Advances in Mechanical Engineering and its Applications (AMEA)
Vol. 1, No. 3, 2012, ISSN 2167-6380

www.worldsciencepublisher.org

Design and Simulation of turbine speed control system based on Adaptive Fuzzy PID Controller

[1]Saeed Balochian, [2]Soheil Vosoughi

[*1]Islamic Azad University ,Gonabad Branch, Gonabad, Iran
[2]Islamic Azad University ,Gonabad Branch, Gonabad, Iran

Email: saeed.balochian@gmail.com; Soheil_vosoughi@yahoo.com

Abstract –It is known that PID controller is employed in every facet of industrial automation. In refineries, in chemical plants and other industries the gas turbine is a well known tool to drive compressors. In this paper, we have tried to based on self-adaptive fuzzy PID control, for turbine speed control system is designed, which uses the theory of self-adaptive control and combines the traditional PID control method with fuzzy control method. The results of this simulation has been mentioned in the conclusion. It seems that the results be acceptable results.

Keywords – fuzzy control; self-adaptive control; PID control.

1. Introduction

The PID controller is one of popular controllers in industry. Because of its simple structure and good robustness in a wide range of operating conditions, it is used in a variety of industrial processes such as metallurgy and chemical processes [1]. Now many researchers are interested in the optimization of control algorithm or parameters [2-3]. The classical PID controller is optimized by many intelligent algorithms including neural network [4-5], genetic algorithm (GA), ant swarm [6] and so on. For example, the particle swarm optimization algorithm was adopted to optimize the parameters of self-tuning PID decoupling controller of ball mill pulverizing system [7]. In [9], the authors present a power control of an isolated wind turbine water pumping system.

This paper presents a new type of adaptive fuzzy PID controller for turbine speed control system. The algorithm is tested on an experimental model to the Turbine Speed Control System. A comparison between Conventional method and Adaptive Fuzzy Controller are done.

This paper is organized as follows. Approximation of turbine speed control system model is introduced in section II. Analytical design of PID decoupling control and an implicit adaptation approach for PID controller by means of fuzzy logic control are presented in Section III. Some simulations are executed to verify the validity of the proposed approach in Section IV.

2. Modeling an turbine speed control system

For this study, the model selected is of turbine speed control system. The reason for this is that this model is often encountered in refineries in a form of steam turbine that uses hydraulic governor to control the speed of the turbine as illustrated above in figure 1.

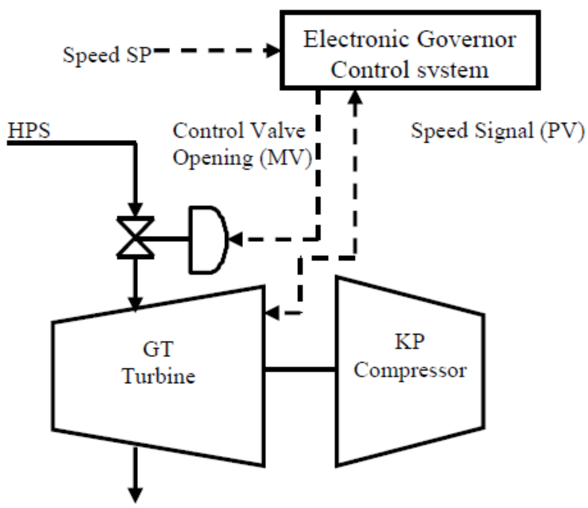

Figure 1. Turbine Speed Control

The complexities of the electronic governor controller will not be taken into consideration in this dissertation. The electronic governor controller is a big subject by it and it is beyond the scope of this study. Nevertheless this study will focus on the model that makes up the steam turbine and the hydraulic governor to control the speed of the turbine. In the context of refineries, you can consider the steam turbine as the heart of the plant. This is due to the fact that in the refineries, there are lots of high capacities compressors running on steam turbine. Hence this makes the control and the tuning optimization of the steam turbine significant. The model used in this paper was presented in Ref. [8].

the transfer function of the open loop system can be approximated in the form of a third order transfer function:

$$\frac{1}{S(S+1)(S+5)} \tag{1}$$

The identified model is approximated as a linear model, but exactly the closed loop is nonlinear due to the limitation in the control signal. For more details, refer to Ref [8].

