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A Novel P-Q Control Algorithm for Grid Connected Based PWM Converter Applied a Synchronous Generator for a Variable Speed Wind Turbine

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Abstract. This paper presents the electrical power conversion system which is developed for a synchronous generator in order to apply with a variable speed wind turbine system. In the wind energy conversion system, a synchronous generator is converted the mechanical energy into electrical energy. A B6 rectifier and a boost chopper circuit are utilized to maintain constant intermediate DC voltage. The average power is converted entirely by the PWM converter, consists of B6 voltage-source inverters. Output currents and active power of switch mode voltage source inverter are flowed into utility grid by current control and PQ theory technique. For the hardware implementation, the system consists of a 1 kW four poles synchronous generator and the voltage source inverter controlled output current by hysteresis controller (bang-bang) method. The algorithm is implemented in a dSPACSds1104DSP together with Matlab/Simulink program. The validity of the proposed method is verified by both simulation and experimental results under power transferred into grid in term of power quality such as real power, reactive power, total harmonics distortion, and so on.

Keywords: Computer simulation, Numerical methods

1. Introduction

Many types of generator concepts have been used and proposed to convert wind power into electricity. The size of the wind turbines has increased during the past ten years, and the cost of energy generated by wind turbine has decreased. The challenge is to build larger wind turbines and to produce cheaper electricity. Thus, there is a need to find a way to convert wind energy into electrical energy from wind turbines that can be scaled up in power without extremely high cost penalties. The use of synchronous generator in wind generation is widely accepted as a generator of choice for variable speed wind turbine system. The synchronous generator is a conventional generator, simple, reliable, cheap, lightweight, and requires little maintenance. Generally, the synchronous generator is connected to the utility bus at constant frequency. With a constant frequency operation, the synchronous generator operates at practically variable speed. The wind turbine operates in optimum efficiency only within a wide range of wind speed variation. The variable-speed operation allows an increase in energy captured and reduces both the torque peaks in the drive train and the power fluctuations sent to the utility. In this paper, a combination of DC power supply is used to excite the field circuit of the synchronous generator while operating at variable speeds. The frequency, the induce voltage and the operating range of the system are affected by the characteristics of the synchronous generators and the choice field current for exciting. The system were tested has the following components: a three-phase four pole, 3 kW induction motor to represent the wind turbine, a three-phase four pole, 1 kW, synchronous generator driven by the induction motor, a B6 rectifier and a boost chopper circuit are utilized to maintain constant intermediate DC voltage. The average power is converted entirely by the PWM converter, consists of B6 voltage-source inverters, to convert the power from the dc bus to the utility grid [1]-[3].

2. Proposed PWM Converter Scheme

The block diagram of voltage control the current topology for wind turbine shows in Fig. 1. This block diagrams consist of a three-phase bridge rectifier, two-capacitors connected cross dc-bus and a voltage source converter. The active and reactive power can be controlled by controlling the magnitude current of voltage source inverter, and ac line grid side is connected with the 3-phase reactors.

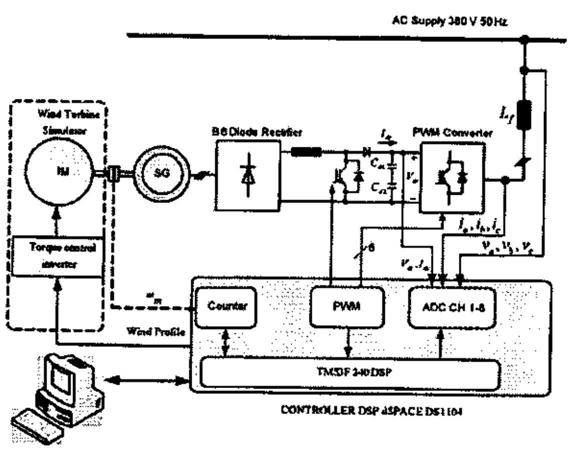

Fig. 1. Schematic of proposed PWM converter for wind turbine.

