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Automation

Application of Single Neuron Adaptive PID Regulators with Auto-tuning Gain in Industrial Parameter (Pressure) Closed-loop Process Control Systems

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Abstract: A type of single neuron adaptive PID regulator with auto-tuning gain is proposed and applied to the work control of fans, water pumps and air-pressers *etc.* in Handan Iron & Steel Company, China. The robustness of industrial parameter closed-loop process control systems is improved, and the work quality of the systems bettered.

Keywords: single neuron; gain; adaptive; PID regulator; pressure closed-loop control

1 Introduction

The work control of fluid machines such as fans, water pumps and air-pressers *etc.* frequently employ pressure closed-loop process control systems [1]. Industrial producing and practicing show that the systems have a serious pressure fluctuation phenomenon during working process. This makes the work quality of the systems poor.

Although the pressure fluctuate situation is improved after the re-tuning parameter of the PID regulator in the worksite, the robustness of pressure closed-loop control systems with conventional PID Regulators is still poor. The reason is analyzed as follows.

The transfer function of the generalized control object made up by an asynchronous motor, a fan and some pipelines *etc.* may be obtained by step response,

$$G(s)=\frac{K_Q}{\tau_Q s(1+t_g s)} \tag{1}$$

Equation (1) shows the control object has no balance, with nonlinear characteristic and integral saturation. The integral time constant τ_Q is decided by value opening of pipelines, resolving of frequency converters and time setting of speed of the increasing or decreasing, and its value is approximate to τ_g (the machine inertia time constant). Thus, PID regulator parameters (K_p, τ_i, τ_β) set according to τ_Q, τ_g can not adapt the variations of control object parameters and nonlinear influence. This is the basic reason making system unstability through PID Control.

In recent years, intelligent control has a great progress, and artificial neural network control can comprehend structure, parameters, nonlinearity and uncertainty of systems through auto-learning, and express control rules needed by systems. This paper develops a type of single neuron adaptive PID regulator with auto-tuning gain, and applies it to pressure closed-loop process control systems.

2 Design and Control Algorithm

Establish the control algorithm of the single neuron adaptive PID regulator with auto-tuning gain according to **figure 1**, where $W_1(k)$, $W_2(k)$ and $W_3(k)$ correspond to the weights of $X_1(k)$, $X_2(k)$ and $X_3(k)$. Set the threshold value $\theta=0$. Then the input of the single neuron is

$$U(k)=K(k)\frac{\sum_{i=1}^{3} W_i(k)X_i(k)}{\sum_{i=1}^{3}\|W_i(k)\|} \tag{2}$$

where $K(k)$ is the gain of the single neuron adaptive PID regulator. Employ weighting and dividing Euclidean norm $\|W_i(k)\|$ of the weight vectors for ensuring control convergence better [2]. In equation (2),

integral term

$X_1(k)=K_i\sum_{i=1}^{k} e(i)$,

where, the integral proportion coefficient $K_i=K_p\tau_0/\tau_i$, and τ_0 is the sample time;

proportion term

$X_2(k)=K_p e(k)$,

where, K_p is the proportion coefficient;

differential term

$X_3(k)=K_d[e(k)-e(k-1)]$,

where, the differential proportion coefficient $K_d=K_p\tau_d$;

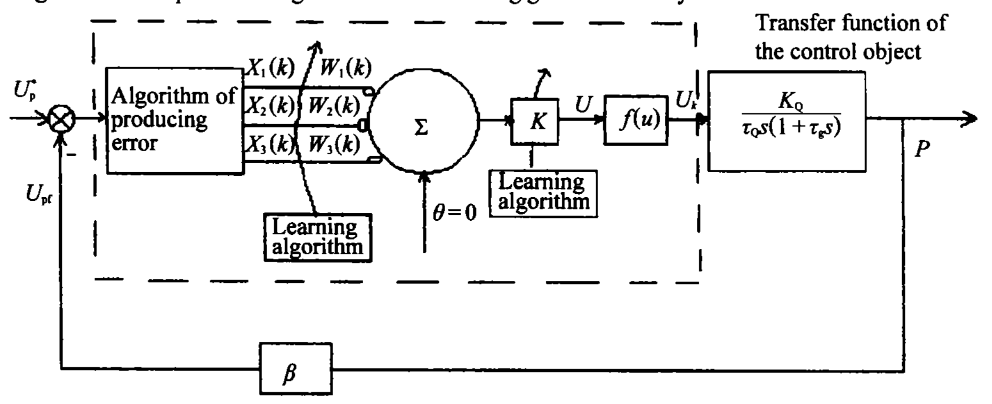

Figure 1 Dynamic block of pressure closed-loop process control systems provided with the single neuron adaptive PID regulator with auto-tuning gain.

