

**INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH
TECHNOLOGY****UNDER DISTORTED GRID VOLTAGE DIRECT POWER CONTROL OF DOUBLY
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ABSTRACT

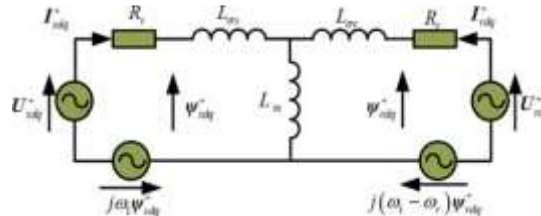
This paper presents a direct power control strategy for a doubly fed induction generator based wind power. By analyzing the six times grid frequency power pulsation produced by the fifth and seventh grid voltage harmonic components, DPC strategy with vector proportional integrated (VPI) regulator has been proposed to implement the smooth active and reactive power output of DFIG. The performance analysis of the proposed DPC strategy, including the steady and dynamic state performance, closed-loop operation stability, and rejection capability for the grid voltage distorted component and back EMF compensation item has been investigated. The availability of the proposed DPC strategy with a VPI regulator is verified by experiment results of DFIG system under harmonically distorted grid condition.

KEYWORDS: Direct power control (DPC), doubly fed induction generator (DFIG), harmonically distorted grid voltage, vector proportional integrated (VPI) regulator.

INTRODUCTION

WIND power generation based on the doubly-fed induction generator (DFIG) has gained increasing popularity due to several advantages, including smaller converters rating around 30% of the generator rating, variable speed and four quadrant active and reactive power operation capabilities, lower converter cost, and power losses compared with the fixed-speed induction generators or synchronous generators with full-sized converters. Several novel control strategies have been investigated in order to improve the DFIG operation performance, i.e., the vector oriented control (VOC), direct power control, and predictive current control. There are always voltage harmonic distorted components in the transmission system of the power grid. It has been pointed out that the highly distorted stator/rotor current, significant electromagnetic torque and power oscillations would occur if grid voltage harmonics are not taken into account by DFIG's control strategy. A theoretical analysis and an improved VOC strategy for DFIG, in which alternative control targets were proposed to keep the three-phase sinusoidal stator/rotor current, or remove pulsations in both stator active and reactive powers, or remove pulsations in the electromagnetic torque and stator reactive power. Furthermore, in addition to the conventional rotor current control loop, a distinctive and independent stator current resonant control loop was also used to successfully eliminate the stator current harmonic components. Under harmonically distorted grid conditions, the DFIG would contain six times grid frequency pulsation item and an average item of stator active and reactive power. Therefore, PI regulator would not be appropriate due to the insufficient gain at the six times grid frequency. PIR regulator could achieve zero steady-state error, in which the PI and resonant part is used to deal with the average item and the pulsation item respectively. However, unexpected peak of magnitude response at the frequency larger than resonant 300 Hz may arise due to the pole distribution of control object DFIG, which is detrimental to the stable closed-loop operation. Considering that it needs one specific resonant controller to deal with one specific harmonic sequence in the PR regulator, the control loop structure complexity would increase as the number of harmonic sequence increases, which is harmful to the stable closed-loop operation. The VPI regulator, based on pole-zero cancellation to avoid the unexpected gain peak can be used to remove the DFIG stator active and reactive power pulsation components due to the adequate closed-loop phase margin and accurate ac signal tracking capability.

This paper investigates the DPC strategy of wind-turbine driven DFIG generation systems under distorted grid voltage conditions. First, the mathematical model of a DFIG system under fifth- and seventh-order harmonically distorted grid supply is briefly mentioned as a foundation. Considering that the wind power generation should focus on the energy quality injected into the grid, the stator active and reactive power without any oscillation is selected as the harmonic control target. Then, focused on the steady-state tracking accuracy, dynamic performance analysis, closed-loop operation stability, as well as the rejection capability of the grid voltage distorted component and back EMF compensation item, the performance analysis of the proposed DPC control strategy with VPI regulator is conducted.



