IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 4, Issue 6, January 2016)

Simulation of Wind Turbine System and Performance Evolution of PMSG using MATLAB

Vishu Choudhary
Vishu.brijeshchoudhary@gmail.com

Aakash Jain
aakashjain6851@gmail.com

Abstract – **In this paper we are making a model control of direct driven 2 MW wind turbine permanent magnetic synchronous generator (PMSG) which feeds alternating current (AC) power to the utility grid. The machine side converter is used to extract maximum power from the wind, and also WECS is done by using a constant speed direct-driven wind turbine in MATLAB. The proposed wind turbine and energy storage system supplies and delivers the power absorbed by the connected loads. Thus the resulting system has low cost and higher reliability. In order to obtain the maximum power point tracking, the duty cycle of DC-DC boost converter switch controlled by the measurement of DC current and DC voltage, for simulate wind turbine with PMSG MATLAB test bench is created.**

Keywords – **MSG, DC-DC boost converter, WECS, SCIG.**

I. INTRODUCTION

In wind energy conversion systems (WECSs), the key technologies include wind turbine technology, power electronics technology, and system control technology. For the wind turbines, based on the orientation of the rotation axis of the wind turbine, there are horizontal-axis wind turbines and vertical-axis wind turbines [6]. In the horizontal-axis wind turbines, the rotation axis of the wind turbine is parallel to the ground, while in the vertical-axis wind turbines, the rotation axis is perpendicular to the ground. Compared to the vertical-axis wind turbines, horizontal-axis wind turbines have higher wind energy conversion efficiency, which are widely applied in the wind energy industry. The wind turbines can also be classified as fixed-speed wind turbines and variable-speed wind turbines based on whether the operation speed is controllable. The fixed-speed wind turbines possess the merits that they are simple, robust, and require lower construction and maintenance cost. However, their operation speed is fixed and cannot be controlled with the variation of the wind speed, which results in lower energy conversion efficiency compared to the variable-speed wind turbines. Nowadays, most of the wind turbines .applied in industry are variable-speed wind turbines. Among various types of variable-speed WECSs, three kinds are most widely applied in industry: (1) doubly-fed induction generator (DFIG) WECSs with reduced-capacity power converters, (2) geared/gearless squirrel-cage induction generator (SCIG) WECSs with full-capacity power converters, and (3) geared/gearless wound-rotor synchronous generator (WRSG)/permanent magnet synchronous generator (PMSG) WECSs with full-capacity power converters [6]. In the DFIG WECSs, only 30% of the rated power is processed by the power converters, which greatly reduces the cost of the converters while preserving the capability to control the speed of the generator in the range of about of its rated speed [6]. In SCIG, WRSG and PMSG WECSs, full-capacity power converters are needed to process the power generated by the generators up to the rated power of the systems. With the application of the full-capacity power converters, the generators are fully decoupled from the grid, and are able to operate in the full speed range. As the large scale wind turbines (up to 10 MW) attract more and more attention nowadays, the direct-drive PMSG based WECSs which are very suitable for large scale wind plants have become a "hot topic". In this paper, the control algorithms for the direct-drive wind turbine PMSG systems are studied and simulated. The direct-drive wind turbine PMSGs do not have the gearbox between the wind turbine and the PMSG rotor shaft, which avoids the mechanical power losses caused by the gearbox. Moreover, the removal of the gearbox also helps in reducing the cost of the system. The overall configuration of a direct-drive wind turbine PMSG system. As can be seen in this figure, this system is composed of a wind turbine PMSG, a rectifier, and an inverter. The wind turbine PMSG transforms the mechanical power from the wind into the electrical power, while the rectifier converts the AC power into DC power and controls the speed of the PMSG. The controllable inverter helps in converting the DC power to variable frequency and magnitude AC power. With the voltage oriented control algorithm, the inverter also possesses the ability to control the active and reactive powers injected into the grid For the control of direct-drive PMSG systems, the information of the rotor position and speed is needed to implement the advanced control algorithms such as the field oriented control (FOC) and direct torque control (DTC). Conventional methods to acquire the rotor position and speed information are based on an encoder or a transducer mounted on the rotor shaft. However,

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such electrical speed sensors increase the hardware complexity and system cost. In addition, the rotor mounted sensors have to endure the constant oscillations of the rotor shaft, which reduces the reliability of the system. According to [7], speed sensor failures cause more than 14% of failures in such WECSs. The malfunction of the speed sensor will cause the breakdown of the whole system, which will contribute to considerable losses in power production. Moreover, the repair of the failed components results in additional cost. Based on this issue, this paper proposes a back EMF based rotor position and speed sensor less control algorithm, which will be analysed later.

II. WIND GENERATION SYSTEM

Wind power uses the force of the wind to drive a turbine which drives a generator to produce electricity. Wind power is renewable because it is created by the energy from the sun that drives the earth's weather patterns. Typically, turbines are clustered in "wind farms" scattered throughout reliably windy areas and often share space with productive agricultural lands. These large installations supply electricity to regional power grids for sale to homes and businesses. Smaller installations to meet specific needs are also common where grid electricity is not available. Wind farms, like other large scale electricity generation facilities, are connected to the electricity grid. It is delivered to homes and businesses just like other sources of electricity.

