

Research on Grid Side PWM Control of Synchronous Permanent Magnet Wind Power Generation System

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Abstract

Wind power generation is one of the most mature and scale development conditions of new energy power generation technology. In this paper, the MW class direct drive permanent magnet synchronous wind generator, which is widely used in wind power generation system, is taken as the research object. The control system of direct drive permanent magnet synchronous wind power generation with dual pulse width modulation (PWM) control of AC-DC-AC voltage type inverter is introduced in the main circuit of grid connected system. The mathematical model of permanent magnet synchronous motor (PMSM) is analyzed in detail. Combined with the characteristics of wind turbine, the maximum wind power tracking control strategy with the given optimal power is studied. The mathematical model of grid side converter is analyzed, and the control strategy of grid side converter is studied.

Keywords

Wind power generation; permanent magnet direct drive; PWM.

1. Introduction

Wind energy is a kind of clean and sustainable energy. Compared with traditional energy, wind power generation does not rely on mineral energy, has no fuel price risk, stable power generation cost, and does not include environmental costs such as carbon emissions. In addition, the available wind energy is widely distributed around the world. Because of these unique advantages, wind power has gradually become an important part of the sustainable development strategy of many countries, and has developed rapidly. Wind power generation system is composed of wind turbine, control device, monitoring and display device, etc. Wind turbine is the equipment to realize energy conversion, which includes two parts. One is wind turbine, whose function is to convert wind energy into mechanical energy, and the other is generator, whose function is to convert mechanical energy into electrical energy. There are two main operation modes of modern wind turbine: one is independent operation mode, the other is grid connected operation mode. The independent operation mode is to convert the power output of wind turbine after rectification to meet the load requirements and supply the load directly. This method is often used in islands, remote rural areas and pastoral areas. At present, large-scale wind power generation units adopt the mode of grid connected operation. Grid connected operation is to directly or indirectly send the power generated by wind turbines into the grid, and then the power is distributed to users by the grid.

2. Permanent Magnet Direct Drive Wind Power Generation System

The wind wheel of direct drive wind power generation system is directly connected with the permanent magnet synchronous generator, without the need of speed up gearbox. Firstly, the wind energy is converted into alternating current with frequency and amplitude variation, which is converted into DC after rectification, and then transformed into three-phase constant amplitude alternating current by three-phase inverter and connected to the power grid. The

active power and reactive power of the system are controlled by the intermediate power electronic conversion link to realize maximum power tracking and maximum efficiency utilization of wind energy.

There are different topologies of power electronic converter in direct drive wind power generation system. This paper adopts double PWM structure. Figure 1 is a topology of direct drive wind power generation system based on Dual PWM converters. PWM converters are used in both generator side and grid side. In this system, the output voltage of generator can be transformed into stable DC voltage through PWM rectifier, and then connected to power grid through PWM inverter. The output voltage of the inverter is controlled by inverter, and the active power and reactive power of the system are controlled by PWM converter. Using PWM rectifier to control the generator stator current can make better use of the characteristics of permanent magnet synchronous generator, with good control performance and low harmonic content, but the control is complex and the cost is high. With the continuous development of control technology and the continuous improvement of power electronic component technology and the continuous decline of cost, the application of this kind of wind turbine will be more and more widely, and is gradually It is an important direction for the future development of large direct drive wind power system to develop from small and medium-sized wind turbines to large-scale wind turbines. This paper mainly studies the control of grid side converter.