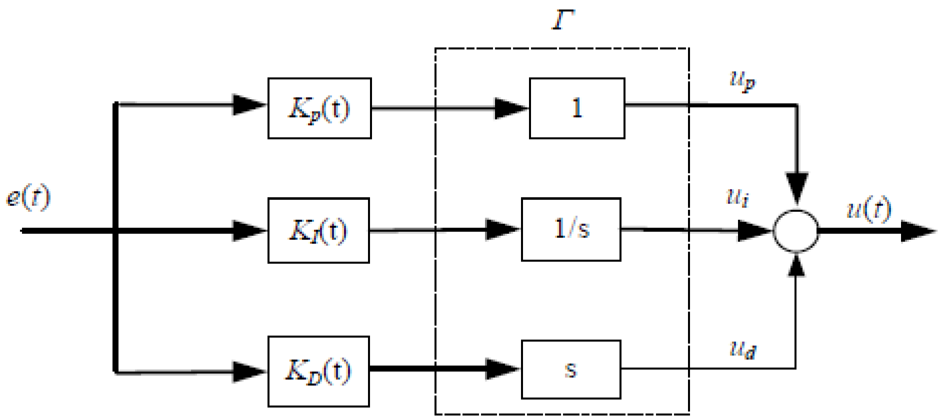

Fig.2 PID structure

3. Structure and principle of the controller

A variation of PID structure is shown in Fig .2. The model be formulated as follows:

$$u(t)=[k_P(t)e(t)]+\int_0^t [k_I(\tau)e(\tau)]d\tau+\frac{d[k_D(t)e(t)]}{dt}$$

$$=[1 \quad 1 \quad 1]\begin{bmatrix} [k_P(t)e(t)] \\ \int_0^t [k_I(\tau)e(\tau)]d\tau \\ \dfrac{d[k_D(t)e(t)]}{dt} \end{bmatrix}$$

$$=\psi.\Gamma(k_P(t)e(t),k_I(\tau)e(\tau),k_D(t)e(t)) \tag{2}$$

Where,

$$\psi=[1 \quad 1 \quad 1]$$

$$\Gamma^T=\left[k_P(t)e(t) \quad \int_0^t [k_I(\tau)e(\tau)]d\tau \quad \frac{d[k_D(t)e(t)]}{dt} \right] \tag{3}$$

The PID controller in (2) can be equivalently represented as:

$$u(t)=[k_P(t)e(t)]+\int_0^t [k_I(\tau)e(\tau)]d\tau+\frac{d[k_D(t)e(t)]}{dt}$$

$$=\left[k_P^0+\Delta k_P(t)\right]e(t)+\int_0^t [k_I^0+\Delta k_I(\tau)]e(\tau)d\tau$$

$$+\frac{d[k_D^0+\Delta k_D(t)e(t)]}{dt} \tag{4}$$

Where,

$$\begin{cases} K_P(t)=k_P^0+\Delta k_P(t) \\ K_I(t)=k_I^0+\Delta k_I(t) \\ K_D(t)=k_D^0+\Delta k_D(t)e(t) \end{cases} \tag{5}$$

The parameters k_P^0, k_I^0 and k_D^0 to be pre-tuned are time-invariant constants while the PID controller is working. The parameters $\Delta k_P(t)$, $\Delta k_I(t)$, and $\Delta k_D(t)$ are time-varying and adapted to the working situation in real time. In order to develop the implicit adaptation for $\Delta k_P(t)$, $\Delta k_I(t)$, and $\Delta k_D(t)$,(4) is modified as

$$u(t)=k_P^0 e(t)+k_I^0\int_0^t e(t)d\tau+k_D^0\frac{de(t)}{dt}$$

$$+\Delta k_P(t)e(t)+\int_0^t \Delta k_I(\tau)e(\tau)d\tau+\frac{d[\Delta k_D(t)e(t)]}{dt}$$

$$=u^0(t)+\Delta u(t) \tag{6}$$

Where,

$$\begin{cases} u^0(t) = k_P^0 e(t) + k_I^0 \int_0^t e(t) d\tau + k_D^0 \dfrac{de(t)}{dt} \\ \Delta u(t) = \Delta k_P(t) e(t) + \int_0^t \Delta k_I(\tau) e(\tau) d\tau \\ + \dfrac{d[\Delta k_D(t) e(t)]}{dt} \end{cases} \quad (7)$$

As a result, if the relationship between the three signals and the system error is assumed to be any generalized functions, the change of the three signals implies the implicit adaptation of $\Delta k_P(t)$, $\Delta k_I(t)$ and $\Delta k_D(t)$. So, the implicit adaptation approach is not to make the parameters of PID controller adaptive but produce adaptively a series of signals in such a way that the PID parameters $k_P(t)$, $k_I(t)$ and $k_D(t)$ is implicitly adaptive.

