SIMULATION AND INVESTIGATION OF INDUCTIVE LOAD AFFECTING ON GRID CONNECTED FOR WIND TURBINE USING PMSG

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ABSTRACT

Permanent Magnet Synchronous Generator (PMSG) is widely used to connect to wind turbine system. To generate electricity from wind turbine with PMSG for three-phase of grid connected, the mechanical energy is transformed into electrical energy. The simulation system is designed based on grid connected with PMSG with inductive load. This load is connected to the grid side of the system. The objective of this paper is to investigate the behaviour of voltage, current and active power including an effect of implementing inductive load. The simulation results show that the voltage, current and active power interactive between inverter and grid for grid supplies to the load. Including inductive load, the system can maintain the voltage from PMSG by the DC to DC converter circuit, constantly. Therefore, the inductive load has affected to the wind turbine system using PMSG on grid connected.

KEYWORDS: *Simulation Wind Turbine; Inductive Load; Grid Connected; PMSG*

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INTRODUCTION

In recent year, renewable energy from the wind is sustainable and clean. The wind turbine technology has been developed and widely used in various areas such as desert, ocean and mountain. During the past decades, the wind energy has increased to 30 percent compared to total renewable energy [1]. The wind turbine, used to transform kinetic energy of the wind to a mechanical energy is able to inertial energy in the blades and operating with generator. The mechanical energy from the rotation axis of the wind turbine is converted to electrical energy. The generator is connected to the axis of rotation of the wind turbine and then the electricity flows through the electrical control system and the power supply system. The amount of electricity depends on the speed of the wind [2]. Permanent Magnet Synchronous Generator (PMSG) based on a principle of transforming the mechanical energy into electrical energy is generally utilized as a synchronous generator. It does not have a field coil and a slip ring. Moreover, it has light weight, small and low inertia when it compares to a generator at the same coordinates [3].

In this paper, the objective is to investigate the behavior of voltage and effect of an inductive load which is included on grid connected to wind turbine using PMSG. The modeling and simulation of the grid side of a wind turbine system have been designed and implemented by MATLAB/Simulink.

MATERIALS AND METHODS

Permanent magnet synchronous generator (PMSG)

PMSG is high efficiency and it does not require the power for excitation source. To generate the electromotive force, it is in proportion to rotational speed. Fig.1 (a) shows equivalent circuit per phase that is an inner circuit of generator system to estimate the current, I_g and voltage of PMSG, V_g and phasors diagram shows in Fig1 (b).

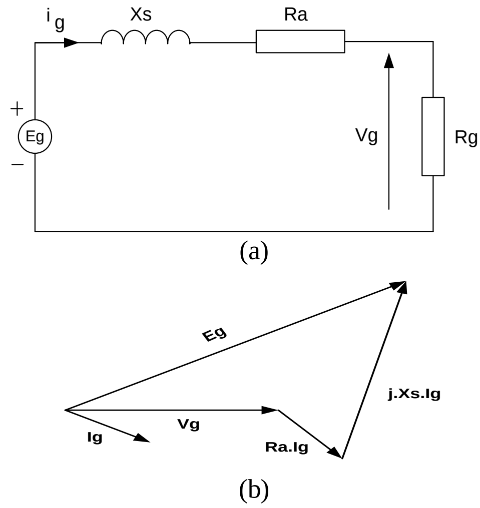

Fig. 1 PMSG diagram of (a) equivalent circuit per phase; (b) phasors diagram [4].

The DC-to-DC Converters

Direct current (DC) could provide a constant voltage or current and it is defined as the current only flows in one direction. Voltage and current may flow over time which the direction of flow does not change. Rectifying an AC voltage source can receive an unregulated dc voltage from PMSG. It needs to use a DC-to-DC converter to control the unregulated DC voltage to be a constant [5].

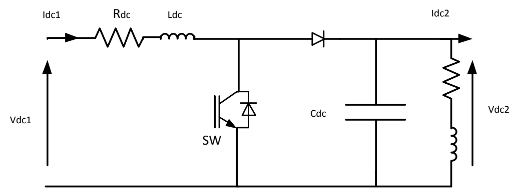

Fig. 2 Boost DC to DC converter.

Fig. 2 shows a boost DC to DC converter which has been controlled to be a constant output DC voltage level V_{dc1} is a voltage direct current by varying the duty ratio. D is a diode in response to variations in V_{dc2}.

