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The Experimental Study on the Secondary Pump Control of Central Air-conditioner Chilled Water System

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Abstract: The secondary pump of central air-conditioner chilled system is the important equipment that can save energy, the control quality to the secondary pump will affect the energy-saving effect and stability of central air-conditioner. The traditional PID and single neuron adaptive PID separately is used to control the secondary pump in the pressure difference control experiments in this article. The experiment results show that traditional PID control has faster response in the period of dynamic responses and the single neuron adaptive PID control has less steady-state errors in the steady period. Because less steady-state errors cannot lead to larger temperature fluctuation which makes sure the comfort in the air-conditioning room, the single neuron adaptive PID is more suitable for the secondary pump control than traditional PID.

Key Words: Central Air-conditioner, Pressure Difference, Single Neuron, Adaptive PID

1 Introduction

Chilled water system is one important research object of central air-conditioner for saving energy, it saves energy by mean of variable frequency pump adjusting the chilled water flow and making the cold energy provided by chilled water system match the load needed in the air-conditioning room. There are two methods, the pressure difference control and the temperature difference control, to control frequency pump and adjust the chilled water flow. In the process of pressure difference control, the controller continue compare its pressure setting and the measured value that is measured by the pressure difference sensor installed between the chilled water supply pipe and return pipe, the error of pressure is calculated and some control algorithm is used to calculated the inverter output frequency that drive the secondary pump of the chilled water system and make the cold energy provided by chilled water system match the load needed in the air-conditioning room[1].

In practice, the traditional Proportion-Integral-Differential （PID）algorithm is used to control the frequency pump. However, because of the changed parameter of central air-conditioner and the strong nonlinear characteristic, and because of P, I and D parameters that is difficult to adjust online, the traditional PID maybe lead to worse control effect, some adaptive control algorithm should be adopted to adjust automatically the P, I and D parameters and improve the control effect. The single neuron adaptive PID algorithm, a very simple and effective algorithm, is employed to study the pressure difference control of chilled water system in this paper, and the experiment show that the control effect with single neuron adaptive PID algorithm is superior to that with the traditional PID.

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2 The Design and Realization of Single Neuron Adaptive PID Controller

2.1 The Design of Single Neuron Adaptive PID Controller

The single neuron network is the most simple neuron network, it realize the self-tuning and self-organizing function with one neuron. The single neuron network combines with traditional PID algorithm and forms the single neuron adaptive PID algorithm. The controller construction of the single neuron adaptive PID is showed as Fig.1.

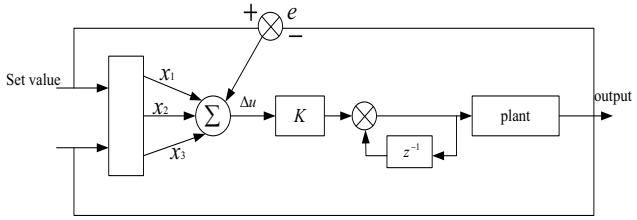

Fig.1: The controller construction of the single neuron adaptive PID

The single neuron adaptive PID controller realizes the self-tuning and self-organizing function by means of adjusting its weighted coefficients that affects the P, I and D. There are three methods that include the non-supervisory Hebb study rule, the supervisory Delta study rule and the supervisory Hebb study rule to adjust the weighted coefficients of the single neuron adaptive PID controller. The supervisory Hebb study rule is used to adjust the weighted coefficients in this paper.