For the auxiliary PID controller in (7), its output can be equivalently given by

$$\Delta u(t) = \Delta e_p(t) + \int_0^t \Delta e_I(t) + \frac{d[\Delta e_D(t)]}{dt} \quad (8)$$

Where,

$$\begin{cases} \Delta e_p(t) = \Delta k_P(t) e(t) \\ \Delta e_I(t) = \Delta k_I(t) e(t) \\ \Delta e_D(t) = \Delta k_D(t) e(t) \end{cases} \quad (9)$$

To produce the signals, $\Delta e_p(t)$, $\Delta e_I(t)$ and $\Delta e_D(t)$ a FLC is used in this paper. The design of the FLC is discussed in the following. Like the commonly-used FLC, the FLC has two inputs. One is the system error $e(t)$ and the other is its change $ec(t)$. To produce the three signals, the FLC needs three outputs. Consequently, the FLC in this paper has two inputs and three outputs as shown in Fig.3 and AFPIDC structure is shown in Fig .4.

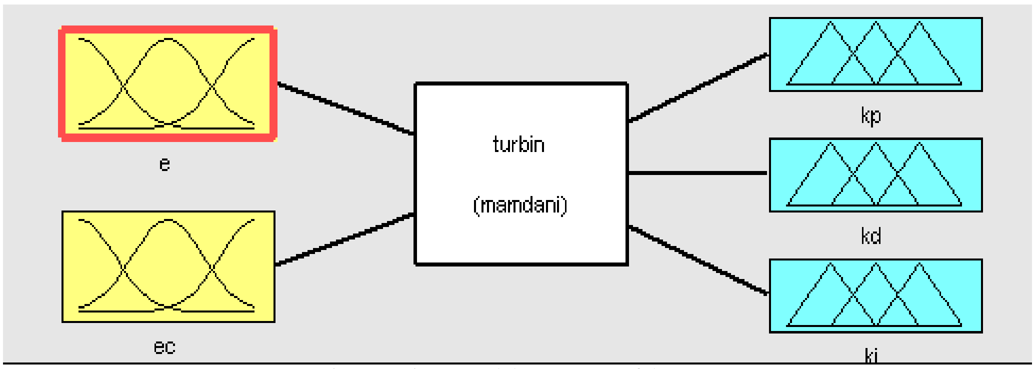

Fig.3. two inputs and three outputs of the FLC

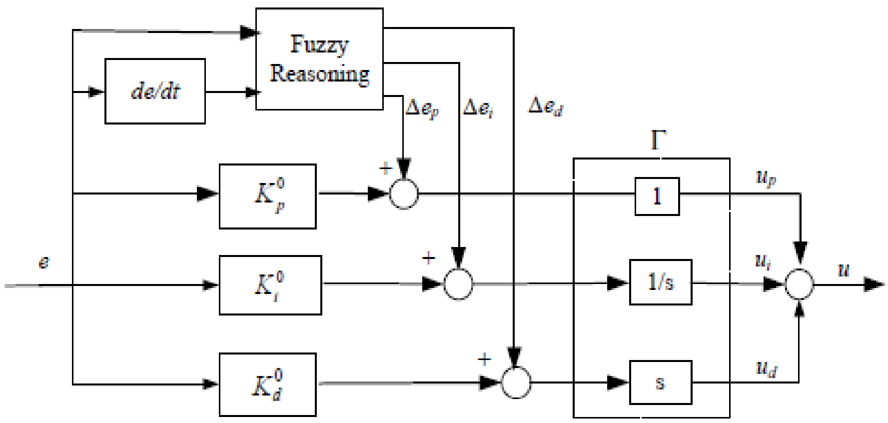

Fig. 4. The proposed AFPIDC structure

In a fuzzy logic system, the membership function is the operation that translates crisp input data into a membership degree. In this paper, all the fuzzy sets of the inputs and outputs of the FLC are NB NM NS 0 PS PM PB.

The membership functions for the inputs and the outputs are shown in Fig.5 and Fig.6, respectively.

