Maximum Power Point Tracker for Permanent Magnet Synchronous Generator Based Wind Energy System using Fuzzy Logic Algorithm

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Abstract

The use of boost chopper in Permanent Magnet Synchronous Generator (PMSG) aims to capture maximum power at any wind speed condition. It is reached by adjusting the duty cycle of boost chopper. In this paper, fuzzy logic algorithm is used to find the duty cycle value which yields the maximum power output. This control scheme is verified by PSIM simulation. Another MPPT method is also simulated as a comparison.

Keywords – Wind power, maximum power control, PMSG, boost chopper, fuzzy logic

1. Introduction

The lack of oil and any other conventional resources which are used to generate electricity makes renewable energy research become so interesting. In recent years, compared to any other renewable energy systems, the implementation of wind energy system is significantly increasing as the availability of wind energy resource at the cheaper price comparatively.

In wind energy system, the induction generators are applied to the conventional wind power generation because it is solid and cheap. But, it also has several drawbacks such as low power factor and the need of excitation resources. So it is now preferable to use a PMSG. By using the permanent magnet in its rotor, the flux produced by the rotor can be kept constant. The mechanical speed of rotor is proportional to the stator voltage. Then it is easy to analyze the mechanical side of generator without measuring it directly.

In this paper, the use of a boost chopper in maximum power control for Permanent Magnet Synchronous Generator is described. Fuzzy logic algorithm is used to find the duty cycle value which yields the maximum power output.

2. Wind Turbine Model

The wind turbine extracts the kinetic energy from the swept area of the blades. There is a power coefficient of wind turbine which characterizes the efficiency of wind turbine in capturing the wind power.

$$P_{windturbine} = C_p \times \frac{1}{2} \rho A v^3 \qquad (1)$$

Where ρ is air density (kg m^{-3}), A is swept area (m^2) and v is upwind free wind speed (m s^{-1}). Power coefficient (C_p) is then determined by tip speed ratio (λ).

$$\lambda = \frac{\omega R}{v} \qquad (2)$$

Where is ω the rotational speed of rotor (rad s^{-1}) and R is the radius to tip of rotor (m). In fact, C_p value is in the range of 25-45%. Figure 1 shows the correlation between the wind turbine power and the tip speed ratio as the variation of wind speed. In this paper, maximum C_p value 0.48 is achieved for 8.1 tip speed ratio and 0 pitch angle.

3. System Configuration and Control

Figure 2 shows system configuration and control. It consists of PMSG, 3-phase rectifier, boost-chopper and RL-load. RL-load can be represented with the driving inverter and RL-load. There is only one switching device resulting low cost and simple control.

The idea of the control system is to try to find the maximum output power by adjusting the duty cycle. We can see in figure 3, for a constant wind speed the power captured depends on the value of duty cycle. By detecting the change of power (dP) and the change of duty cycle (dD) as an input, this fuzzy control will increase or decrease the duty cycle value until it remains constant. Which means that maximum power output has been reached, $dP/dD = 0$.

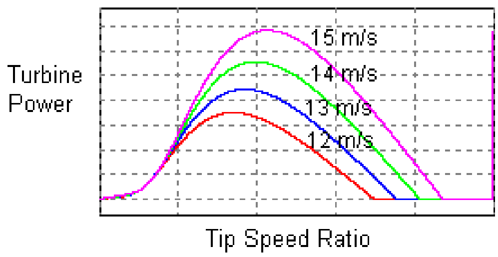

Fig. 1 Wind turbine power to tip speed ratio

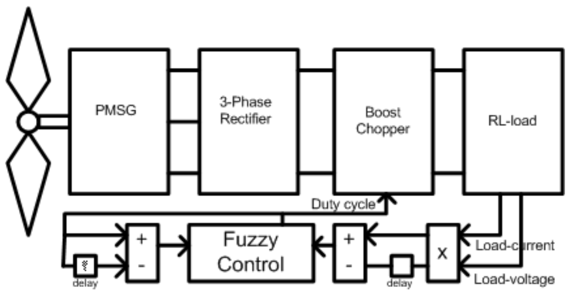

Fig. 2 System Configuration

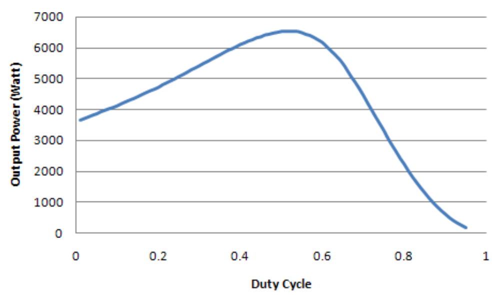

Fig. 3 Characteristic of Output Power to Duty Cycle

In this fuzzy control, the inputs, *dP* and *dD* each has 7 fuzzy sets. Which are represented by negative big (NB), negative medium (NM), negative small (NS), zero (ZR), positive small (PS), positive medium (PM) and positive big (PB). The fuzzy sets value of each input are described in table 1.