and output of the single neuron

$$U_k(k)=f(u)=f\left[K(k)\frac{\sum_{i=1}^{3}W_i(k)X_i(k)}{\left\|\sum_{i=1}^{3}W_i(k)\right\|}\right] \quad (3)$$

where $f(u)$ is a nonlinear function bounded, this paper select sigmoid function, it is advantageous to starting control of fluid machines because $f(u)=U_k(k)$ is the input control signal of frequency converters,

$$U_k(k)=f(u)=U_{\max}\frac{1}{1+e^{-U(k)}},\ |f(u)|\leq U_{\max}=10\,\mathrm{V} \quad (4)$$

Employ the feedback principle and adjust the weights by the unsupervised Hebb and supervised widrow-Hoff rule to establish a learning rule of real time control easily,

$$r_i(k)=e(k)\,|U_k(k)|\,X_i(k) \quad (5)$$

Make the cross-link weight $W_i(k)$ of neuron direct proportion to the learning law, consider the real working experience, and transform $X_i(k)$ into $X_i(k)=e(k)+\Delta e(k)$, thus the learning algorithm of the neuron is

$$\begin{cases} W_1(k+1)=W_1(k)+\eta_i e(k)U_k(k)[e(k)+\Delta e(k)] \\ W_2(k+1)=W_2(k)+\eta_p e(k)U_k(k)[e(k)+\Delta e(k)] \\ W_3(k+1)=W_3(k)+\eta_d e(k)U_k(k)[e(k)+\Delta e(k)] \end{cases} \quad (6)$$

where $\Delta e(k)=e(k)-e(k-1)$, η_i is the integral term learning rate, η_p the proportion term learning rate, and η_d the differential term learning rate.

In order to adjust the gain $K(k)$ online, a self-adaptive algorithm is used in this paper as follows [3].

Suppose $K_d(k)=\left|\overline{\Delta e(k)}\right|/\Delta e^2(k)$, infer and establish the learning algorithm of the gain $K(k)$ according to the Marsik, Streje's iteration rule. The learning algorithm is

$$\begin{cases} K(k)=K(k-1)\left[1+\frac{c}{K(k-1)}\right], & \operatorname{sign} e(k)=\operatorname{sign} e(k-1) \\ K(k)=0.75K(k-1), & \operatorname{sign} e(k)\neq\operatorname{sign} e(k-1) \end{cases} \quad (7)$$

Auto-learning, auto-organizing, auto-tuning is the most important characteristics of the neuron controller and these characteristics are fully shown by equations (3), (6) and (7). Moreover, the nonlinear property of the neuron is expressed by equation (4).

3 Result of Industrial Application

The single neuron adaptive PID regulator with auto-tuning gain has been used in pressure closed-loop control systems of fluid machines such as fans, water pumps and air-pressers *etc.* for more a year. Comparing with the conventional PID control model, shown in **figure 2**, it works stably and reliably and has not pressure fluctuation phenomena, work quality of fan systems, water pump systems and air-press systems improves relatively obvious.

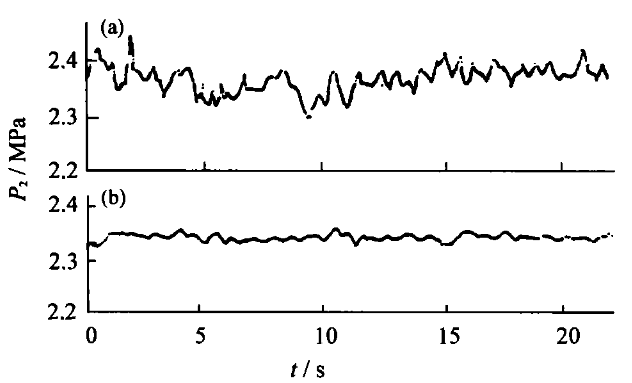

Figure 2 Pressure fluctuate phenomena of pressure closed-loop process control systems provided with (a) PID regulators and (b) single neuron adaptive PID regulators with auto-tuning gain.

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