III. WIND TURBINES

A wind turbine is a rotating machine which enables the conversion of kinetic energy in wind into mechanical energy. If the mechanical energy is used directly by machinery, such as a pump or grinding stones, the machine is usually called a windmill. If the mechanical energy is then converted to electricity, the machine is called a wind generator, wind turbine, wind power unit (WPU), or wind energy converter (WEC).

Virtually all modern wind turbines convert wind energy to electricity for energy distribution. The turbine can be divided into three components. The rotor component, which is approximately 20% of the wind turbine cost, includes the blades for converting wind energy to low speed rotational energy. The generator component, which is approximately 34% of the wind turbine cost, includes the electrical generator, the control electronics, and most likely a gearbox component for converting the low speed incoming rotation to high speed rotation suitable for generating electricity. The structural support component, which is approximately 15% of the wind turbine cost, includes the tower and rotor pointing mechanism. For a given temperature and pressure, the power contained in the wind at a particular site is proportional to the cube of the wind speed. Ideally, the maximum power that a turbine can extract is 0.593, the *Betz coefficient*, times the power contained in the wind. However, the maximum extractable power from a practical turbine is limited to 35 – 40 % of the wind power. For a given turbine, this limit is achievable for a specific ratio of the turbine's rotational speed to the wind speed. At other ratios, the turbine output reduces. So, with constant change in wind speed, a natural occurrence, it is desirable for the turbine speed to be adjustable to the wind speed in order to maximize the output.

IV. SIMULATION RESULT

To simulate the WIND ENERGY GENERATION SYSTEM WITH PMSG system a MATLAB test bench is created.

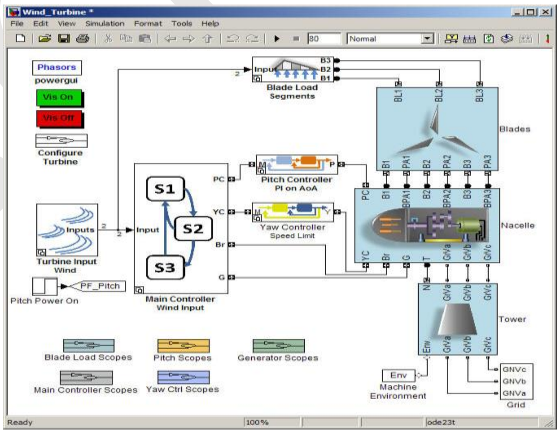

Fig 1: Simulation of wind energy generation system

Simulation Model of PMSG

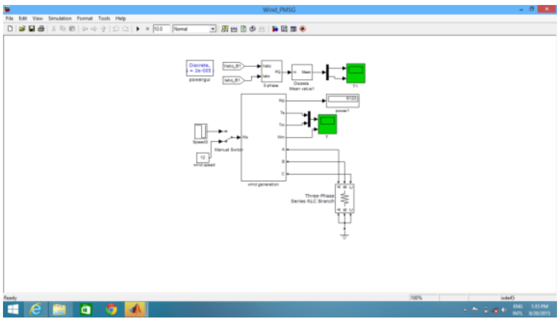

Fig 2: Simulation model of PMSG

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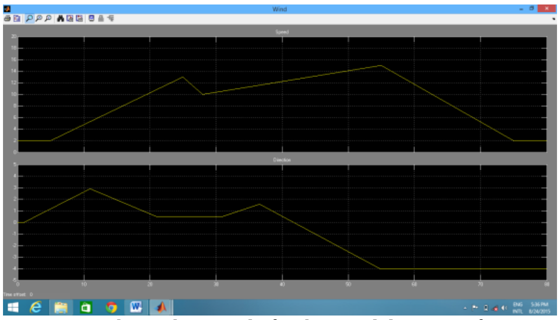

Fig 3: Shows that speed of turbine and direction of air

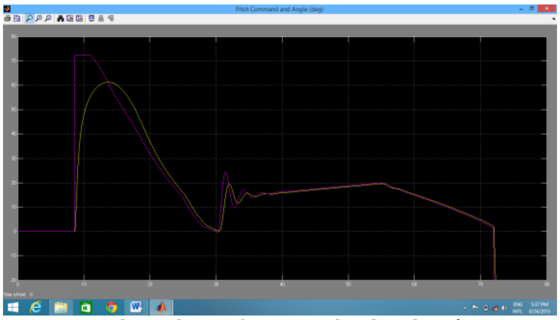

Fig 4: Shows that pitch command and angles of rotor

V. CONCLUSION

In this paper, several important control algorithms for the wind turbine for PMSG systems were studied and analyzed. In order to further validate the control methods, the control algorithms were applied to a case study 2 MW wind turbine PMSG system and a simulation study was performed in this paper. For the generator-side converter control, the optimal tip-speed ratio based MPPT control algorithm and vector control method were applied. From the simulation results, the MPPT method has shown the capability of controlling the wind turbine PMSG to generate the maximum power at different wind speeds. In addition, the high dynamic performance of the vector control method was also indicated in the simulation results, that is, when the wind speed changed, the generator speed which was controlled by the vector control algorithm reacted to the wind speed change very fast. Thus, for the wind turbine PMSG systems require high dynamic performance and high power capture efficiency, the optimal tip-speed ratio based MPPT control and vector control algorithms are qualified candidates.

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