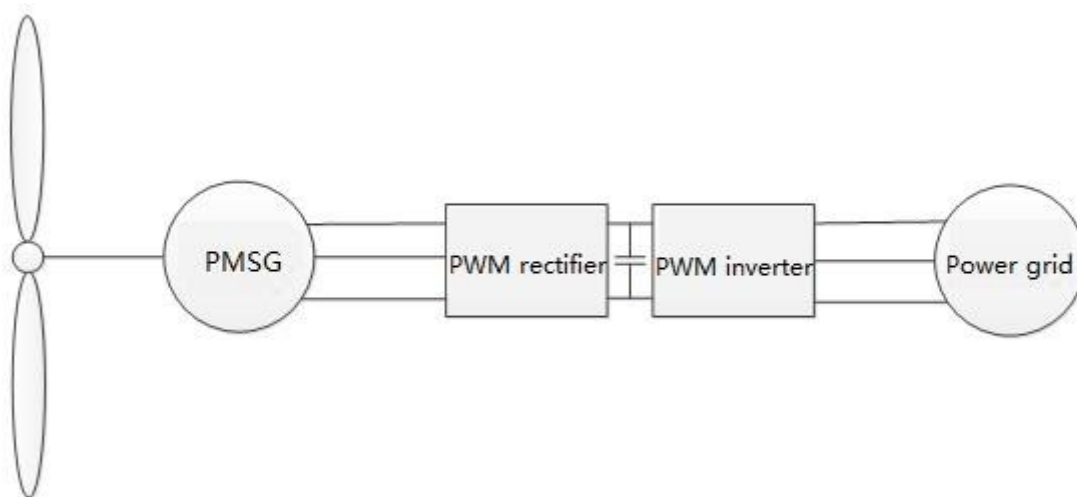


Fig 1. Block diagram of Dual PWM permanent magnet synchronous wind power system

Dual PWM permanent magnet direct drive wind power generation system mainly includes four parts: wind turbine, permanent magnet synchronous generator (PMSG), full power converter and unit control system. The full power converter system can be divided into generator side converter, DC link and grid side converter. The PWM converter on the grid side completes the feed control to the grid and realizes the sinusoidal current control of unit power factor.

3. Mathematical Model of Grid Side Converter

Under normal working conditions, the grid side converters are in inverter mode, which inverts the voltage and current from DC side into AC that meets the requirements of combined grid. As shown in Fig.3, the structure diagram of three-phase voltage source grid connected inverter used in wind power generation system is shown.

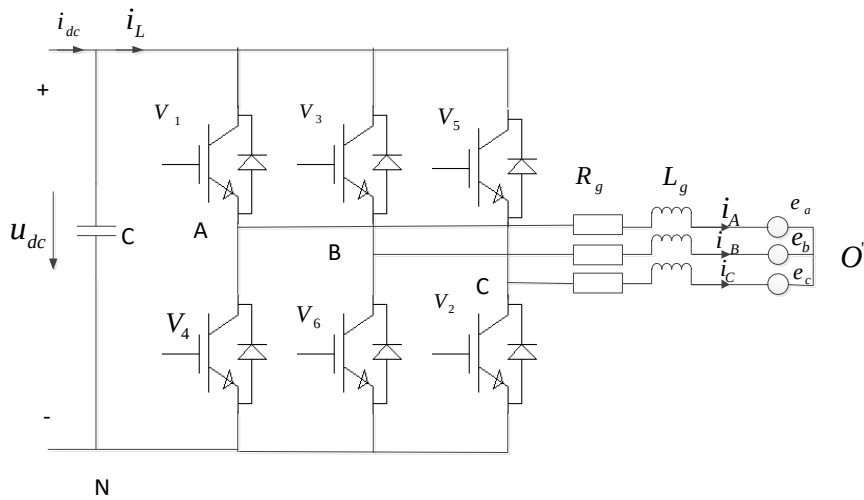


Fig 2. Three phase voltage source inverter circuit structure diagram

4. Control of Composite Voltage Vector of Grid Side

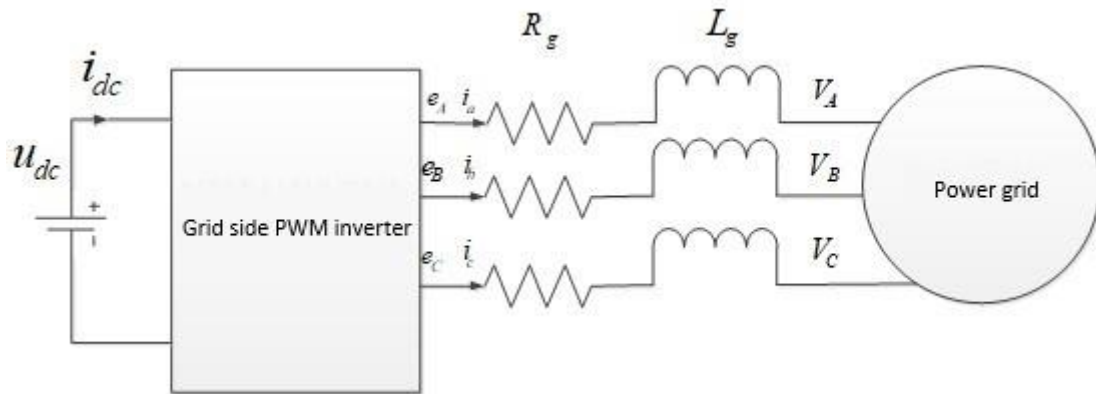


Fig 3. Network side circuit structure

From the above figure, we can get the voltage equation of grid side

$$P \begin{bmatrix} i_A \\ i_B \\ i_C \end{bmatrix} = \frac{-R_g}{L_g} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} i_A \\ i_B \\ i_C \end{bmatrix} + \frac{1}{L_g} \begin{bmatrix} e_A - V_A \\ e_B - V_B \\ e_C - V_C \end{bmatrix} \quad (1)$$

