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Performance Analysis of a Grid connected Wind Energy system

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Abstract: - This paper is concerned with the study of a small wind generation system used for battery charging. A topology that aims at the exploitation of maximum energy from the generator, generated at low speed is proposed. The characteristics of the wind turbine and the generator are discussed, providing the overview of the system modeling. Simulation tests of the system are obtained using MATLAB/SIMULINK. We adopt compact permanent magnet type synchronous generator, which doesn't need exciting current, and step- up /down buck-boost chopper to wind power generating system of a few kW output with rotor speed sensor. In addition, we employ rectifier circuit using Diode Bridge instead of AC-DC converter with PWM method and a battery charging system. Using these methods we achieve a simple wind power generation system.

Keyword: - *Wind Generation, Modeling, MATLAB*

I. INTRODUCTION

A wind generation system can be used basically in three distinct applications: isolated systems, Hybrid systems and grid connected systems. Basic characteristics of the systems include a power stage and energy storage capability. Generally, small size isolated systems demand energy storage, by the use of batteries. This paper deals in particular with the study of a wind generation system for battery charging. The complete analysis of the system is presented, and an alternative of optimum control at low speeds so that the extraction of energy occurs in a wide range of wind speedy is also described. Power electronics have an important role for controlling electrical characteristics of wind turbine. For small wind turbine generator in battery charging application DC-DC converter have been used for modifying the electrical load in order to maximize energy generation. Input of DC-DC converter is connected to bridge rectifier and a bulky capacitor (DC bus) and output is connected to battery. Finally the dc power is connected to ac power by inverter and supplied to the local grid. This scheme with proper control algorithm to modify duty cycle of DC-DC converter for maximum energy generation is known as maximum power point tracking. The converter is used to change the apparent DC bus voltage seen by the generator. Thus by controlling the DC converter the terminal voltage of PMSG is adjustable in order to maximize power production. For maximum power transfer in all wind speed the converter must be able to reduce PMSG terminal voltage in low wind speeds. Thus the recommended converter for this type of application must have buck boost voltage characteristics.

II. PROPOSED TOPOLOGY

In this figure 1, we adopt a permanent magnet type synchronous generator, a rectifier circuit for the AC-DC converter. Synchronous generator has many advantages over the induction generator, e.g. no exciting current, high efficiency, etc. Moreover, we use step-up/down buck-boost chopper with smoothing capacitor to control battery charging current. Finally, DC power is converted to AC power by the inverter and step up to required level, and finally supplied to the local grid. Although this chopper is an ordinary one, the load side voltage of chopper keeps constant because battery is connected to the load side. As the generating power, which is kept in the reactor of chopper, is used to charge battery and to supply power to the line, smoothed power supply is achieved. In other case, we can use this battery as power storage unit. For example, we can charge during the night, when small load is demanded, and discharge when required. The advantages of this system are follows:

1. Generated AC power is converted to DC power through simple Diode Bridge rectifier instead of switching devices.
2. As this system has no reverse power flow for step-up/clown buck-boost chopper, many generating units can be in parallel connected to one battery and inverter.
3. As proposed generating unit does not need microprocessor like DSP for the control the system, this unit can be produced in low cost.

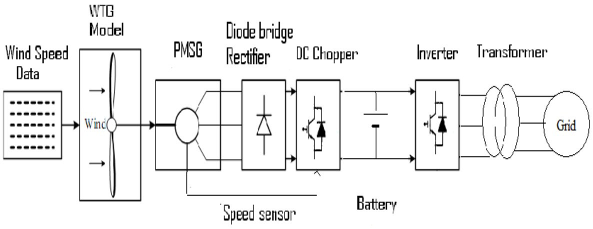

Fig 1 Proposed Block diagram of wind turbine driving permanent magnet synchronous generator with battery storage

