Comparison of Voltage Oriented Control and Direct Power Control under Command Mode Transition for PMSG Wind Turbines

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ABSTRACT

This paper proposes a comparison of Voltage Oriented Control (VOC) and Direct Power Control (DPC) under command mode transition for PMSG Wind Turbines (WT). Based on a neutral point clamped three level back to back type Voltage Source Converter (VSC), proposed control scheme automatically control the generated output power to satisfy a grid requirement from the hierarchical wind farm controller. Automatic command mode transition based on the dc-link voltage error provides a command mode changing between grid command and MPPT mode. It is confirmed through PLECS simulations in Matlab. Simulation result shows that proposed control scheme of VOC and DPC achieves a much shorter transient time of generated output power than the conventional control scheme of MPPT with optimal torque control and VOC under a step response. The proposed control scheme makes it possible to provide a good dynamic performance for PMSG wind turbines in order to generate a high quality output power.

1. Introduction

Recently, wind power system is one of the fastest growing renewable energy systems. High performance control of power converter in Fig. 1 is a must to maintain high power quality and system stability[1]. In particular, large scaled wind farms have become a subject to various grid codes demanding tougher grid adaptive features such as voltage support, ramp rate control, rapid shut down control, and etc[2]. Previous studies regarding power control scheme have focused on the MPPT irrespective of the type of generator used[3]. Based on the principle of direct torque control strategy, namely DPC was developed for the control. This DPC scheme is designed to effectively obtain the requested amount of power and improve transient performance. Considering grid codes and requirements, VOC and DPC scheme together with MPPT control and command mode transition for wind turbines has not been explored in detail in previous literatures. This paper proposes a novel way of securing seamless transition between grid command and MPPT mode under the sudden change of reference power command. Using a dc-link voltage, this mode changer is triggered by either grid command from the wind farm controller or external interruption such as wind speed variation and grid disturbances. Therefore, the proposed control method of VOC and DPC makes it easier to comply with various grid codes and requirements on wind power system.

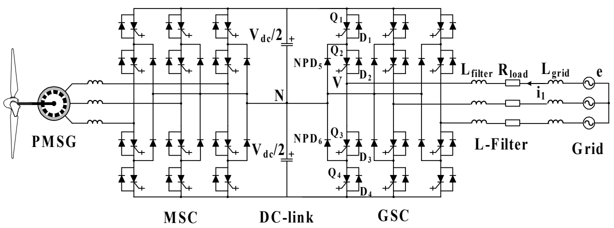

Fig. 1. 3L-NPC back-to-back converter for PMSG WTs

2. Conventional and Proposed Control Scheme for Wind Turbines

2.1 Conventional control scheme

Among many MPPT approaches reported, torque control based on squared rotor speed are widely used in MSC[3]. The control strategys of GSC is to transfer generated active power from MSC to ac grid. The conventional control scheme is described in Fig. 2.

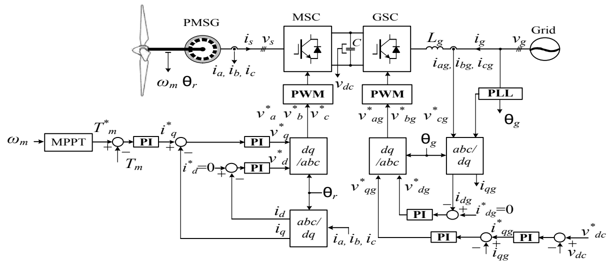

Fig. 2. Control block diagram of conventional control of MPPT with to que reference proportional to speed squared and VOC for PMSG WTs

2.2 DPC modeling and proposed control scheme

The rectifier model in a stationary $\alpha\beta$-frame can be expressed. e and i_1 are space vector of grid voltage and current[4], [5]. V and i_2 are space vector of rectifier voltage and current. V is represented as $V_n e^{j\theta_n}$ where V_n and θ_n depend on the switching state of GSC. Differentiating active and reactive power can be represented as (1).

