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이중여자 권선형 유도발전기의 출력조정을 위한 제어 기법

박영호*, 원동준**, 박진우*, 문승일*
서울대학교*, 인하대학교**

Modified Control Scheme to Regulate the Active Power Output of Doubly Fed Induction Generator

Young Ho Park*, Dong Jun Won**, Jin Woo Park*, Seung Il Moon*
Seoul National University*, Inha University**

Abstract - As the number of wind turbines installed increase, the power from wind energy starts to replace conventional generation units and its influence on power system can not be neglected. Because of the intermittent nature of wind resource, the output power of wind turbine fluctuates according to wind speed variation. In this point of view, it is necessary for wind turbines to be equipped with power regulation ability. The doubly fed induction generator (DFIG) is one of the main techniques used in variable speed wind turbines. This thesis focuses on the development of modified control scheme of DFIG to regulate output power. The proposed control scheme achieves active power output regulation so as to stabilize the power system.

1. Introduction

There are increasing attentions made to generate electricity from renewable energy source. Among these source, wind energy is one of the most widely used way to generate electricity and the wind power penetration level is continuously increasing.

In the past, wind power penetration level was low that the amount of power generation from wind resource covers only a small part of the total power system load. To this time, the overall dynamic behavior of the power system will mainly be determined by the synchronous generators in power plants [1].

As the number of wind turbines installed increase, the power from wind energy starts to replace conventional generation units and its influence on power system can not be neglected. The fluctuation of large scale wind power makes the power system difficult to meet the system demand. If it comes to the severe power fluctuation, it may not possible to run a power system by only controlling conventional power generation unit like synchronous generator. When the wind variation is large, so will be the frequency excursions, which may trigger the under-frequency protection, resulting in load curtailment, or in extreme cases leading to loss of synchronism. In addition, continuous variation of the output power of the conventional power generation units has a harmful effect on their operation, maintenance, and life expectancy which is difficult to assess and quantify [2].

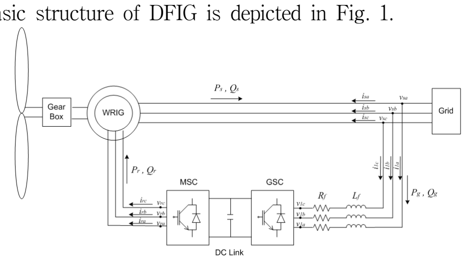
In this point of view, it is necessary for wind turbines to be equipped with power regulation ability to prevent such events. A large number of wind turbines installed recently are variable speed wind turbines. The DFIG is one of the main techniques used in variable speed wind turbines. This thesis focuses on the development of modified control scheme of DFIG to regulate total output power. The proposed control scheme achieves active power output regulation so as to stabilize the power system.

2. Doubly Fed Induction Generator

2.1 Description of DFIG

The wind turbine is coupled to the wound rotor induction generator through a gear box. The stator circuit is connected to the grid and the rotor circuit is connected to the converter via slip rings. Two AC/DC and DC/AC converters are connected back-to-back between the rotor and the grid. These power electronics are divided in machine side converter (MSC) and grid side converter (GSC). Both are the PWM voltage source converters using insulated gate bipolar transistors (IGBTs).

The basic structure of DFIG is depicted in Fig. 1.



<Figure 1> The structure of DFIG

2.2 Active Power and Reactive Power of DFIG

The general machine equations of wound rotor induction machine is well presented in [3]. the stator active and reactive power expressed in d-q reference frame is as follows.

$$P_s = -\frac{3}{2}(v_{ds}i_{ds} + v_{qs}i_{qs}) \tag{2.1}$$

$$Q_s = -\frac{3}{2}(-v_{ds}i_{qs} + v_{qs}i_{ds}) \tag{2.2}$$

Under stator flux vector position, stator active power and reactive power are given by

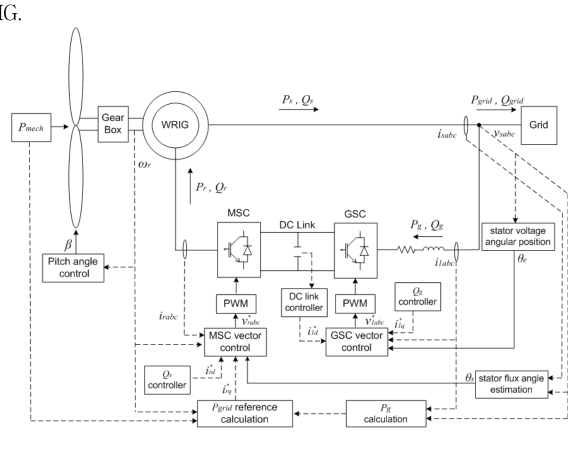
$$P_s = \frac{3}{2}\left(\frac{L_m}{L_s}v_{qs}\right)i_{qr} \tag{2.3}$$

$$Q_s = \frac{3}{2}v_{qs}\frac{L_m}{L_s}\left(-\frac{v_{qs}}{\omega_s L_m} + i_{dr}\right) \tag{2.4}$$

3. Proposed Control Scheme

3.1 Overview of Proposed Control Scheme

Fig. 2 shows the block diagram of proposed control scheme of DFIG.



<Figure 2> The structure of DFIG

3.2 Regulation of Total Active Power Output of DFIG

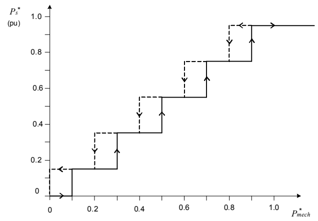
The objective of the GSC is to keep the DC link voltage constant regardless of the magnitude and direction of the rotor power. A vector control approach is used, with a reference frame oriented along the stator voltage vector position, enabling independent control of the active and reactive power flowing between the grid and the GSC [4].