III. SYSTEM MODELING

3.1 Generator Characteristics

The electrical machine used in the system is a permanent magnet synchronous generator (PMSG) rated at 1kW, 1000 rpm, 7 pole pairs and axial flux. This type of machine is particularly interesting for applications in wind generation due to its inherent characteristics. Several studies such as those in [2] deal with the characteristics of this machine. The dynamic model of the machine is obtained in [3], described by expressions (1) to (4)

$$T_e = \frac{E_a \cdot I_a + E_b \cdot I_b + E_c \cdot I_c}{\omega_g} \quad (1)$$

$$J \cdot \rho \cdot \varpi_g = T_m - T_e - B \cdot \varpi_g \quad (2)$$

$$\rho \cdot \theta_g = \omega_g \quad (3)$$

$$\rho \cdot \theta_r = P \cdot \omega_g \quad (4)$$

The values considered in the simulation are 0.5 Ω/phase (resistance), 3.35mH (self-inductance) and 3.06mH (mutual inductance).

TABLE 1. SYSTEM CONSTANTS

System constants		
Cd:	22[µF]C	: [2200µF]
Ld:	1[mH],Vb	: 72[V]
Switching	Device	: IGBT
Switching	Frequency	: 4[kHz]

Strategy For Maximum Power Point Tracking

In order to obtain maximum electrical power point, generator characteristics must be considered. Mechanical power produced by wind rotor (Pm) and electrical power produced by PMSG (P_{ca}) verses wm for various speed can be determined by simulation.

The control method of this work is based on the maximum electrical power curve. The aim is to control power generated by PMSG to follow P_{ca} max (wm). The block diagram of maximum power point tracking algorithm is shown. Voltage and current of one phase is measured and modified to determine the instantaneous power. A first low order filter is used to obtain the DC part of power signal which represent the active phase power.

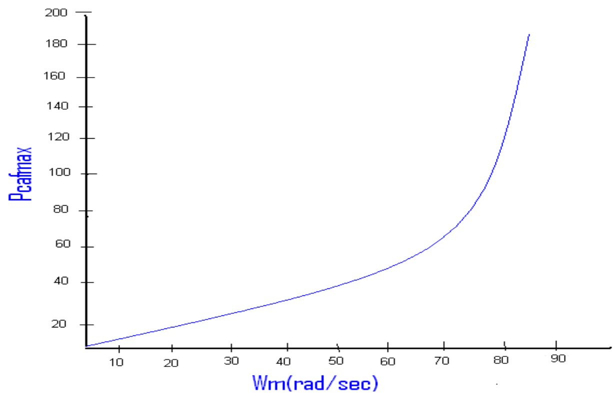

Fig 2.Maximum electrical power of PMSG Versus angular speed wm for one phase

Rotor angular speed (or generator frequency) is measured and used as input parameter of a lookup table containing the maximum power curve of PMSG for one phase. Output parameter of the lookup table is the reference of active power for one phase. Both power signals are subtracted, generating an error signal to PI controller. Control signal modifies the duty cycle the switching device, actively modifying power generated by PMSG

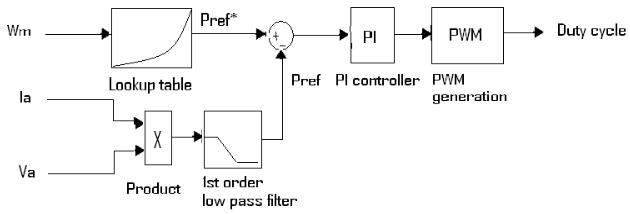

Fig 3. Block diagram of maximum power point tracking control

IV. SYSTEM SIMULATIONS AND RESULT

The system modeling is obtained considering the expressions presented in the previous session. Simulation tests are performed using MATLAB/SIMULINK as shown in Fig.

