONS

This paper used a detailed model of a wind turbine and power network to study dynamic interactions in a holistic manner highlighting the need for combined controllers. The model is developed for further research on improving wind turbine Fault Ride-Through and grid support ability. The modelling of wind turbine, conventional generator and power grid were briefly presented. Simulation results show the dynamic response of the system when a grid fault occurs. The advantage of this model is that the dynamics of both the mechanical system and the electrical system are modelled in detail, which allows accurate investigation on the interaction between them. How the electrical system disturbance affects the operation of wind turbine is clearly shown in the simulation results. In conclusion, both the wind turbine and power system dynamics are accurately modelled.

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