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Integrated Model of DFIG and SFR for Frequency Regulation Control Research of Wind Turbine Generator

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I. INTRODUCTION

In the power system, wind power generation plays a significant role. Research on the frequency regulation capability of wind turbines is very important. MATLAB is a commonly used simulation platform for control method research, however, the simulation speed of a large-scale power system containing wind power generation is quite slow. To improve the research efficiency as much as possible while meeting research needs, an integrated model of the doubly-fed induction generator (DFIG) model and system frequency response (SFR) model is proposed in this paper. First, a simplified DFIG model is established which only retains the wind turbine, swing equation of rotor, speed regulator with frequency regulation control, and pitch controller. Then, the integrated method of the simplified DFIG model and SFR model is introduced. The simulation result shows that the frequency response of the integrated model is consistent with the complete power system model containing a detailed DFIG model, and the simulation speed is increased by more than 130 times. In addition, since the wind speed input-related part is preserved, the integrated model can be used for frequency regulation control research of wind turbine generators considering the continuous change in wind speed.

II. SIMPLIFIED MODEL OF DFIG WIND TURBINE GENERATOR

We take the “DFIG Average Model” provided in the MATLAB platform as a detailed DFIG model. The controllers of the DFIG average model, especially the speed regulator and pitch control, are based on the GE wind turbine generators. The *df/dt* based virtual inertia control is added to the speed regulator of DFIG to achieve the response to the frequency change.

To improve the simulation speed and retain the correct frequency response characteristics, we simplified the detailed model of the DFIG-based wind turbine generator as follows:

- The two-mass drive chain model is simplified to a one-mass model.
- For the induction generator model, only the swing equation of the rotor is retained.
- Both the rotor-side and grid-side converters and their controllers are ignored.

Based on the above simplification, the structure of the simplified DFIG model is shown in Figure 1. The simplified DFIG model consists of a wind turbine model, generator model, speed regulator with *df/dt* frequency regulation control, and pitch controller.