$$\frac{dP}{dt} = 1.5\left(\frac{|e|^2 - |V_n||e|\cos(\omega t - \theta_n)}{L_{filter+grid}}\right) - \frac{R_{load}}{L_{filter+grid}}P - \omega Q$$
$$\frac{dQ}{dt} = 1.5\left(\frac{-|V_n||e|\sin(\omega t - \theta_n)}{L_{filter+grid}}\right) - \frac{R_{load}}{L_{filter+grid}}Q + \omega P \qquad (1)$$

In general, MPPT and VOC control scheme does not have a good dynamic performance under varying active power command. The proposed control scheme of VOC and DPC in this paper is presented in Fig. 3. The proposed control scheme made up VOC for MSC and DPC for GSC with dc-link voltage regulation feature. DPC for GSC acts on a reference power command while dc-link voltage regulator of MSC provides the demanded power from GSC. This command mode transition based on the dc-link voltage error is provided as a smooth and seamless mode changing between grid command mode and MPPT mode.

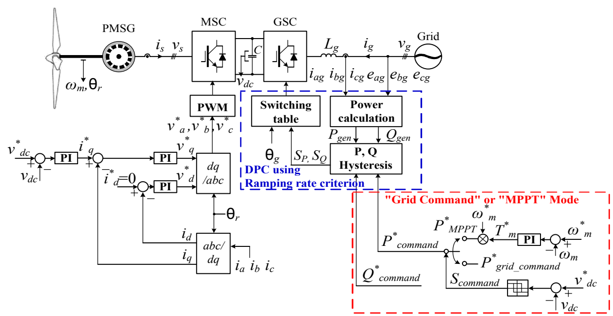

Fig. 3. Control block diagram of p oposed control of VOC and DPC for PMSG WTs

3. Simulation Verification

In order to effectively confirm the proposed control scheme of VOC and DPC, the simulation is performed under three different operating conditions; Case 1 and Case 2.

3.1 Case 1: from MPPT to grid command mode

The simulation is performed based on the parameters of 5 MW PMSG[6] and simulated in Table 1. The simulation waveforms both of conventional and proposed control scheme are shown in Fig. 4. It is evident from Fig. 4 (a) and (b) that the proposed control scheme of VOC and DPC exhibits better transient behavior with less overshoot and shorter setting time as compared to the conventional control scheme.

TABLE 1. From MPPT to grid command mode change

Target / Time	~ 1s	1s ~ 2.5s
Reference power (Fixed wind speed: 12m/s)	Active power: 5MW (Rated power:5MW)	Active power: 4.5MW (Rated power:5MW)
Mode	MPPT	Grid command
Condition	Steady-state	Decreased active power reference

