Modeling of Wind Turbines of the Integration Type and their Networked Control*

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Abstract

Energy and environment crisis is becoming increasingly serious, energy saving and low-carbon are advocated worldwide. Renewable energy such as the wind power, and solar energy are drawing growing attention and research enthusiasm from scientists and engineers all over the world. Wind power is a comprehensive research area that involves aerodynamics, automatic control, mechanical engineering, electrical engineering, computer science and material science, et al. Nowadays, the research concentrates on large-scale wind turbines design, wind generation integration, low voltage ride through, advanced control scheme and optimization algorithms design. Progress in wind energy will have a significant promotion in the development and innovation of information technology, energy, mechanical engineering, material science and power systems, which brings economic and social profits for human beings. Wind generation of the integration type has its own advantage. It transfers the electrical power form the area that has abundant wind energy to the area that has high demand of electrical power. This thesis focused on wind generation of the integration type and contribute to thefollowing aspects.

1. The aerodynamic model of wind turbines was built. First, blade model was built based on blade element momentum theory. Wind turbines stall phenomenon was explained by the model obtained. Second, wind speed model was derived by utilizing statistical data, which brings convenience to simulation of wind turbines design. Finally, rigid and flexible transmission system models were derived that suit to different research focus.

2. Electromagnetic model of wind turbines was built. The widely used doubly-fed induction generator was chosen as the generator of wind turbines. To begin with, voltage and flux model of doubly-fed induction generator in three phase static framework and two phase synchronous framework were derived. With regard to the characteristic of doubly-fed induction generator, the obtained model can be simplified via flux orientation. Furthermore, modelling of integration interfacebidirectional PWM converter was finished. Compared with the integration interface model in other literature, this thesis took dynamic behavior of DC section into account, which is an improvement.

3. For high penetration of wind generation to modern power grid, wind generation played growing important role in power grid regulation. Aiming at this situation, this thesis put up with networked control method for wind integration operation. Networked model of wind generation is derived. For the down power regulation circumstance that the power grid restricts output of wind generation, networked robust controller was designed when the network induced delay is time-varying, uncertain and upper-bounded. The robust controller can be obtained via solving linear matrix inequalities (LMIs). Effectiveness of the robust controller was verified through numerical simulations.

4. Integration model that took dynamic load model into account was derived by analyzing the network of wind generation integration. From the perspective of power system stability, chaotic phenomenon which should be avoided in power systems, was discovered when the injection power of wind generation was in a special region. The chaotic phenomenon in power systems should be suppressed. However, since the integration model is strong coupling and nonlinear, it is difficult to design control law to control the complex nonlinear chaotic system. Because of the universal approximation precision of the fuzzy hyperbolic model, this thesis used fuzzy hyperbolic model to approximate the complex chaotic integration system to simplify controller synthesis. Thus, control scheme can be designed based on intelligent control theory for fuzzy hyperbolic model. The safe region for the power injection of wind generation was derived. Numerical simulation verified the designed control schemes.

Keywords: wind generation, integration, doubly-fed induction, networked control, robust control, Linear Matrix Inequality (LMI), power system stability, chaos, fuzzy hyperbolic model.

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