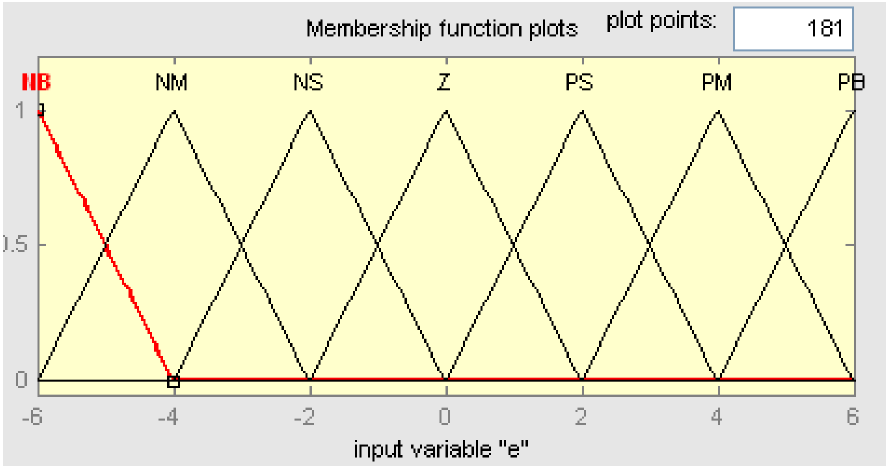

Fig.5. The membership functions of e and ec

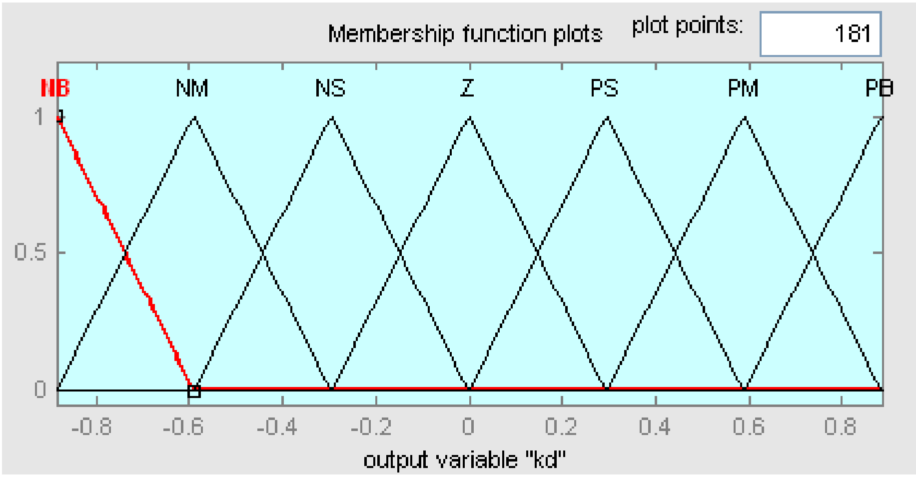

Fig.6. The membership functions of $\Delta k_P(t)$, $\Delta k_I(t)$ and $\Delta k_D(t)$

For the tuning of $\Delta e_p(t)$, $\Delta e_I(t)$, and $\Delta e_D(t)$ is used the following three rules of thumb:

1) If $|e|$ is larger, then $\Delta e_p(t)$ should be larger and $\Delta e_D(t)$ should be smaller so that the system responds quickly. Meanwhile, the integral action should be limited, usually $\Delta e_I(t)=0$, to avoid the system appearing large overshoot.

2) If $|e|$ is moderate, then $\Delta e_p(t)$ should be smaller, the value of $\Delta e_D(t)$ is more important to obtain a small overshoot.

3) If $|e|$ is smaller, then $\Delta e_p(t)$ and $\Delta e_I(t)$ should be larger to make the system have better steady-state performance. When $|ec|$ is smaller, $\Delta e_D(t)$ should be larger. When $|ec|$ is larger, $\Delta e_D(t)$ should be smaller. In such a way, the system can avoid oscillation near the set-point.

The control strategy in the proposed AFPIDC can be expressed as:

if e is (...) and ec is (...), then $\Delta e_p(t)$is (...), $\Delta e_I(t)$is (...) and $\Delta e_D(t)$is (...).

The fuzzy rules to compute $\Delta e_p(t)$, $\Delta e_I(t)$, and $\Delta e_D(t)$ are tabulated in Table 1, Table 2, and Table 3, respectively.