In Fig. 2, the relation between the input and output voltage and currents of the boost converter can be written as equation (1) and (2), respectively.

$$V_{dc2} = \frac{1}{(1-D)} V_{dc1} \tag{1}$$

$$I_{dc2} = (1-D) I_{dc1} \tag{2}$$

Where I_{dc1} and I_{dc2} are input and output currents, respectively.

In boost Boost DC to DC converter circuit, the input current is defined as

$$I_{dc1} = \frac{V_{dc1}}{R_{dc1}} \tag{3}$$

where R_{dc1} is the load resistance.

The propose of grid connected for wind turbine using PMSG

According to Fig.3, Provincial Electricity Authority (PEA) system has 380 V and 50 Hz.. A wind turbine can transform kinetic energy to mechanical energy, by PMSG. It can convert mechanical energy to electricity, AC voltage and currents. These are transformed by rectifier circuit. The DC to DC converter maintains the voltage, current and active power. The inverter circuits convert DC to AC voltage and currents. These are equal to voltage and currents of PEA.

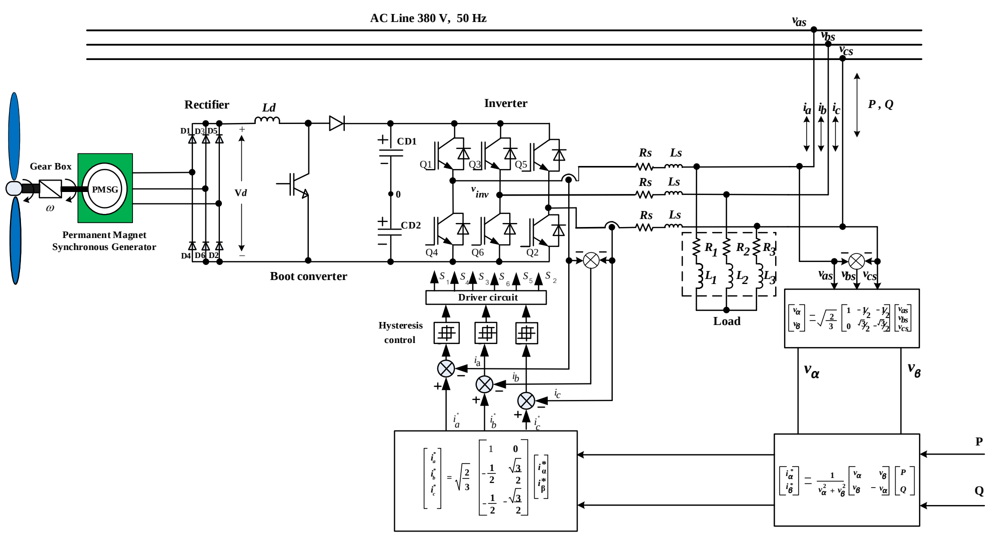

Fig. 3 Diagram of PMSG system for wind turbine.

By mathematical transfor mation clark transformation convert frame from stationary *a-b-c* frame to stationary $\alpha-\beta$ frame. Clark transformation of d-q system can be defined as

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_{as} \\ v_{bs} \\ v_{cs} \end{bmatrix} \quad (4)$$

In stationary $\alpha-\beta$, the real voltage v_α and imaginary voltage v_β are multiplied with to command currents i_α and i_β Hence. The instantaneous power of the $P-Q$ is given as

$$\begin{bmatrix} P \\ Q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \quad (5)$$

In stationary $\alpha-\beta$, instantaneous currents can be formulated as

$$\begin{bmatrix} i_\alpha^* \\ i_\beta^* \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_\alpha & v_\beta \\ v_\beta & -v_\alpha \end{bmatrix} \begin{bmatrix} P \\ Q \end{bmatrix} \quad (6)$$

Where i_α^* and i_β^* are command currents

The command currents, i_a^*, i_b^*, i_c^* in stationary a, b, c frame can calculated by inverse Clark transformation as

$$\begin{bmatrix} i_a^* \\ i_b^* \\ i_c^* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_\alpha^* \\ i_\beta^* \end{bmatrix} \quad (7)$$