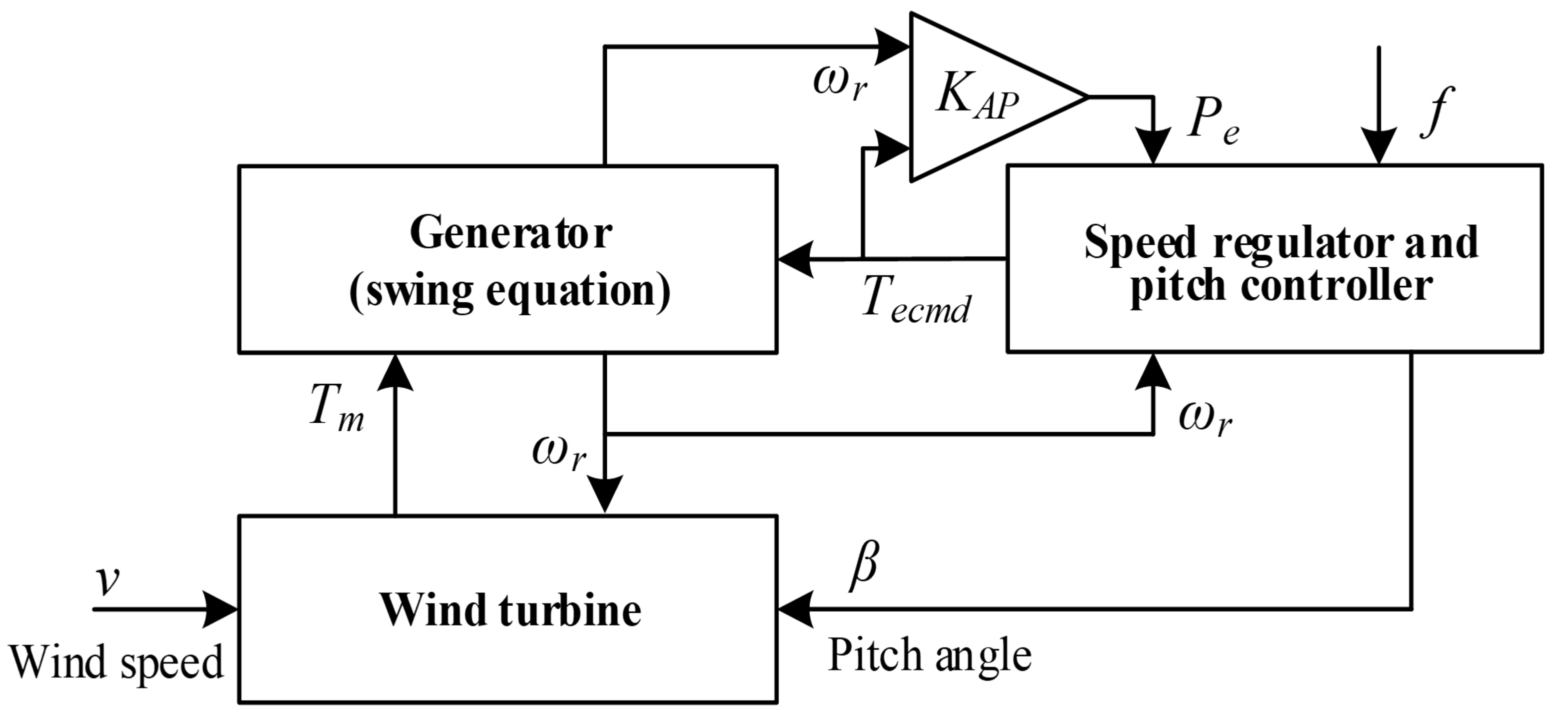

Fig. 1 Structure of the simplified DFIG model.

III. INTEGRATED MODEL OF THE SFR AND DFIG

Figure 2 shows the integration method of the SFR model and simplified DFIG model, where the blue part connects the two models. The output of the SFR model is the Δf. The Δf and the steady-state frequency f_0 are added together to get the system frequency f. The system frequency f is input to the simplified DFIG model. The active power P_e output by the DFIG subtracts its steady-state value P_0 to obtain the change in active power ΔP_{DFIG} of the DFIG. The difference between the ΔP_d and ΔP_{DFIG} is used as the input of the SFR model $G_{SFR}(s)$.

As shown in Figure 3, the frequency response of the integrated model is consistent with the frequency response of the detailed IEEE 9-bus system model. The simulation result verifies that the integrated model is effective.