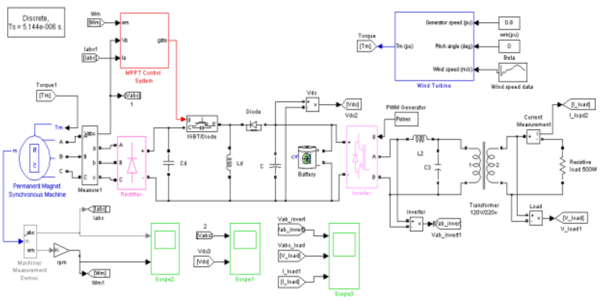

Fig.4 MATLAB/Simulink model wind energy conversion system without MPPT control

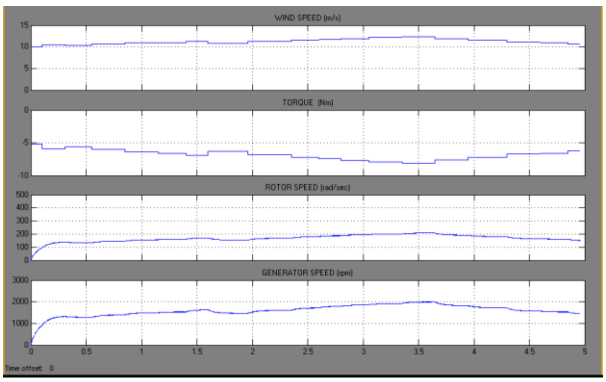

Fig.5 Output waveform at pitch angle β=5 and generator speed ω_m = 1 pu

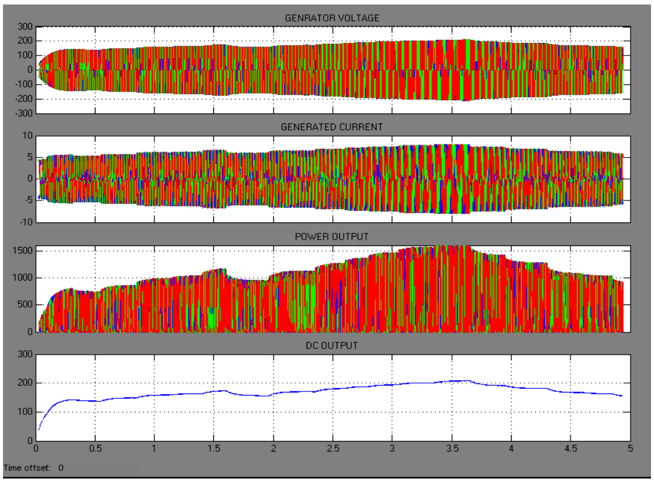

Fig.6 Output waveform at pitch angle β=5 and generator speed ω_m = 1 pu

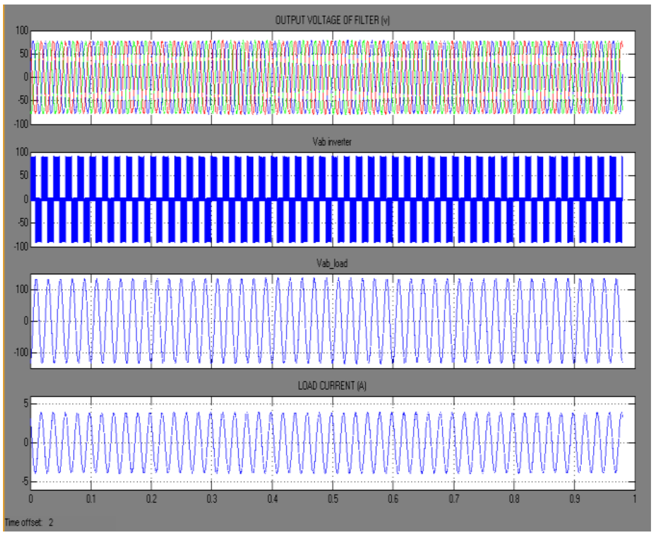

Fig.7 Output waveform at pitch angle β=5 and generator speed ω_m = 1 pu

V. CONCLUSIONS

A simple system and control method for small scaled wind power generating system using permanent magnet type synchronous generator whose output is from 1 to 1.5 kW or so, has been proposed. We consider that we set many generating units (from generator to chopper) in parallel and only one power storage, inverter and total power control unit. The proposed system does not need microprocessor like DSP for the control the system. We expect that use of this type synchronous machine adopted with the proposed simpler control methodology will be able to make an inexpensive alternative for small-scale wind- power generation systems.

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