These values are determined by simulating the system at a constant rated wind speed. Then we can determine *dP* and *dD* characteristic.

Both inputs are related by a logical AND operator and then processed by fuzzy rules as shown in table 2. These fuzzy rules based on perturbation and observation (P&O) with variable step size depends on how large the inputs are. The Sugeno zero order method is chosen as an implication method in this fuzzy control due to its simplicity.

4. Simulation Results

This control scheme is simulated in PSIM. Wind turbine is modeled as the mathematical equation with wind speed, pitch angle and generator rotation speed as the inputs. The output of wind turbine model is torque. The scenario is set to evaluate the performance of DC chopper under fluctuating wind speed conditions. The parameters of subsystems are described in Table 3.

This simulation result is compared to another MPPT method which has been described previously [4]. Previous method [4] analyzes PMSG system mathematically then the equation of maximum duty cycle is derived. Maximum duty cycle equation is like this one,

$$\alpha_{\max} = \frac{\pi\sqrt{R_L}}{\pi\sqrt{R_L} + 3\sqrt{2\sqrt{R_a^2 + X_s^2}}} \qquad (3)$$

We can see from figure 4, the proposed method can capture higher power compared to the previous one. But has bad waveform of power. It may be caused by the way how to define fuzzy sets.

5. Conclusions

In this paper, maximum power control for PMSG has been described. By sensing the change of power and the change of duty cycle, fuzzy control can increase or decrease the value of duty cycle to find the maximum power output.

As we can see in the simulation results, this method is able to capture higher power compared to the previous one[4]. But it still has a bad waveform of power output.

Reference

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Table 1. Fuzzy Membership Values

Fuzzy Sets	***dP* Value**	***dD* Value**
NB	-200	-0.05
NM	-100	-0.03
NS	-10	-0.01
ZR	0	0
PS	10	0.01
PM	100	0.03
PB	200	0.05

Table 2. Fuzzy Rules

dD/dP	NB	NM	NS	ZR	PS	PM	PB
NB	PB	PM	PS	NS	NS	NS	NS
NM	PB	PB	PM	NS	NS	NM	NB
NS	PB	PB	PS	NS	NS	NB	NB
ZR	PB	PM	PS	ZR	NS	NM	NB
PS	NB	NB	BS	PS	PS	PB	PB
PM	NB	NB	NM	PS	PS	PM	PB
PB	NB	NM	NS	PS	PS	PS	PS

Tabel 3. System parameters

Subsystem	Parameters
Wind Turbine	R = 1.7m, A = 19m^2 P = 1.225kg m^{-2} pitch angle = 2^0
PMSG	Prated = 6.5 kW ωrated = 1000 rpm P = 10 Rs = 0.425 Vpk/krpm = 600 Ld = 0.027 Ls = 0.067
DC Chopper	L = 1.5 mH fs = 10kHz
RL-load	R = 48 ohm L = 0.001mH

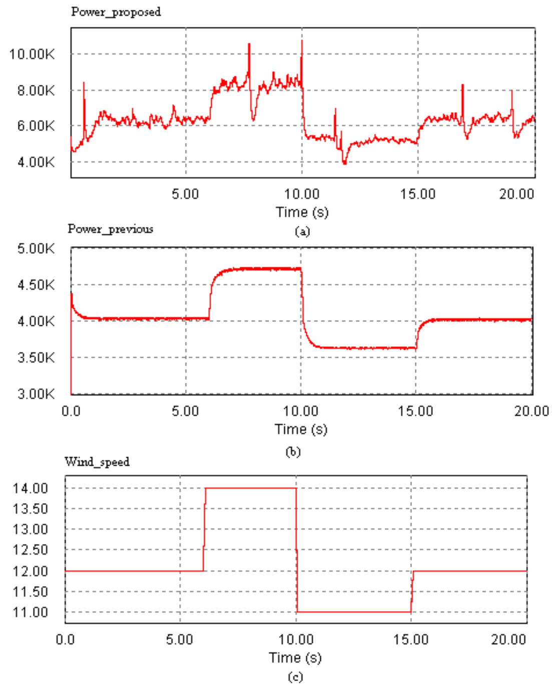

Fig. 4 (a) proposed method output power
(b) previous method output power
(c) wind speed