The algorithm of single neuron adaptive PID controller is showed as the follow equations[2-3]:

$$u(k) = u(k-1) + K\sum_{i=1}^{3} w_i'(k)x_i(k) \qquad (1)$$

$$w_i'(k) = w_i(k) / \sum_{i=1}^{3} |w_i(k)| \quad (2)$$

$$w_1(k) = w_1(k-1) + \eta_I z(k) u(k) x_1(k) \quad (3)$$

$$w_2(k) = w_2(k-1) + \eta_P z(k) u(k) x_2(k) \quad (4)$$

$$w_3(k) = w_3(k-1) + \eta_D z(k) u(k) x_3(k) \quad (5)$$

In the equations, $x_1(k) = e(k)$, $x_2(k) = e(k) - e(k-1)$, $x_3(k) = \Delta^2 e(k) = e(k) - 2e(k-1) + e(k-2)$, $z(k) = e(k)$. $w_1(k)$, $w_2(k)$ and $w_3(k)$ are the weighted coefficients of single neuron adaptive PID controller affect separately I, P and D parameters. η_P, η_I, η_D are the learning rates of proportion, integral and differential. K is the proportion coefficient of neuron and K >0.

2.2 The Realization of Traditional PID Controller and Single Neuron Adaptive PID Controller

Because the software of control system in the host computer is the Labview, the traditional PID controller and single neuron adaptive PID controller are realized by the Labview software. The traditional PID controller is realized by PID module supported by the Labview software, and the single neuron adaptive PID controller is realized with program in the Formula Node that is one basic function of the Labview software[4]. The realization of traditional PID controller and single neuron adaptive PID controller are showed separately as Fig.2 and Fig.3.

