Comparison of MPPT Based on Fuzzy Logic Controls for PMSG

Adinda Ihsani Putri, Jaeho Choi

School of Electrical Engineering, Chungbuk National University, KOREA

Abstract

Maximum Power Point Tracker (MPPT) is the big issue in generating power based on Wind Energy Conversion System. In case of unknown turbine characteristic, it is useful to implement MPPT based on fuzzy logic control. This kind of control is able to find the value of duty cycle to meet maximum power point at particular wind speed. There are many methods to develop MPPT based fuzzy logic controls. In this paper, two of the methods are compared both at low and high fluctuating wind speed.

Keywords – Wind power, maximum power control, PMSG, fuzzy logic comparison

1. Introduction

Wind energy becomes popular to be developed since conventional power plant contributed to global warming. There are several types of wind energy conversion system. Based on its speed, there are variable speed and fixed speed. Considering that wind speed is fluctuating by the time, fixed speed is not preferable nowadays due to its low efficiency in capturing wind power. At variable speed wind energy conversion system, it is able to change the speed to meet the maximum power at particular wind speed.

Permanent Magnet Synchronous Generator (PMSG) and Double-Fed Induction Generator (DFIG) are the most commonly used in variable speed wind energy conversion system. DFIG is solid and cheap, but has several drawbacks such as low power factor and external excitation is needed. Since PMSG using permanent magnet on its rotor, the external excitation is not needed. PMSG also has greater power factor compared to DFIG. In case of small power, simple boost chopper can be used to control output power of PMSG. As we know there is only one controlled-switching component in boost chopper, hence it is simpler and low cost.

In this paper, MPPT control will be implemented in PMSG. Assumed that turbine characteristic is unknown. So the controller needs to find the point of work to reach maximum power point. Besides perturbation and observation (P&O) method for MPPT control, there is another method known as fuzzy logic algorithm. Two MPPT based on fuzzy logic controls will be described in this paper and compared under low and high fluctuating of wind speeds.

2. Wind Turbine Model

Not all of wind power will be captured by wind turbine. Percentage of power captured by wind turbine is represented by turbine power coefficient, C_p.

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

Where ρ is air density (kg m^{-3}), A is swept area (m^2) and v is upwind free wind speed (m s^{-1}). Below equation is used to determine C_p. value,

$$C_p(\lambda,\beta) = C_1\left(\frac{C_2}{\lambda_1} - C_3\beta - C_4\right)e^{-\frac{C_5}{\lambda_i}} + C_6\lambda \qquad (2)$$

Where λ is the tip ratio,

$$\lambda = \frac{\omega R}{v} \qquad (3)$$

The constant C_1, C_2, C_3, C_4, C_5 and C_6 depends on characteristic of turbine. By using $C_1=0.5176$, $C_2=116$, $C_3=0.4$, $C_4=5$, $C_5=21$, $C_6=0.0058$ and constant pitch angle, $\beta = 2^0$, the characteristic of turbine coefficients are derived as shown in figure 1.

We can see from figure 1, at particular wind speed, the maximum value of turbine coefficient is same. On another words, it can be said that to capture maximum power is similar as to keep constant value of maximum C_p at particular wind speed.

3. System Configuration and Control

PMSG system for small power consists of PM Generator, three phase diode rectifier and boost chopper (see figure 2). Boost chopper is used to regulate output voltage of rectifier. The output voltage of rectifier is proportional to the generator voltage. Since the use of permanent magnet in its rotor, the generator voltage will be proportional to the generator speed. On another words, we can control the rotor speed by regulating the value of duty cycle.

$$V_{in} = (1-D)V_{out} \qquad (3)$$

$$k\phi\omega = V_a + I_g(X_s + R_a) \qquad (4)$$

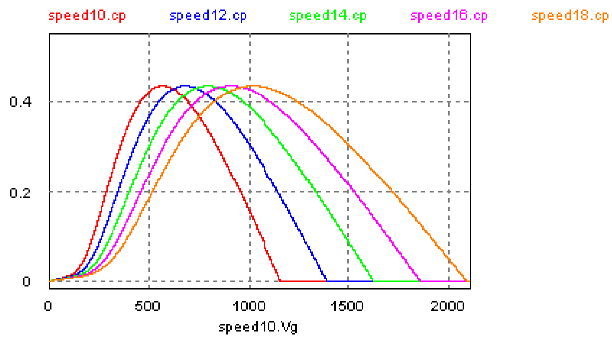

Figure 1. Turbine coefficient characteristic

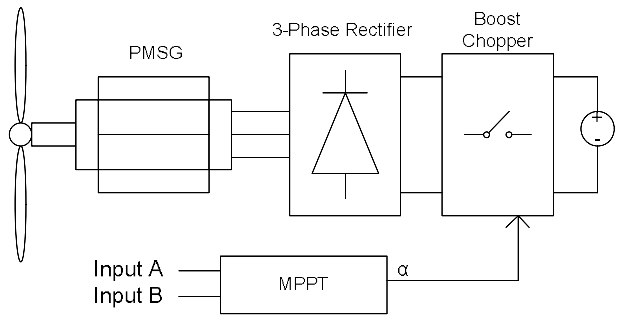

Figure 2. PMSG System

Fuzzy logic algorithm is used to decide the value of duty cycle which yields maximum output power. Several parameters can be considered as the input of this controller. Some of them are torque, power, duty cycle, and output voltage of rectifier. In this paper, there are two algorithms of fuzzy logic control. First method is considering the change of power and rotor speed. Second method is considering the change of power and the duty cycle. Both of the methods will decide the change of duty cycle.