3. PWM Voltage Source Converter

The PWM converter and current control technique as shown in Fig. 2, the simplified equivalent circuit of a grid-connected 2L-VSC ac supply is connected with three reactors(Lf) for inject current to cancel the harmonic component current. The dc-link voltage (Vdc) must be regulated and the capacitor voltage (E) must be balanced [4]-[6].

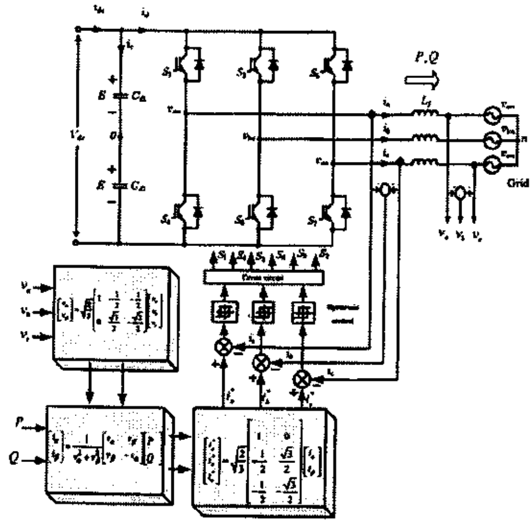

Fig. 2. Current Controlled Techniques for PWM Converter.

From fig. 2 the grid voltage can be written to equation 1

$$v_{grid} = v_{conv} + v_L \tag{1}$$

The active and reactive power flow between grid side and converter side can be written to equation 2 and 3

$$P = \frac{V_{grid}^2}{\omega L}\left(\frac{V_{conv}}{V_{grid}}\sin\delta\right) \tag{2}$$

$$Q = \frac{V_{grid}^2}{\omega L}\left(1 - \frac{V_{conv}}{V_{grid}}\cos\delta\right) \tag{3}$$

Where apparent power is

$$S = vi^* = P + jQ \tag{4}$$

The instantaneous real and imaginary power is part to the instantaneous complex power defined equation 5

$$S = (v_\alpha i_\alpha + v_\beta i_\beta) + j(v_\beta i_\alpha + v_\alpha i_\beta) \tag{5}$$

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} \tag{6}$$

The instantaneous power of the theory

$$\begin{bmatrix} P \\ Q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \tag{7}$$

In the following explanation, the currents will be set as functions of voltage and the real and imaginary power and . This is very suitable for better explaining the physical meaning of the powers defined in the theory, it is possible to write

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_\alpha & v_\beta \\ v_\beta & -v_\alpha \end{bmatrix} \begin{bmatrix} P \\ Q \end{bmatrix} \tag{8}$$

The inverse Clark transformation can be decomposed into the sum of two terms, as follows

$$\begin{bmatrix} i_a^* \\ i_b^* \\ i_c^* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \tag{9}$$

4. Experimental setup

The experimental setup as shown from Fig. 1, mainly consists of a dSPACE DS1104 DSP controller board, a Pentium IV 1.5 GHz PC with Windows XP, a PWM converters, 3-phase reactors connected and a four-pole synchronous generator is given a three phase generator which has the detail as follows: 1 kW, 380 V, 3 A. A 3600 pulse/rev incremental encoder for rotor speed of generator measurement is used. The DS1104 board is installed in Pentium IV PC. The control program is written in Simulink environment combined with the real-time interface of the DS1104 board. The main ingredient of the software used in the laboratory experiment is based on Matlab/Simulink programs. The control law is designed in simulink and executed in real time using the dSPACE DS1104 DSP board. Once the controller has been built in Simulink block-set, machine codes are achieved that runs on the DS1104'TMS320 F240 DSP processor. While the experimental is running, the dSPACE DS1104 provides a mechanism that allows the user to change parameter online. Thus, it is possible for the user to view the real process while the experiment is in progress. A dSPACE connector panel (CP1104) provides easy access to all input and output signals of the DS1104 board. The current control of the PWM voltage source converters is controlled by the hysteresis current which is suitable for the desired control range [7].