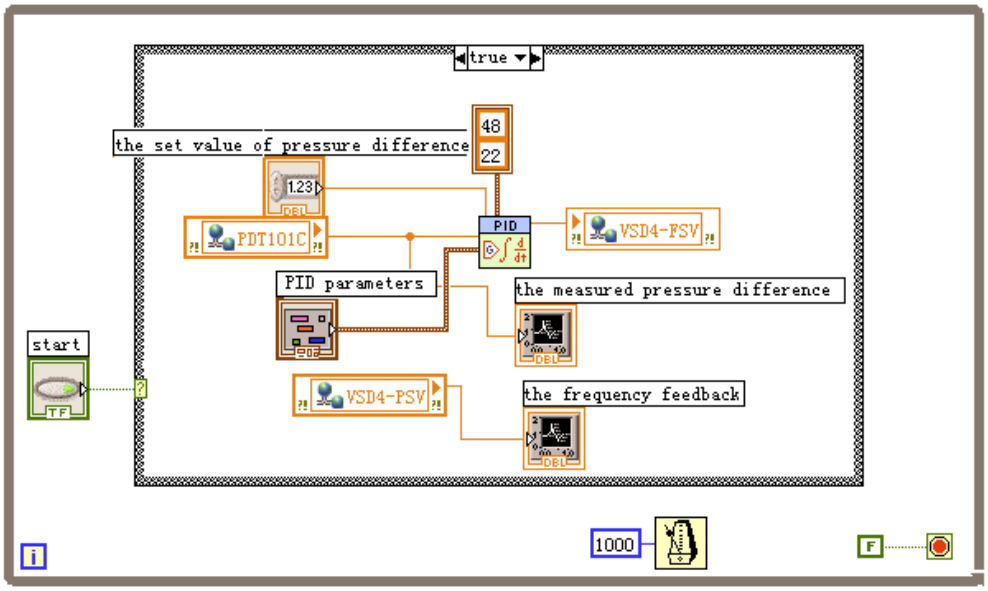

Fig.2: The realization of traditional PID controller based on the Labview

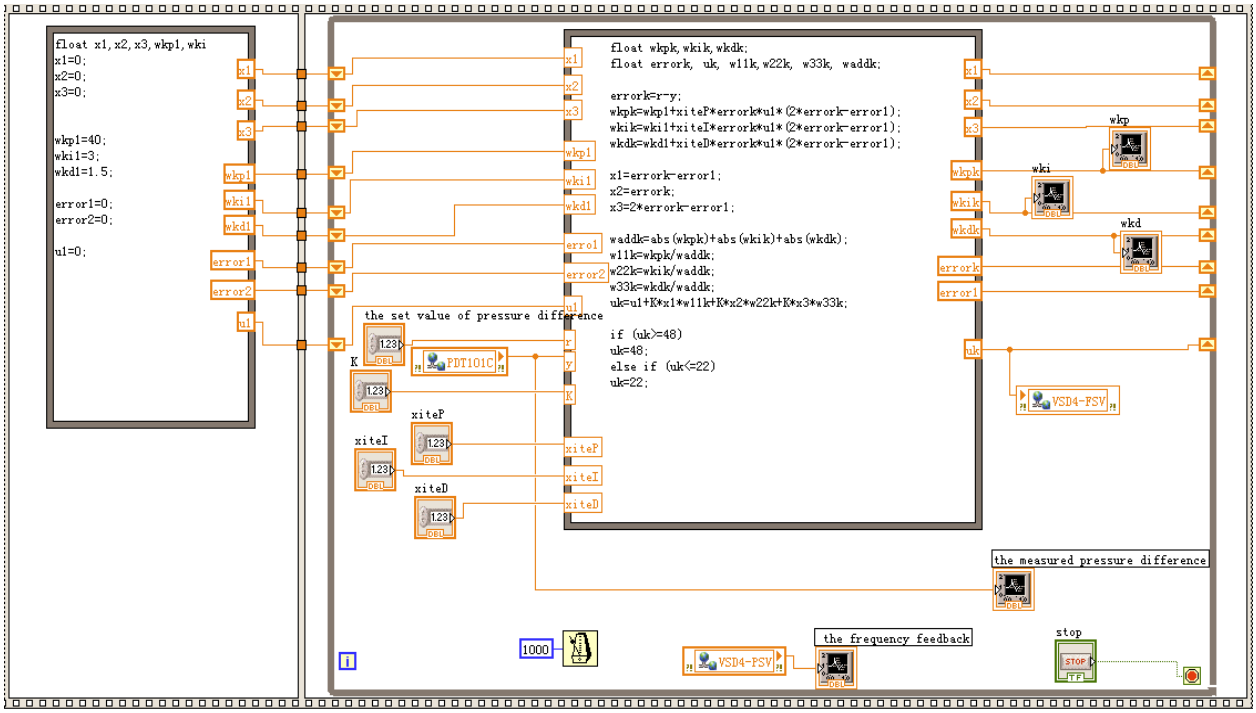

Fig.3: The realization of single neuron adaptive PID controller based on the Labview

In the Labview software panel of Fig.2 and Fig.3, the network invariable PDT101C is t*he measured pressure difference*, VSD4-FSV is *the inverter output frequency*, VSD4-PSV is *the frequency feedback*. The set value of pressure difference is appointed by the control that names after *the set value of pressure difference*. The P, I and D are appointed by the control that names after the PID parameters. xiteP、xiteI and xiteD are the learning rates of proportion, integral and differential.

3 The Experimental Study

To protect the control plant and the inverter, the top frequency of 48 Hz and the bottom frequency of 22 Hz are set in the variable frequency control of the secondary pump. In the process of experiment, the system starts. The output frequency of inverter is 22 Hz and the pressure difference is 0.0755MPa. When the system is stable, the control algorithm acts and the pressure difference is adjusted to 0.08MPa. When the system is stable again, the pressure difference is adjusted to 0.09MPa.

When the pressure difference is controlled using the traditional PID algorithm, because the system model has been obtained before this experiment and the parameters of P、I、D has been determinated by MATLAB simulation, P=20, I=0.035, D=0.002. when the pressure difference is controlled using the single neuron adaptive PID algorithm, the model is unnecessary and xiteP=0.8、xiteI=0.5 and xiteD=0.2. In fact, xiteP、xiteI and xiteD can be assigned at random. The experimental results are show as Fig.4 and Fig.5.