The active power and reactive power absorbed by the grid side can be expressed as

$$P = \frac{3}{2} (V_d i_d + V_q i_q) \quad (2)$$

$$Q = \frac{3}{2} (-V_d i_q + V_q i_d) \quad (3)$$

If the d-axis of dq two-phase rotating coordinate system is oriented on the composite vector of grid voltage, and the direction of leading d-axis is defined as q-axis, then there is

$$\begin{cases} \vec{V}_d = \vec{V}_g \\ \vec{V}_q = 0 \end{cases} \quad (4)$$

The composite vector of current is also decomposed on the dq axis, which is defined as active current in the direction of d axis and reactive current in the direction of q axis

$$P = \frac{3}{2} |V_g| i_d \quad (5)$$

$$Q = -\frac{3}{2} |V_g| i_q \quad (6)$$

It can be seen from the above formula that the active power P and reactive power q are only related to i_d and i_q respectively, which realizes the decoupling of active power and reactive power.

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$$P \begin{bmatrix} i_d \\ i_q \end{bmatrix} = \begin{bmatrix} -\frac{R_g}{L_g} & \omega \\ -\omega & -\frac{R_g}{L_g} \end{bmatrix} \begin{bmatrix} i_d \\ i_q \end{bmatrix} + \frac{1}{L_g} \begin{bmatrix} e_d - |V_g| \\ e_q \end{bmatrix} \quad (7)$$

It can be seen from the above formula that i_d and i_q are also coupled. The decoupling control chart is shown in Fig. 4.

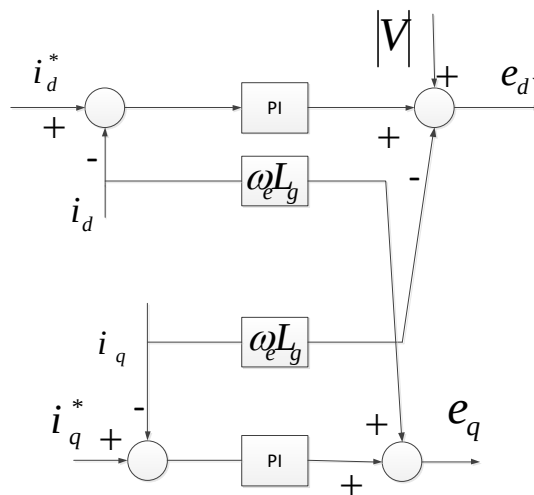


Fig 4. Decoupling feedback control of power grid side

The overall control structure of Dual PWM step permanent magnet wind power generation system is shown in Fig.5. The grid side control strategy is the given closed-loop of DC voltage and reactive power of the outer loop, and the inner loop is the double closed-loop control of current loop. In this control strategy, the voltage of the intermediate DC bus is stabilized by the

grid side, and the grid side is also responsible for regulating the power factor of the grid. Q^* is the given value of reactive power. When the given value of reactive power $Q^* = 0$, the power factor of the grid side is 1, which realizes the unit power factor control of the grid side. The main task of the generator side is to track the maximum wind energy according to the optimal speed. In order to achieve the maximum wind energy capture, the command value of the generator adjusts the electromagnetic torque of the generator and then controls the speed.