Simulation of grid connected for wind turbine using PMSG

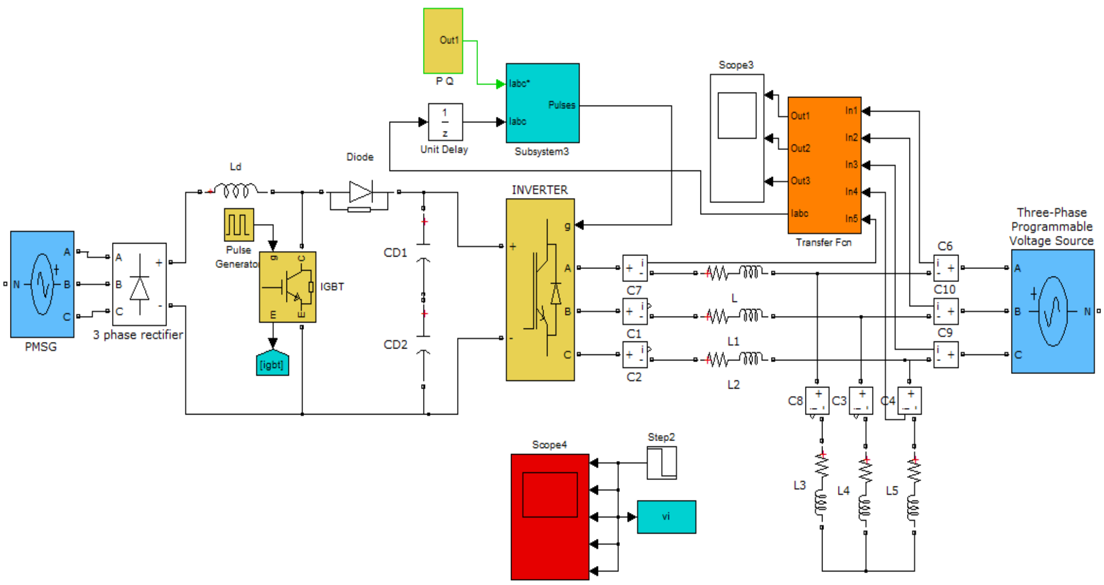

Fig. 4 Shows the simulink diagram of mind turbine based on PMSG.

RESULTS AND DISCUSSION

Fig. 5 shows the simulation results of the difference characteristics of wind turbine by PMSG. This simulation system has inductive load. Fig. 5(a) has the range of power between -2000 to 2000 watt at time 0.2 sec where the power is back to negative power. Fig. 5(b) shows initial V_{grid} that is ±380 voltage. From Fig. 5(c), it has a current lagging. In considering I_{inv} in Fig. 5(d), if the power is 2000 watt then is in phase. After 0.2 sec I_{inv} is out of phase with I_{grid}. However, the currant, I_{load} in Fig. 5(e), is in phase corresponding on I_{grid}. The power of P_{in} in Fig. 5(f), includes the power of P_{grid} in Fig. 5(g). It can maintain the power at P_{load} as showns in Fig.5 (h).