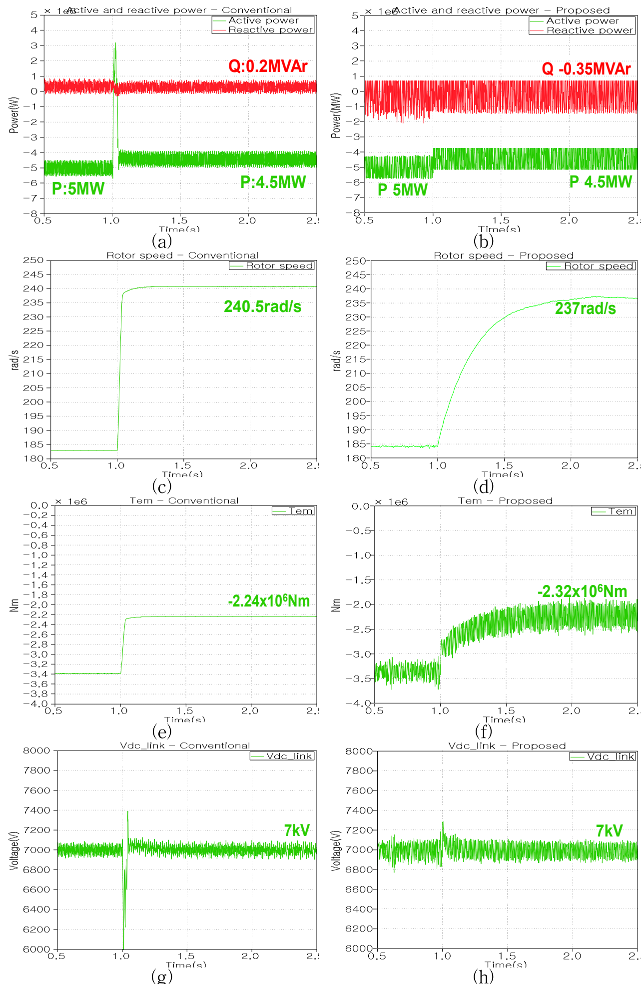

Fig. 4. Simulation result based on Case 1; Active and reactive power from (a) MPPT with optimal torque control and VOC scheme, and (b) proposed control scheme of VOC and DPC. Rotor speed from (c) MPPT with optimal torque control and VOC scheme, and (d) proposed control scheme of VOC and DPC. Electromagnetic to que from (e) MPPT with optimal torque control and VOC scheme, and (f) proposed control scheme of VOC and DPC. DC-link voltage from (g) MPPT with optimal torque control and VOC scheme, and (h) proposed control scheme of VOC and DPC

3.2 Case 2: from MPPT to grid command mode and from grid command to MPPT

The controller is subject to two mode changing transients as explained in Table 2. At the moment when the dc-link voltage decreases below the minimum hysteresis error band, the control mode is automatically set back to MPPT mode again to generate the available active power. The key waveforms of proposed control scheme are illustrated in Fig. 5.

TABLE 2. From MPPT to grid command mode and from grid command to MPPT

Target / Time	~ 1s	1s ~ 1.21s	1.21s ~ 2.5s
Reference power (Fixed wind speed: 11.2m/s)	Active power: 4.5MW (Rated power:5MW)	Active power: 5MW (Rated power:5MW)	Active power: 4.5MW (Rated power:5MW)
Mode	MPPT	Grid command	MPPT
Condition	Steady-state	Increased active power reference	Steady-state
Minimum V_{dc_link}	V_{dc_link} (0.9pu) = 6.3 kV (Rated V_{dc_link} =7 kV)		

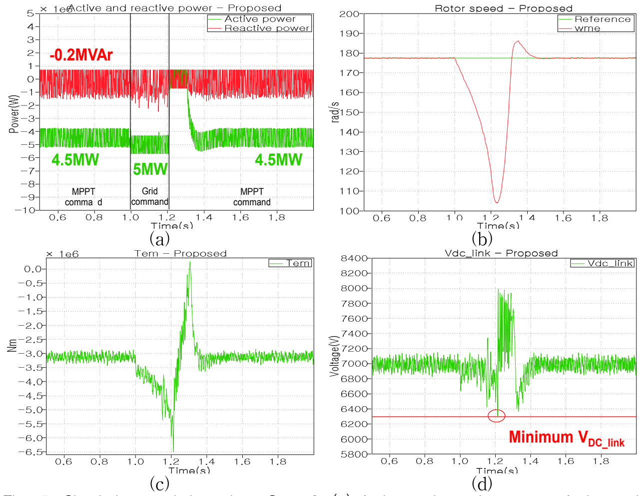

Fig. 5. Simulation result based on Case 2; (a) Active and reactive power of changed command mode, (b) Rotor speed of changed command mode, (c) Electromagnetic torque of changed command mode, (d) DC-link voltage of changed command mode

4. Conclusion

This paper propose a comparison of voltage oriented control and direct power control under command mode transition for PMSG wind turbines. The proposed control scheme involves a dc-link voltage regulation for a MSC and DPC for a GSC using an automatically convertible command mode transition. It is shown that the active and reactive power can be directly controlled under various grid fault conditions and requirements of automatic generation control. In the transient condition of power reference variation, due to DPC characteristic, proposed control scheme of VOC and DPC achieves a much shorter transient time in the step response of output power as compared to the conventional control scheme of MPPT with optimal torque control and VOC. The proposed control scheme of VOC and DPC makes it possible to provide a good dynamic performance for PMSG wind turbines in order to generate a high quality output power under grid fault or steady-state condition.

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (No. 2010-0028509) & (No. 2014R1A2A1A11053678)

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