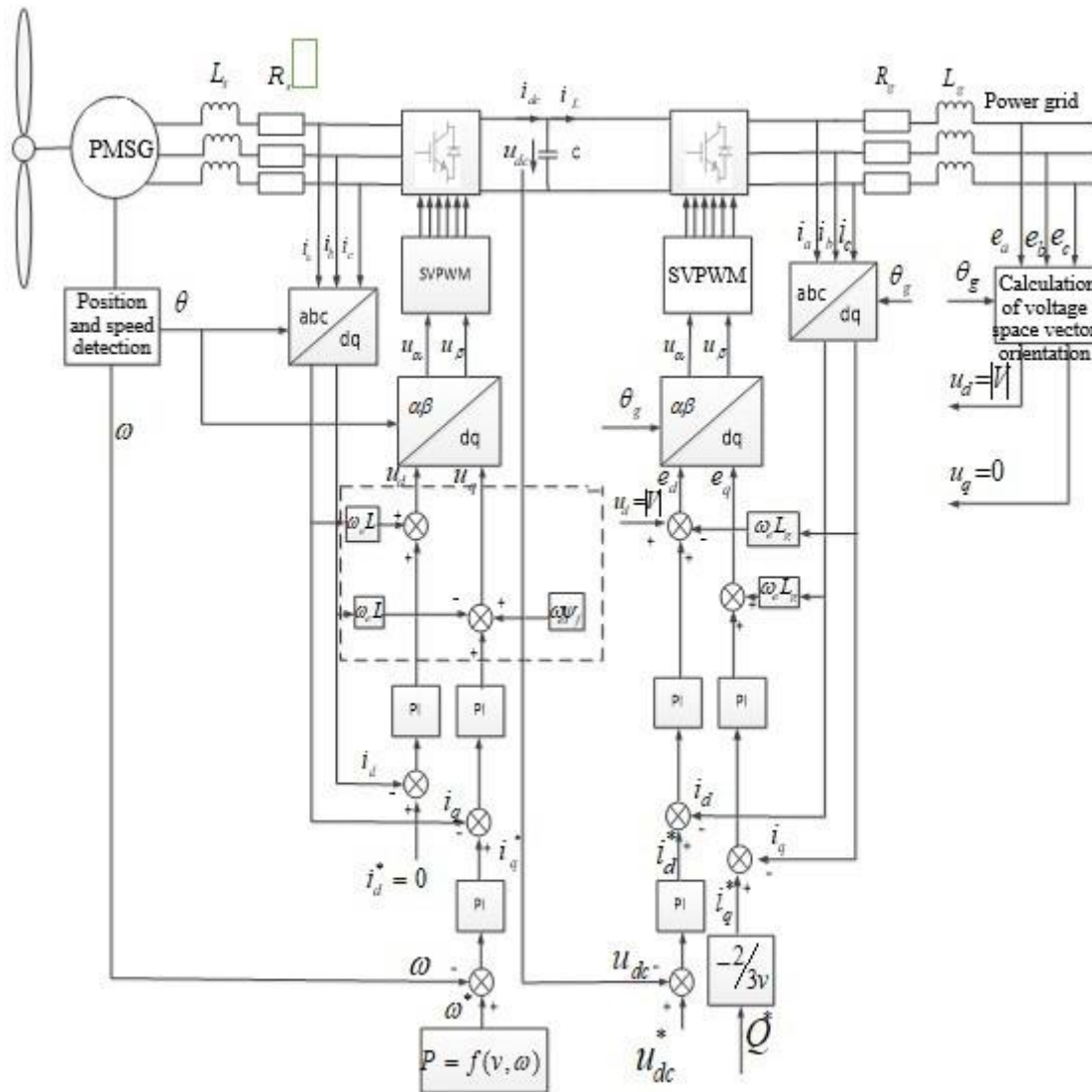


Fig 5. Block diagram of speed control network side voltage stabilizing control system

5. Simulation

In the MATLAB / Simulink environment, the control strategy of speed control and network side voltage stabilization control is simulated. The system simulation parameters are as follows: pole pairs of permanent magnet motor is 16, DC bus voltage reference value is 1000V, DC side capacitance is 0.0047f, and motor inductance parameters

$$L_d = L_q = 8.5 \times 10^{-3} H, \text{ Incoming inductance } L_s = 1mH, R_s = 0.28\Omega.$$

The system simulation diagram is shown in Figure 6. It can be seen from Figure 7 that the DC side voltage is basically constant 1000V, and figure 8 is the actual value of the reactive power at the network side, which fluctuates around the value of 0 throughout the simulation process,

which is basically consistent with the given value 0 of the grid side reactive power, making the network side power factor close to 1.