First Method of Fuzzy MPPT Control

The change of power and rotor is considered to decide the output of controller. The duty cycle will always getting bigger or smaller until the controller reach $dP/d\omega = 0$. Rotor speed is chosen as the input because of it is related to the power coefficient of wind turbine (see figure 1). Whereas there is a value of rotor speed which yields maximum power.

Fuzzy sets and rules of this method described by table 1 and table 2,

Second Method of Fuzzy MPPT Control

The change of power and duty cycle is considered to decide the output of controller. The duty cycle will always getting bigger or smaller until the controller reach $dP/d\alpha = 0$. This method based on observations in PSIM simulation result. Duty cycle is set to be linier from 0 to 1 at constant wind speed. There will be a value of duty cycle which yields maximum power.

Fuzzy sets and rules of this method described by table 3 and table 4.

4. Simulation Results

Both of the methods are simulated in PSIM for the low and high fluctuating wind speeds (figure 3 and figure 4).

5. Conclusions

The second method has a better result compared to the first one at low fluctuating wind speed. But at high fluctuating wind speed, the first method is not able to work. On another side, the second method works better than at the low fluctuating wind speed. It is interesting to combine both of these methods to get the better result in capturing wind power.

Reference

[1] Kenji Amei et. Al., “A Maximum Power Generator System Using a Permanent Magnet Synchronous Generator and a Boost Chopper Circuit,” *in Power Conversion Conference,* pp 1447-1452, 2002.

[2] PUTRUS Ghanim et. Al., “Maximum Power Tracking for Variable-Speed Fixed-Pitch Small Wind Turbines,” *in Conf on Electricity,* pp. 1-4, 2009.

[3] C. Patsios et. Al., “A Comparison of Maximum-Power Point Tracking Control Techniques for Low-Power Variable-Speed Wind Generators,” *in Advanced Electromechanical Motion Systems & Electric Drives Joint Symposium*, pp. 1-6, 2009.

Table 1. Fuzzy sets of first method

The Change of Power	NB	-350
	NS	-100
	ZR	0
	PS	100
	PB	350
The Change of Rotor Speed	NB	-200
	NS	-100
	ZR	0
	PS	100
	PB	200
The Change of Duty Cycle	NB	-0.05
	NM	-0.01
	NS	-0.001
	ZR	0
	PS	0.001
	PM	0.01
	PB	0.05

Table 2. Fuzzy rules of first method

dω \ dP	NB	NS	ZR	PS	PB
NB	ZR	PM	ZR	NM	NB
NS	PM	ZR	ZR	NS	NM
ZR	ZR	ZR	ZR	ZR	ZR
PS	PM	PS	ZR	ZR	NM
PB	PB	PM	ZR	NM	ZR

Table 3. Fuzzy sets of first method

The Change of Power	NB	-350
	NM	-100
	NS	-50
	ZR	0
	PS	50
	PM	100
	PB	350
The Change of Duty Cycle	NB	-0.05
	NM	-0.01
	NS	-0.001
	ZR	0
	PS	0.001
	PM	0.01
	PB	0.05

Table 4. Fuzzy rules of first method

dα \ dP	NB	NM	NS	ZR	PS	PM	PB
NB	PS	PS	PS	PB	NS	NS	NS
NM	PM	PM	PS	PM	NS	NM	NM
NS	PM	PM	PM	PS	NM	NM	NM
ZR	PB	PM	PS	ZR	NS	NM	NB
PS	NM	NM	NM	NS	PM	PM	PM
PM	NM	NM	NS	NM	PS	PM	PM
PB	NS	NS	NS	NB	PS	PS	PS

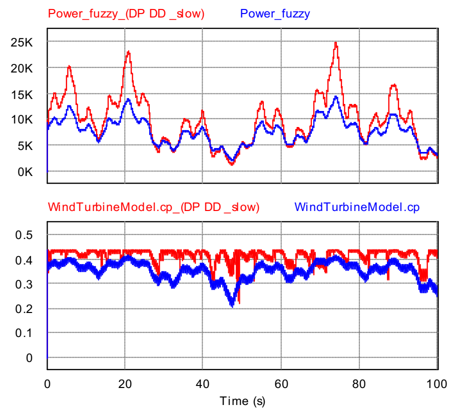

Figure 3. Comparison of Fuzzy MPPT Controls in Low Fluctuating Wind Speed

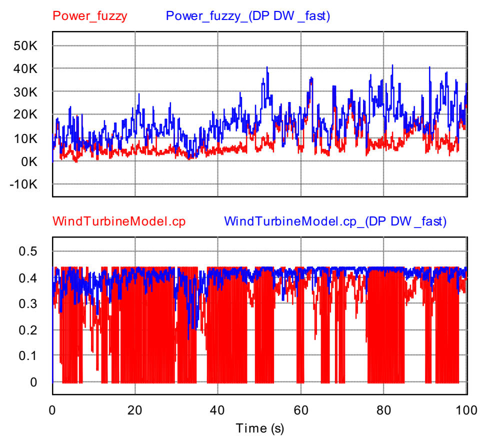

Figure 4 Comparison of Fuzzy MPPT Controls in High Fluctuating Wind Speed