TABLE 1. THE FUZZY CONTROL RULE FOR $\Delta e_p(t)$

e / *ec*	NB	NM	*NS*	*Z*	*PS*	*PM*	*PB*
NB	PB	PB	*PM*	*PM*	*PS*	*PS*	*Z*
NM	PB	PB	*PM*	*PM*	*PS*	*Z*	*Z*
NS	PM	PM	*PM*	*PS*	*Z*	*NS*	*NM*
Z	PM	PS	*PS*	*Z*	*NS*	*NM*	*NM*
PS	PS	PS	*Z*	*NS*	*NS*	*NM*	*NM*
PM	Z	Z	*NS*	*NM*	*NM*	*NM*	*NB*

PB	Z	NS	*NS*	*NM*	*NM*	*NB*	*NB*

TABLE 2. THE FUZZY CONTROL RULE FOR $\Delta e_I(t)$

e *ec*	NB	NM	*NS*	*Z*	*PS*	*PM*	*PB*
NB	NB	NB	*NB*	*NM*	*NM*	*Z*	*Z*
NM	NB	NB	*NM*	*NM*	*NS*	*Z*	*Z*
NS	NM	NM	*NS*	*NS*	*Z*	*PS*	*PS*
Z	NM	NS	*NS*	*Z*	*PS*	*PS*	*PM*
PS	NS	NS	*Z*	*PS*	*PS*	*PM*	*PM*
PM	Z	Z	*PS*	*PM*	*PM*	*PB*	*PB*
PB	Z	Z	*PS*	*PM*	*PB*	*PB*	*PB*

TABLE 3. THE FUZZY CONTROL RULE FOR $\Delta e_D(t)$

e *ec*	NB	NM	*NS*	*Z*	*PS*	*PM*	*PB*
NB	PS	PS	*Z*	*Z*	*Z*	*PB*	*PB*
NM	NS	NS	*NS*	*NS*	*Z*	*NS*	*PM*
NS	NB	NB	*NM*	*NS*	*Z*	*PS*	*PM*
Z	Z	Z	*Z*	*Z*	*Z*	*Z*	*Z*
PS	NB	NM	*NS*	*NS*	*Z*	*PS*	*PS*
PM	NM	NS	*NS*	*NS*	*Z*	*PS*	*PS*
PB	PS	Z	*Z*	*Z*	*Z*	*PB*	*PB*

4. Simulation

Transfer function of the controlled plant is modeled as equation (1). In the proposed AFPIDC, the parameters k_P^o ,k_I^o, , and k_D^o need to be designated.

k_P^o=2

k_I^o=0.3

k_D^o=0.8

The discourse universes for the e and ec are [-6 6] for controller. Considering that the increment of PID parameters is small, the discourse universes for the outputs are Δk_p=[-0.1 0.1] , Δk_D=[-1 1] , Δk_I=[-0.06 0.06], in AFPID controller

The step response is shown in Fig.7. The dashed one line is the output of the proposed AFPIDC-based system, and the solid is the response of the control system based on a traditional PID controller.

At the 30th second, a step load with unit amplitude was added on the output of the system as shown in Fig.8. Using the proposed implicit AFPIDC, the controlled system reached the steady state quickly and smoothly.