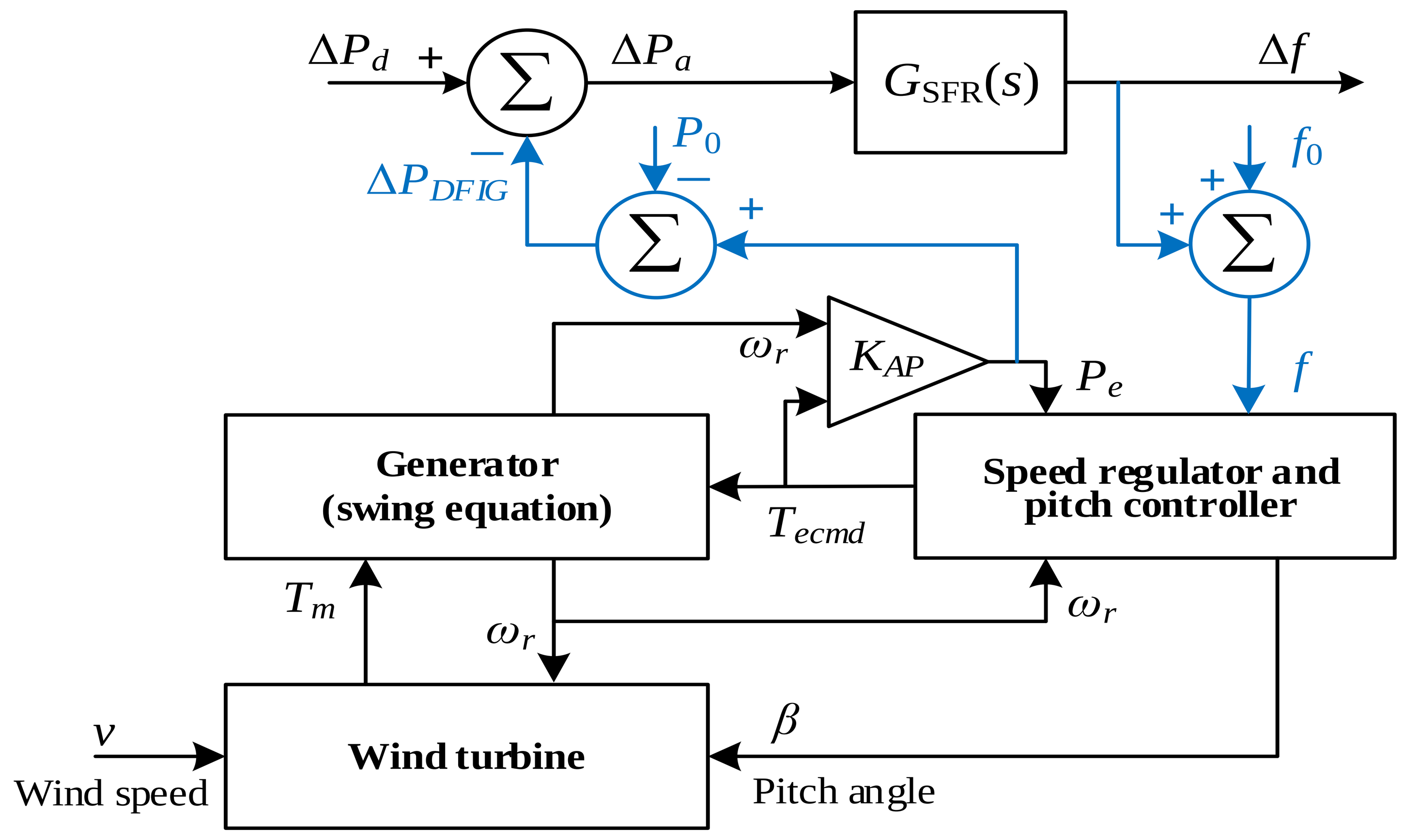

Fig. 2 Integration method of the SFR model and simplified DFIG model.

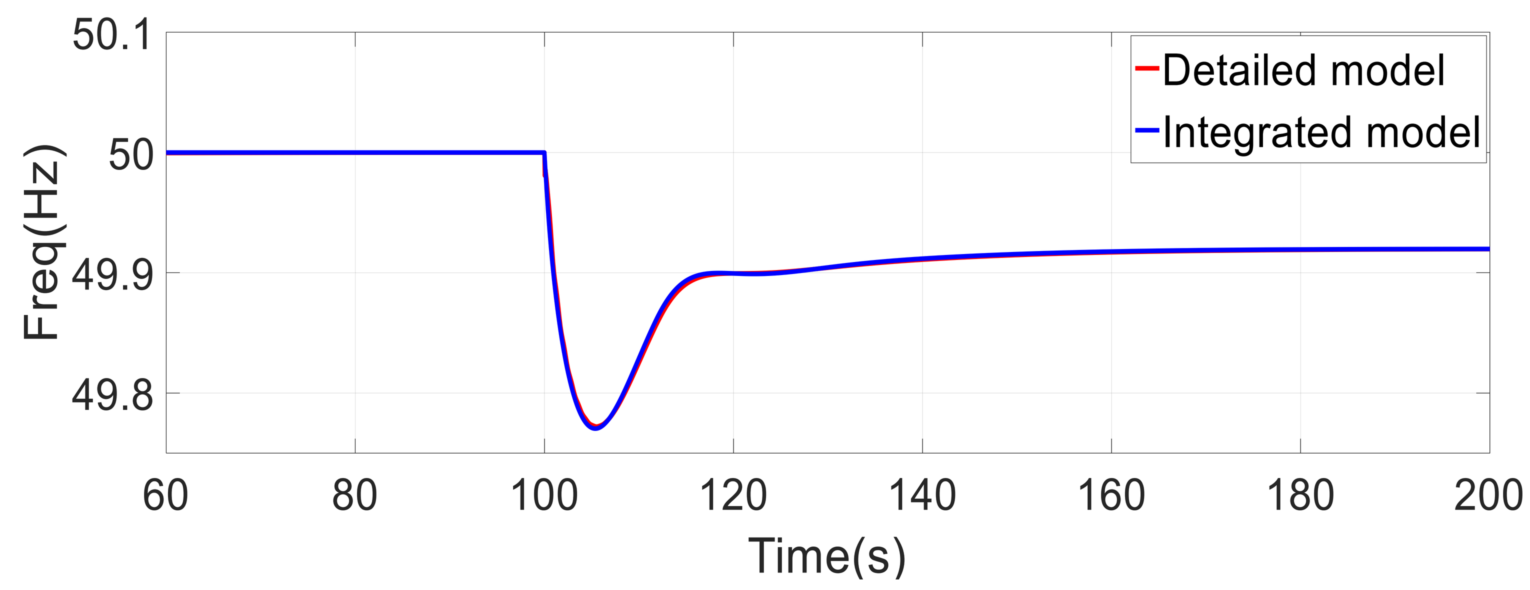

Fig. 3 Frequency response curves of the detailed model and integrated model.

IV. CONCLUSION

To improve the wind turbine generator's simulation speed, this paper proposed an integrated model of the simplified DFIG model and SFR model. The simulation result shows the simplified DFIG model has the same response as the detailed DFIG model to frequency change. The classic SFR model is simplified to a three-order transfer function. In the absence of frequency regulation in the DFIG, parameters of the SFR model parameters can be identified by the frequency response of the entire power system. The simulation result verifies the effectiveness and high efficiency of the integrated model. Furthermore, the integrated model retains the wind turbine module, so it can be used to study the influence of continuous change in wind speed on the frequency regulation control of wind turbine generators.

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