MATHEMATICAL MODEL OF DFIG UNDER HARMONICALLY DISTORTED VOLTAGE

In order to investigate the DPC strategy, DFIG mathematical model under harmonically distorted grid condition should be established first. Under the harmonically distorted grid condition, grid voltage can be decomposed into fundamental frequency component and a series of harmonic frequency components. Considering that the fifth- and seventh-order sequences are the major harmonic components of the grid voltage this paper would focus on the DPC strategy under these two harmonic components.

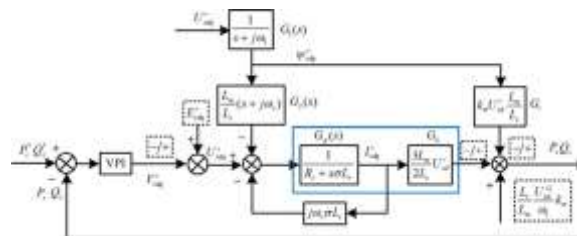
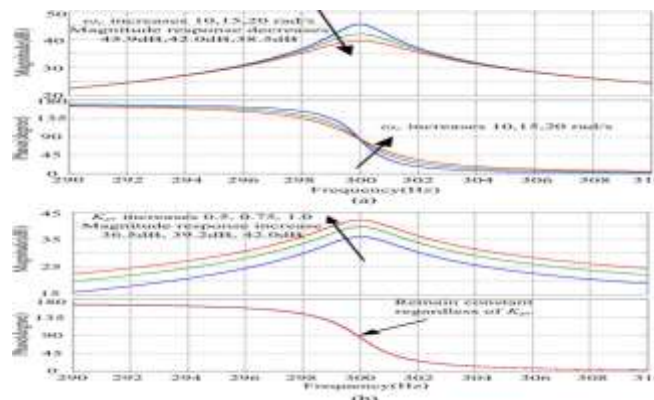


Fig. DPC scheme of the DFIG under the Distorted Grid Voltage using the VPI regulator.

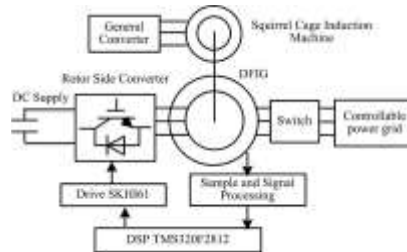
PERFORMANCE ANALYSIS OF THE DPC STRATEGY WITH A VPI REGULATOR

In order to achieve the smooth stator active and reactive power output under the distorted grid voltage, the DFIG steady and dynamic state performance, as well as the disturbance rejection capability of the proposed DPC strategy using the VPI regulator should be investigated. Moreover, as the conventional PIR regulator would cause the deterioration of closed-loop control phase margin and may cause instability operation. the closed-loop stability using the VPI regulator should also be discussed.