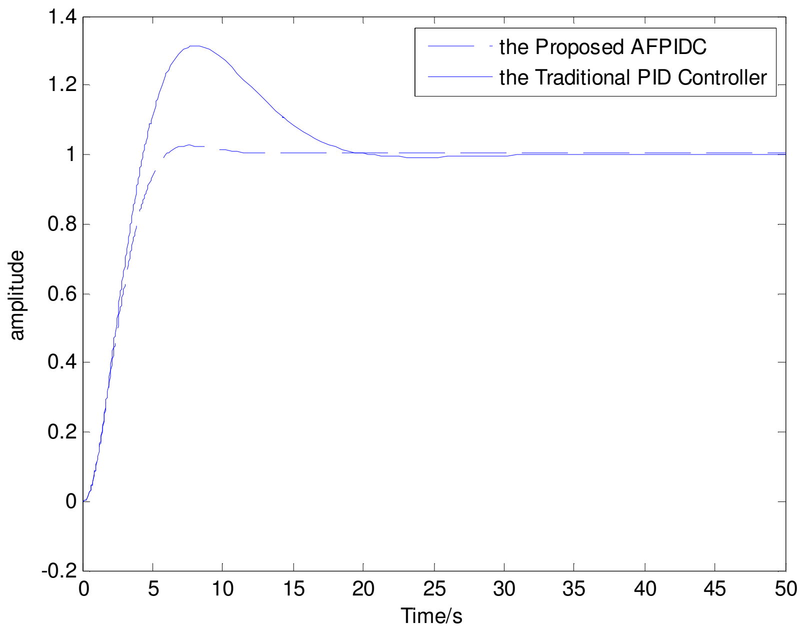

Fig. 7. Step response for turbine speed control system

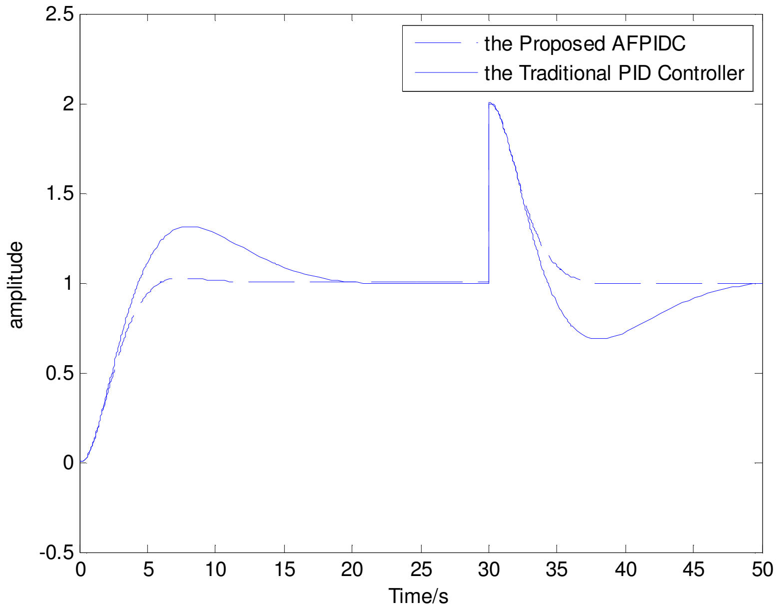

Fig. 8. Comparison for the load rejection Performance

5. Conclusion

In this paper, a fuzzy self-adapting PID controller for a Control Turbine Speed is used. The robustness of the system controlled by the proposed AFPIDC is compared with the system controlled by the traditional PID controller. According to the simulation results in MATLAB, show that the proposed AFPIDC can improve the robustness and small overshoot and fast response compared to the conventional PID. In the area of turbine speed control the faster response to research stability, the better is the result for the plant.

References

[1] Yuanhui Yang, Wailing Yang, Mingchun Wu, Qiwen Yang, and Yuncan Xue. A New Type of Adaptive Fuzzy PID Controller. Proceedings of the 8th World Congress on Intelligent Control and Automation July 6-9 2010, Jinan, China

[2] Tan Liangcai. Digital simulation and experimental study of the constant temperature air conditioning system based on the neural fuzzy control in tall and big spaces[D]. School of Environment Science and Engineering, Tongji University, Shanghai, 1999 (in Chinese).

[3] Xu Chang, Lu Jianhong, Cheng Ming et al. Neural network PID adaptive control and its application[J]. Control Engineering of China, 2007, 14(3): 284-286 (in Chinese).

[4] An Dawei, Wang Jiangjiang, Lou Chengzhi. Application of neural network PID controller to the constant temperature air conditioning system in tall and big space[J]. Journal of Tianjin University, 2005, 38(3): 268-273 (in Chinese).

[5] Wang Jiangjiang, Zhang Chunfa, Jing Youyin. Adaptive PID control with BP neural network self-tuning in exhaust temperature of micro gas turbine [C]. In: Proceedings of the 2008 IEEE International Conference on Industrial Electronics and Applications. Institute of Electrical and Electronics Engineers Inc, Piscataway, NJ, USA, 2008.532-537.

[6] Li Lixiang, Peng Haipeng, Wang Xiangdong et al. PID parameter tuning based on chaotic ant swarm[J]. Chinese Journal of Scientific Instrument, 2006, 27(9): 1104-1116 (in Chinese).

[7] Wang Jiesheng, Wang Wei. Self-tuning PID decoupling controller of ball mill pulverizing system[J]. Control Engineering of China, 2007, 14(2): 135-139 (in Chinese).

[8] K. Gowrishankar, Vasanth Elancheralathan , ADAPTIVE FUZZY CONTROLLER TO CONTROL TURBINE SPEED, Ubiquitous Computing and Communication Journal

[9] Hedi Jedli, Noureddine Hidouri, A Power Drive Scheme for an Isolated Pitched Wind Turbine Water Pumping System based on DC machine, Advances in Mechanical Engineering and its Applications, World Science Publisher, Vol. 1, No. 1, March 2012,