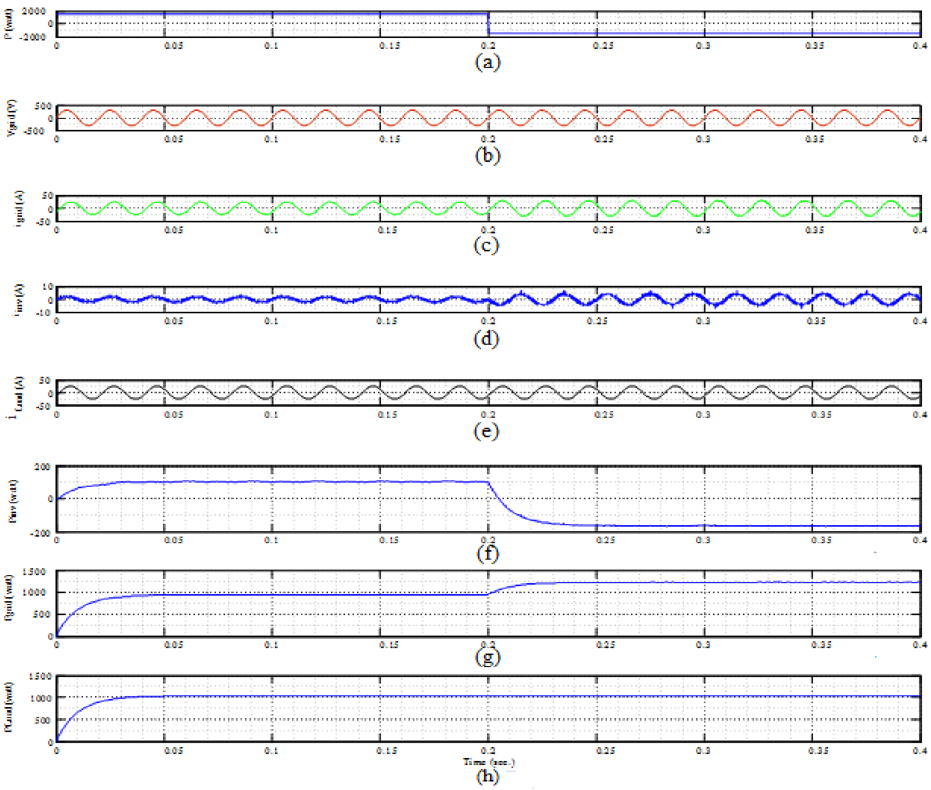

Fig. 5 Diffecnce characteristics of the simulated wind turbine using PMSG with inductive load at Pin ±2000 Watt.

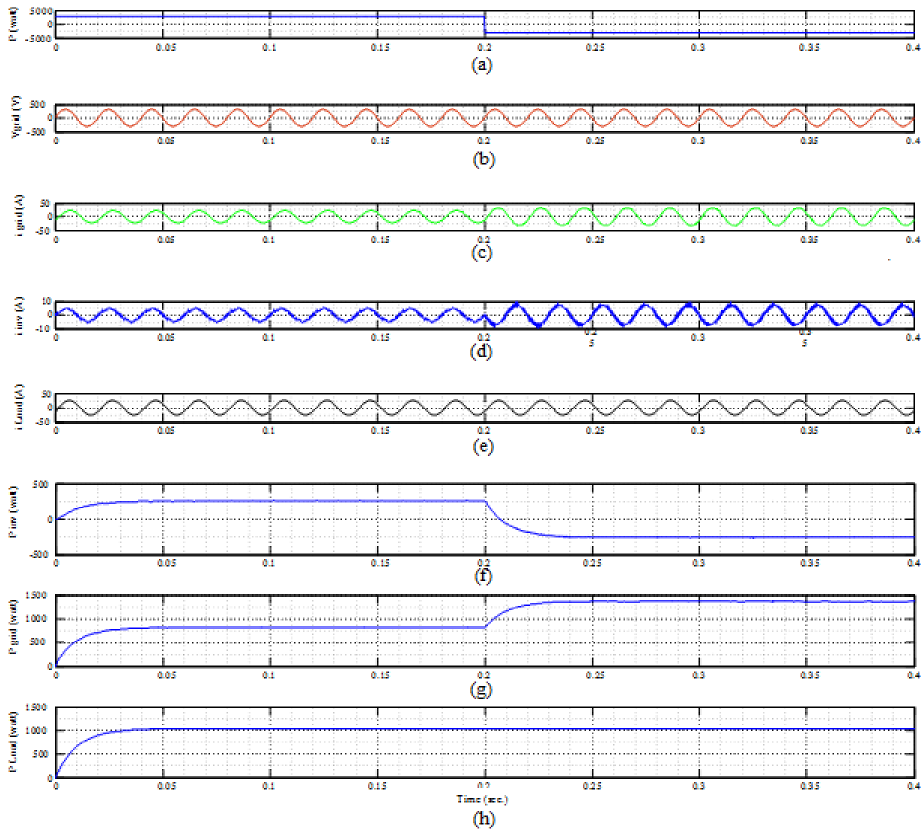

Fig. 6 Diffecnce characteristics of the simulated wind turbine using PMSG with inductive load at pin ±5000 Watt.

As can be seen in Fig.6, the simulation result shows the difference characteristics of wind turbine by PMSG with inductive load. Fig. 6(a) has set the range of power between ± 3000 watt. At 0.2 sec, the power is back to negative power. Fig. 6(b), V_{grid} is initial between 380 to –380 Voltage. According Fig. 6(c), it has a current lagging. In Fig. 6(d), if the power in 3000 Watt such that I_{inv} is in phase to time 0.2 sec, I_{inv} is out of phase. In consequence, the currant in Fig. 6(e), is in phase corresponding to I_{grid}. The power of P_{in} in Fig. 6(f) includes the power of P_{grid} in Fig. 6(g). It can regulate the power at P_{load} in Fig. 6(h).

CONCLUSION

This proposed paper is aim to investigate the inductive load in the simulation system of wind turbine PMSG is applied to transform kinetic energy to electricity. The voltage of PMSG is connected to a rectifier and boot converter. The inverter converts a DC to AC. The simulation results found that the power of PMSG and power of grid connected is utilized supply of the load for balance power. As are result, inductive load has affected.

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