Journal of Applied Science and Engineering Innovation, Vol.3 No.1, 2016, pp. 10-12
ISSN (Print): 2331-9062
ISSN (Online): 2331-9070

Pitch Control of Wind Power Generation Based on Fuzzy Self-turning PID

Fu Guangjie [1], Hu Mingzhe[1] , Mu Haiwei [2]

[1] *School of Electrical Engineering and Information, Northeast Petroleum University, Daqing Heilongjiang 163318, China*

[2] *A School of Electronic Science, Northeast Petroleum University, Daqing Heilongjiang 163318, China*

Abstract: The wind speed has many characteristics, such as high volatility, fast frequency . Therefore, the wind turbine can not stabilize the output of the rated power. When the wind turbine works, the wind energy inevitably will produce the vibration stress to the blade. And bring about the vibration and wear. In order to achieve the purpose of stabilizing output power and reducing vibration wear, a variable pitch control technique based on fuzzy self-tuning PID is proposed in this paper. Control of the traditional PID and fuzzy self-tuning PID are compared by MATLAB. And the simulation of wind power system is carried out. The feasibility and effectiveness of the proposed control method is verified.

Keywords Wind turbine; Pitch control; Fuzzy self-turning PID; MATLAB

INTRODUCTION

In the present age, fossil fuels are becoming increasingly unable to meet the needs of human beings. In order to make up for the shortage of energy supply, the use and research of renewable energy becomes very important. Wind power generation as the main use of wind energy has been widely used. Wind energy has the characteristics of randomness and volatility, which can cause the wind power generation units to be unable to output stable power. In the early stage, the wind power generation unit is regulated by the method of fixed pitch, but the efficiency of this method is low[Omid et al., 2015]. So it is gradually being replaced by the variable pitch regulation method. Pitch control technology is by changing the pitch size to achieve the purpose of keeping the output power stability[Horiuch et al., 2001].

Traditional control algorithm is simple and reliable with traditional PID control. However, because the parameters of the traditional PID are often needed to select the experience of the engineer, it is difficult to adapt to the complex operating conditions. Therefore, a fuzzy self-tuning PID control method is proposed to meet the control accuracy of the system, further improve the system response speed, reduce the static error, the intelligent control of the system is realized by using the fuzzy self-tuning PID algorithm.

SIMPLIFIED MATHEMATICAL MODEL OF WIND TURBINE

In wind power generation system, the function of the wind turbine is to convert the wind energy into the mechanical energy of the rotating form. Therefore, the output characteristic of the wind turbine will directly affect the power quality of the system. By Baez theory, the mechanical power output of the wind turbine to the generator sets is function(1):

$$P_{\mathrm{w}} = \frac{1}{2}\rho\pi R^2 C_{\mathrm{p}}(\lambda,\beta)v^3 \tag{1}$$

In the formula, R is the radius of the wind turbine's rotation and sweep region, the unit is m; v for the wind speed, the unit is $\mathrm{m/s}$; C_{p} for wind energy utilization coefficient; β for the blade pitch angle; λ is the tip speed ratio of wind turbine, $\lambda = \frac{\omega R}{v}$.

The mechanical torque of the generator set of the wind turbine generator sets to the generator set as function(2):

$$T_{\mathrm{w}} = \frac{1}{2}\rho\pi R^3 C_{\mathrm{p}}(\lambda,\beta)v^2 / \lambda \tag{2}$$

In the practical application are generally considered C_{p} as the pitch angle and tip speed ratio is determined, the empirical formula is as follows:

$$C_{\mathrm{p}}(\lambda,\beta) = c_1(c_2/\bar{\lambda} - c_3\beta - c_4)e^{-c_5/\bar{\lambda}} + c_6\lambda \tag{3}$$

In the formula, $\frac{1}{\bar{\lambda}} = \frac{1}{\lambda+0.08\beta} - \frac{0.035}{\beta^3+1}$, $c_1 = 0.5176$, $c_2 = 116$, $c_3 = 0.4$, $c_4 = 5$, $c_5 = 21$, $c_6 = 0.0068$. Under the condition of different pitch angle, wind energy utilization coefficient variation curves of Figure 1.