In here, MSC is controlled to achieve the active power regulation of DFIG. A synchronously rotating d-q reference frame of which the d-axis component is oriented along the stator flux vector position is used.

Stator active power can be controlled by q-axis rotor current. The stator side active power can be controlled by current controller by applying following q-axis reference current signal.

$$i_{qr}^* = \frac{2}{3}\frac{L_s}{L_m}\frac{P_s^*}{v_{qs}} \qquad (3.1)$$

The reference value of stator active power is determined according to the mechanical power input into the blade tower. To prevent too frequent switching to another reference value, following hysteresis is applied.



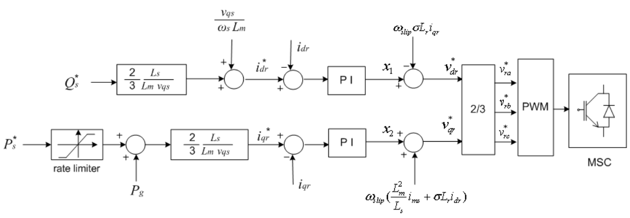
<Figure 3> Reference power setting using hysteresis

By using above hysteresis, it can be prevented that the wind speed fluctuation around the specific speed makes the refernce value repeatedly.

The total power supplied to the grid by DFIG is sum of stator side power and power flow between GSC and the grid. Since the slip power can flow in both directions and varies with the rotor speed, compensating term has been added to the current controller to above reference value calculation to guarantee the suppression of output power fluctuation . The rate limiter is inserted to prevent the sudden change of active power. In this way, both increase and decrease rate of active power can be controlled. From equation (2.4), Similar reactive power control scheme can be made.

$$i_{dr}^* = \frac{v_{qs}}{\omega_s L_m} + \frac{2}{3}\frac{Q_s^*}{v_{qs}}\frac{L_s}{L_m} \qquad (3.2)$$

The overall control scheme presented in this chapter is illustrated in Fig. 3.

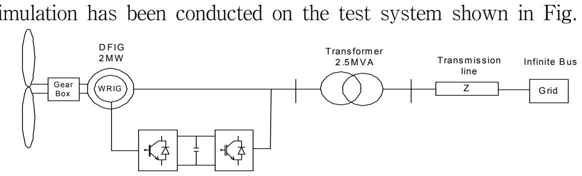


<Figure 4> Overall control scheme of the MSC

4. Simulation Results

4.1 Test System

In order to verify the performance of proposed control strategy, simulation has been conducted on the test system shown in Fig. 4.

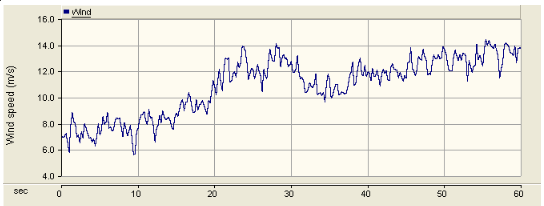


<Figure 5> The structure of DFIG

The 2MW, 0.69kV, 2 pole pairs DFIG is connected to the 0.69/13.8kV, 2.5MVA transformer. After boost-up, the power produced by DFIG is supplied to the grid through the transmission line. The power system simulation tool, PSCAD/EMTDC is used to carry out the simulation of the test system.

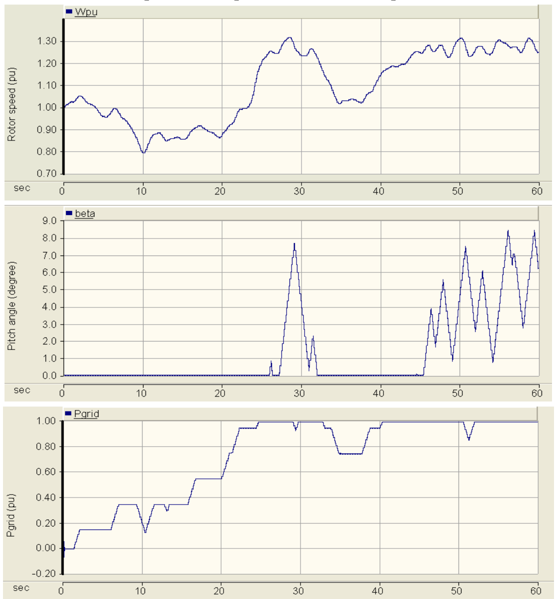
4.2 Simulation Results

After integration of DFIG in PSCAD/EMTDC, following wind speed is applied to the DFIG.



<Figure 6> Applied wind speed

With proposed control scheme applied, the rotor speed, pitch angle, and the total active power output of DFIG are presented as follows.



<Figure 7> Rotor speed, pitch angle, total active power

It can be seen that the total active power flow from DFIG to the grid is regulated by proposed control.

5. Conclusions

Because of the intermittent nature of wind resource and the slip power variation between converter and the grid, the total output power of DFIG fluctuates according to wind speed variation.

To prevent the wind power fluctuation of DFIG, control scheme which can regulate the total active power output is designed. In order to verify the performance of proposed control strategy, simulation using PSCAD/EMTDC is carried out. The result show that the total power from the DFIG can be regulated depending on the wind speed condition. The ramp rate of power increase or decrease can be controlled, too. Under this control scheme, wind power fluctuation is suppressed, however, there is some economic loss caused by regulation in comparison with conventional maximum power tracking control method.

[참 고 문 헌]

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