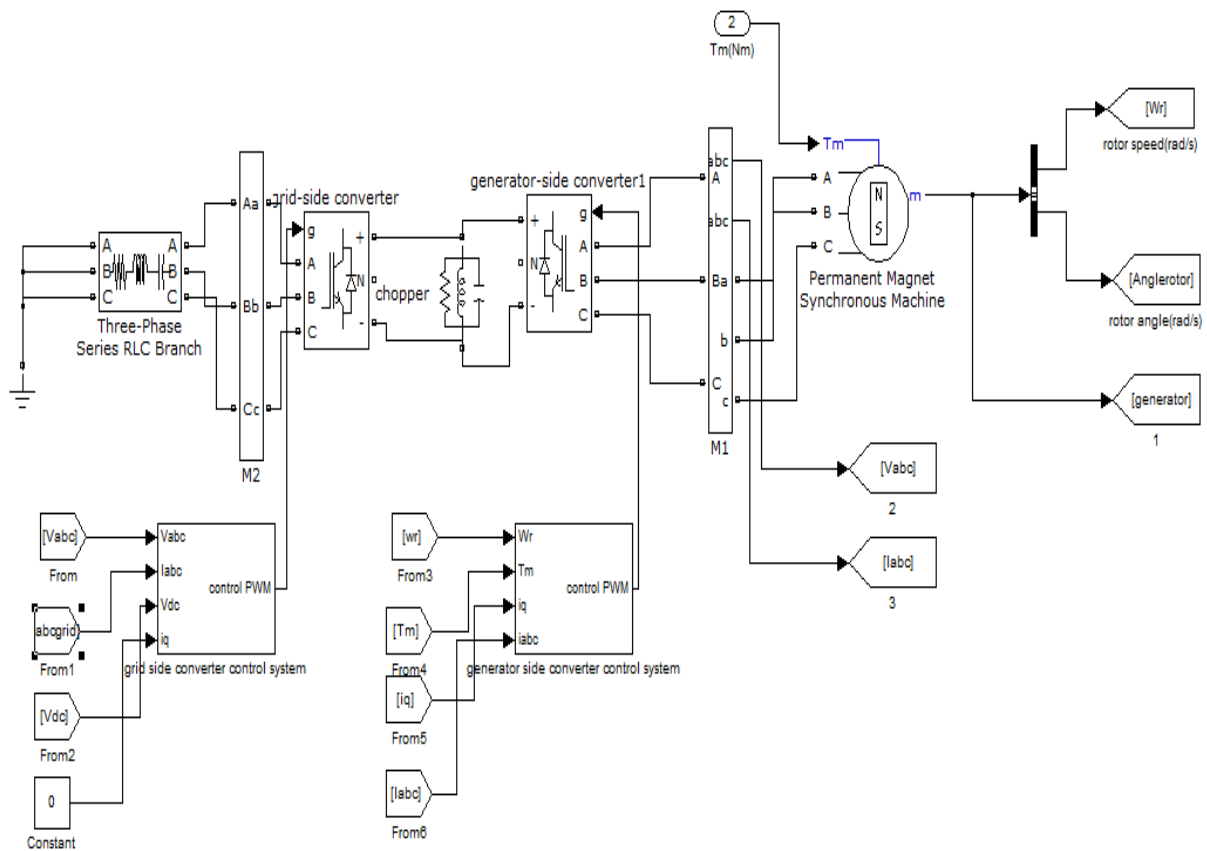


Fig 6. Simulation diagram of Dual PWM step permanent magnet wind power generation system

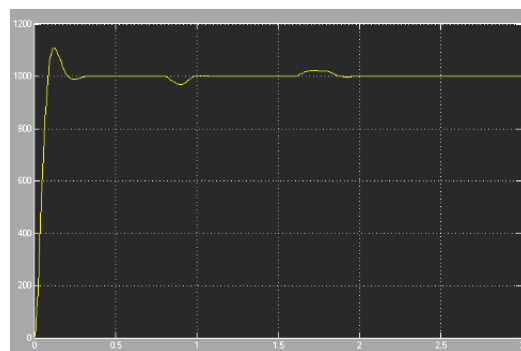


Fig 7. DC bus voltage

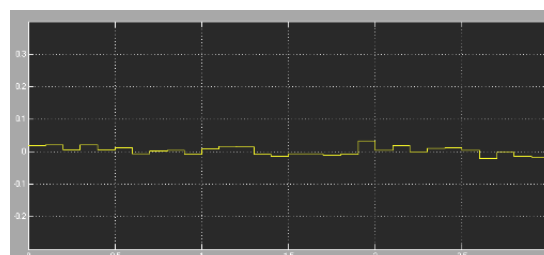


Fig 8. Reactive power Q at network side

6. Conclusion

Based on the detailed analysis of the operation principle of wind turbine, this paper introduces the dual PWM step permanent magnet wind power generation system, and establishes the mathematical model including permanent magnet synchronous motor, generator side rectifier, grid side inverter and intermediate DC link. Based on the detailed introduction of vector control method of generator side permanent magnet synchronous generator, the control strategy of Dual PWM permanent magnet direct drive wind power system is given. According to the difference of function and control between generator side converter and grid side converter, rotor field oriented control is adopted to realize speed control of permanent magnet synchronous motor Maximum wind energy tracking; grid voltage oriented vector control is adopted at the grid side to realize the stable control of unit power factor and DC bus voltage. The wind turbine model and SVPWM model are established in the MATLAB / Simulink environment. The overall simulation results of the dual PWM structure are good. The DC bus voltage has good stability under dynamic conditions, and the AC side current harmonic is less, which verifies the correctness of the control strategy.

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Project Name: Research on LCL control stability technology of grid connected inverter.

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