Corresponding Author: Fu Guangjie, School of Electrical Engineering and Information, Northeast Petroleum University, Daqing Heilongjiang 163318, China

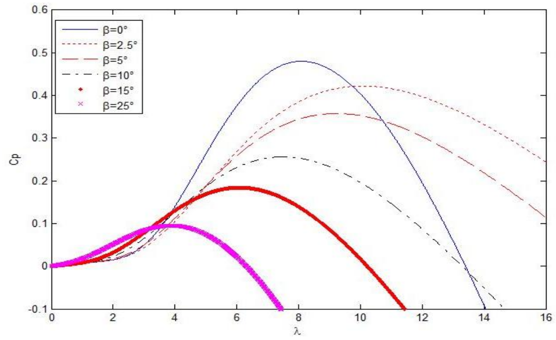

Figure 1. Curve diagram of wind energy utilization coefficient with different pitch angle

FUZZY PID CONTROLLER DESIGN

Fuzzy control system structure

The input of fuzzy self-tuning PID controller is error e and error variation ec , According to the change of the error and the change rate of error, the fuzzy rules are used to modify the PID parameters. The structure of the control system is shown in figure 2[Kocaarslan et al., 2007].

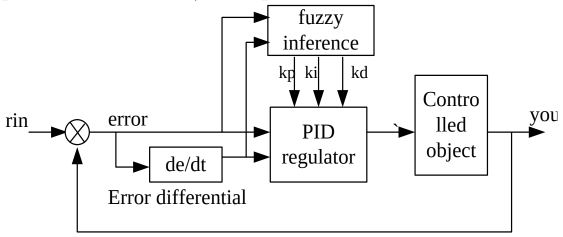

Figure 2. Structure of fuzzy self-tuning PID controller

Fuzzy PID parameter self-tuning is the fuzzy relationship between the three parameters of PID and e , ec , in the course of the operation, the error and error rate are constantly monitored. Then according to the fuzzy control rules, the k_p , k_i and k_d are modified to ensure the good dynamic and static characteristics of the controlled object. Algorithm for PID controller:

$$e(t) = rin(t) - yout(t) \tag{4}$$

$$u(t) = k_p e(t) + \frac{1}{T_i}\int_0^t e(t)dt + T_d \frac{de(t)}{dt} \tag{5}$$

In the formula, k_p is proportional coefficient, k_i is integral coefficient, k_d is differential coefficient.

Establishment of fuzzy control rule table

Different effects of k_p , k_i and k_d on the output characteristics of the system are different according to different error and error rate. The self setting principle of the parameters can be obtained[R.kandiban et al., 2007].. Set:

$$\begin{cases} k_p = k_p' + \Delta k_p \\ k_i = k_i' + \Delta k_i \\ k_d = k_d' + \Delta k_d \end{cases} \tag{6}$$

In the formula, k_p' , k_i' and k_d' is traditional PID parameters in control system. According to the setting principle of PID parameters, and using If-Then form, The tuning rules of Δk_p , Δk_i and Δk_d are obtained as shown in Table 1.

Scope is defined as the domain of fuzzy sets, then $e, ec = \{-3,-2,-1,0,1,2,3\}$, the fuzzy subset is e, ec ={NB,NM,NS,O,PS,PM,PB}. According to the fuzzy rules, a fuzzy PID controller with two inputs (e, ec) and three outputs ($\Delta k_p, \Delta k_i, \Delta k_d$)can be set up.

SYSTEM SIMULATION ANALYSIS

Fuzzy self-turning PID simulation analysis

Set the transfer function of the controlled object:

$$G(s) = \frac{10000}{(s+1/6)+(s+20)+(s+100)} \tag{7}$$

The initial values of the parameters are: : k_p =-4, k_i =0.05and k_d =0.03, join the disturbance in 0.5 seconds, the corresponding control results of conventional PID and fuzzy PID are shown in Figure 3. From the simulation results, we can see that the fuzzy PID has better response speed and more accurate steady state accuracy, and the external environment has a stronger anti disturbance when disturbance.

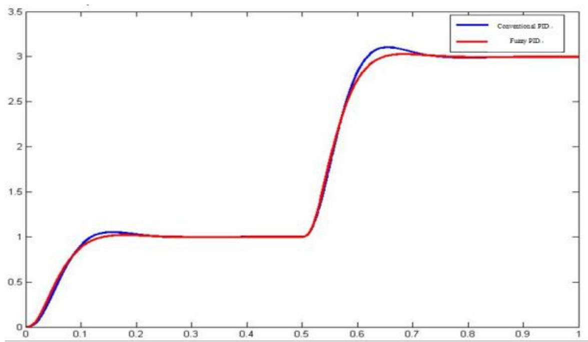

Figure3. Step responses simulation results

Simulation of variable pitch control of wind turbine

In this paper, the main parameters of wind power generation unit are as follows: the radius of the wind turbine blade is 50m, rated speed is $35\mathrm{r/min}$, rated power is $600kW$, rated wind speed is $14m/s$, cut out the wind speed is $25m/s$, air density $1.225kg/m^3$, the moment of inertia of the wind wheel is $3\times10^5 kg\cdot m^2$, Generator moment of inertia is $52kg\cdot m^2$, the variation range of pitch angle is $0^\circ \sim 90^\circ$. Fig 4 and Fig 5 shows the simulation results of the motor speed and torque of the conventional PID and fuzzy self tuning PID control. The comparison shows that, conventional PID control has a large overshoot, steady state effect is not good. In the fuzzy PID control, the output power of the wind turbine is almost no overshoot, and the better steady state accuracy is maintained.