5. Overall System Performance and Discussions

The experimental performance results of the proposed drive are illustrated in case of voltage and current waveforms at various points of the system for the proposed power output of inverter at Vdc 400 V and 600 V from boost chopper circuit respectively. These waveforms were recorded by the dSPACE Controldesk software to save the data to work space of Matlab/Simulink program. Supply phase voltage and grid current waveforms of PWM converter is measured by LEM sensors where the ratio of a voltage sensor is 100V/DIV and a current sensor is 1A/DIV respectively.

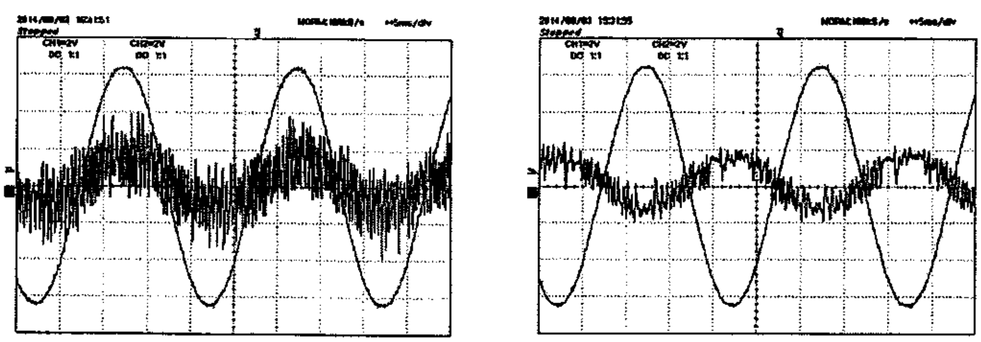

Fig. 3. .Phase voltage, line current and instantaneous power waveforms at Vdc 400 V.

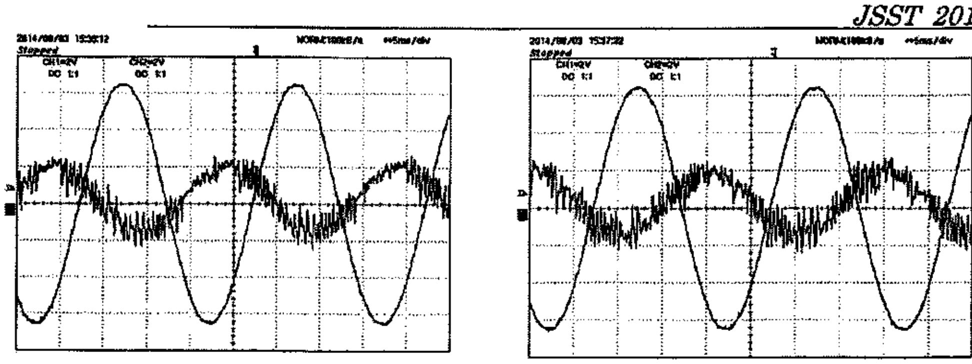

Fig. 4. Phase voltage, line current and instantaneous power waveforms at Vdc 600 V.

6. Conclusions

In this paper, a synchronous generator for wind turbine applications can be applied with the grid connected PWM voltage source converter using current control technique. For the experimental results testing, 1 kW synchronous generator can be increate voltage by current of field excited and boost chopper in DC link. The wind simulator of system can be simulated the velocity of wind turbine by using change the speed of motor driver. The wind energy conversion system an synchronous generator converts the mechanical energy into electrical energy which is converted entirely by A B6 rectifier and a boost chopper circuit then it path through grid connected by PWM voltage source converter. As it has been discussed, the PWM voltage converters were the simplest control.

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