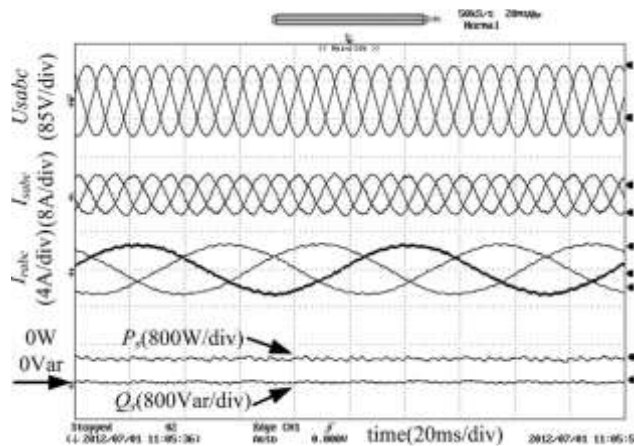


EXPERIMENTAL SETUP

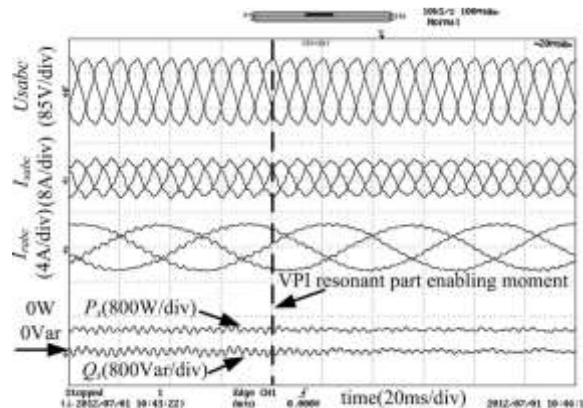
An experimental system was built on a laboratory prototype of 1 kW DFIG system in which the DFIG is driven by a 1.5 kW squirrel cage induction machine as the wind turbine. The induction machine is driven by a general converter. The rotor side converter of DFIG is connected with a dc power supply. A controllable three-phase power grid is set up to simulate the practical harmonic power grid. In the experiment, fifth- and seventh-order harmonic components are set to be 3.4% and 2.8% each, and the rotor speed is initially set to 800 rpm. The control strategy is implemented on the TI DSP TMS320F2812, and the driver for IGBT is SEMIKRON SKH161. The sampling frequency is 10 kHz, and the IGBT switching frequency is 5 kHz. The waveforms are acquired by a YOKOGAWA DL750 scope recorder, the harmonic component analysis is done by FLUKE NORMA 5000 power analyzer.



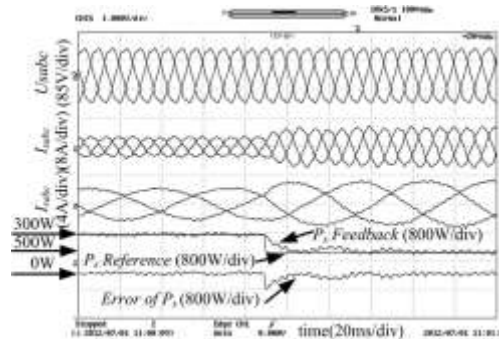
SIMULATION WAVEFORM



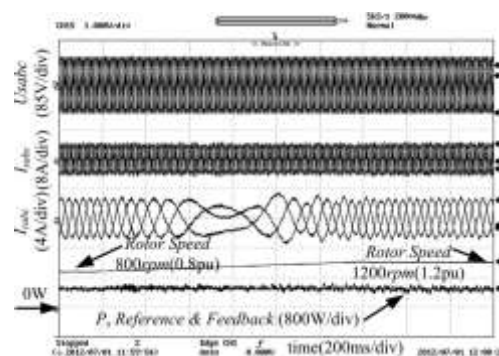
Fig; DFIG performance under the ideal grid voltage condition.



Fig; DFIG system transient performance under the distorted grid voltage condition with VPI enabled.



Fig; DFIG stator active power reference stepping transient performance under the distorted grid voltage with VPI enabled.



Fig; DFIG system operating from sub synchronous to super-synchronous state under the distorted grid voltage condition with VPI enabled.

CONCLUSION

A VPI-based DPC strategy for a wind turbine driven DFIG system under the harmonically distorted grid voltage. By applying the VPI regulator to suppress the power pulsation component, the proposed DPC strategy can successfully implement the smooth active and reactive power output of DFIG under the harmonic voltage. The steady power tracking precision and fast dynamic performance of the proposed DPC strategy are theoretically analyzed and proved experimentally. The proposed DPC strategy also shows an excellent disturbance rejection ability and closed-loop operation stability. Experiment results have been carried out to validate the excellent dynamic and steady operation performance of the proposed DPC strategy.

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