Table 1. The fuzzy rules of $\Delta k_p/\Delta k_i/\Delta k_d$

	Error change rate (ec)						
	NB	NM	NS	ZO	PS	PM	PB
NB	PB/NB/PS	PB/NB/NS	PM/NM/NB	PM/NM/NB	PS/NS/NB	ZO/ZO/NM	ZO/ZO/PS
NM	PB/NB/PS	PB/NB/NS	PM/NM/NB	PS/NS/NM	PS/NS/NM	ZO/ZO/NS	NS/ZO/ZO
NS	PM/NB/ZO	PM/NM/NS	PM/NS/NM	PS/NS/NM	ZO/ZO/NS	NS/PS/NS	NS/PS/ZO
ZO	PM/NM/ZO	PM/NM/NS	PS/NS/NS	ZO/ZO/NS	NS/PS/NS	NM/PM/NS	NM/PM/ZO
PS	PS/NM/ZO	PS/NS/ZO	ZO/ZO/ZO	NS/PS/ZO	NS/PS/ZO	NM/PM/ZO	NM/PB/ZO
PM	PS/ZO/PB	ZO/ZO/NS	NS/PS/PS	NM/PS/PS	NM/PM/PS	NM/PB/PS	NB/PB/PB
PB	ZO/ZO/PB	ZO/ZO/PM	NM/PS/PM	NM/PM/PM	NM/PM/PS	NB/PB/PS	NB/PB/PB

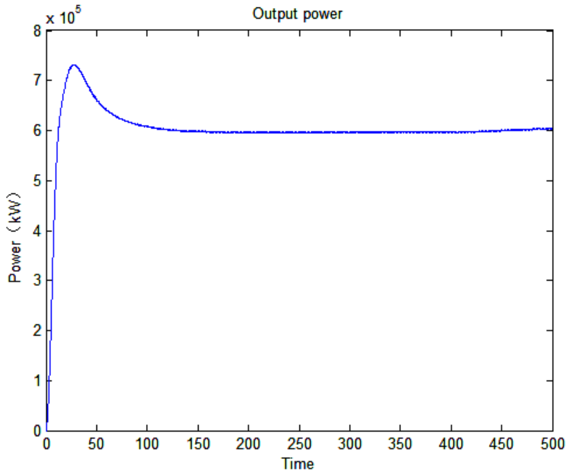

Figure 4 The output power of the wind turbine under the traditional PID control

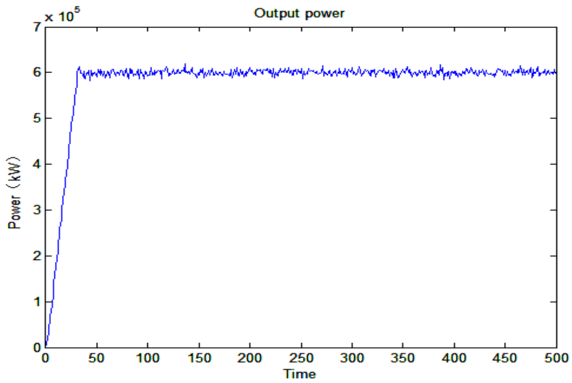

Figure 5 The output power of the wind turbine under fuzzy self-turning PID control

CONCLUSION

In this paper, the wind turbine under fuzzy self-tuning PID control is studied, the PID controller with fuzzy self-tuning PID instead of the traditional fixed gain in control link, to ensure the stability of the output power of wind turbine. Finally, the reliability and validity of the fuzzy self tuning PID are verified by MATLAB simulation.

REFERENCES

Horiuchi N,Kawahito T, 2001,"Torque and power limitations of variable speed wind turbines using pitch control and generator power control". IEEE Power Engineering Society Summer Meeting, Vancouver, Canada.

Kocaarslan I, Cam E, 2007, "Experimental modeling and simulation with adaptive control of a power plant", Energy Conversion and Management, Vol.48,No.3, 787-796.

Omid Bagherieh, Ryozo Nagamune, 2015, "Gain-scheduling control of a floating offshore wind turbine above rated wind speed", Journal of Control Theory and Application, Vol.13,No.2,160-172.

R. Kandiban,R. Arulmozhiyal, 2012, "Speed control of BLDC motor using adaptive fuzzy PID controller", Vol. 38,No.4,306-313.