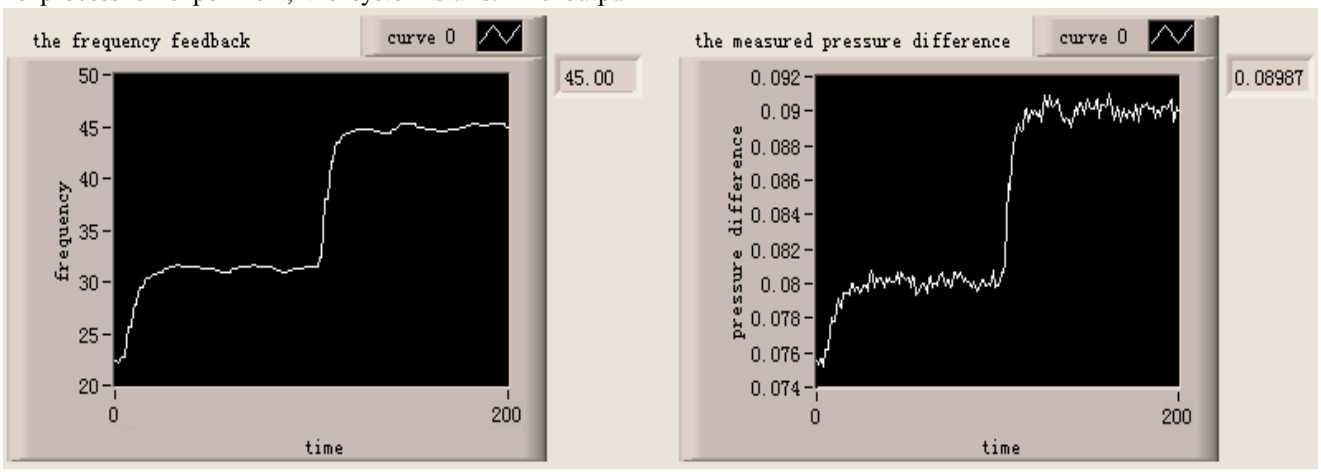

Fig.4: The control result using the traditional PID algorithm

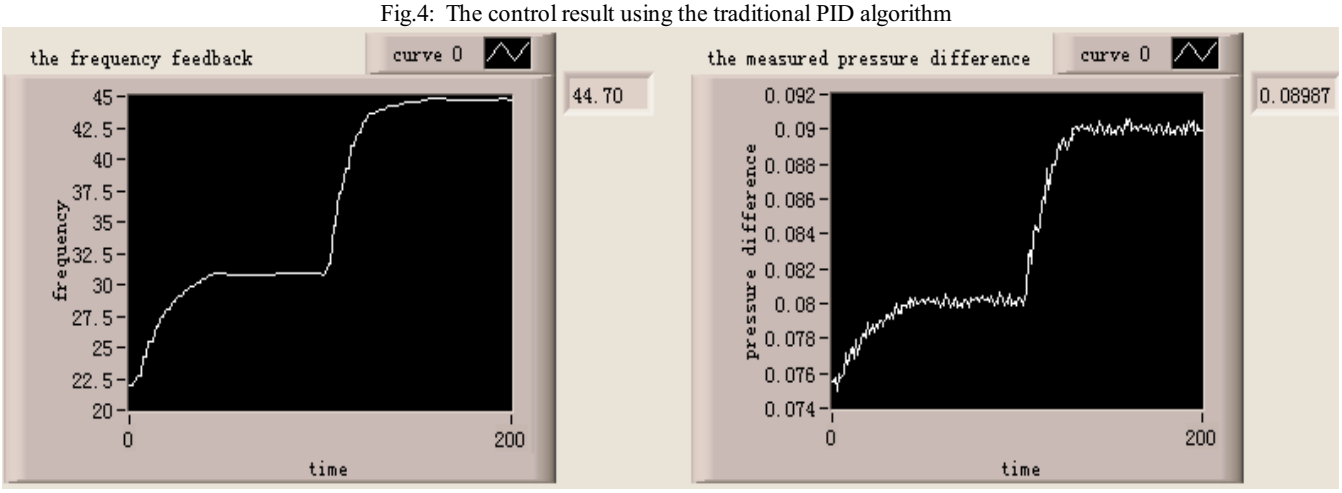

Fig.5: The control result using the single neuron adaptive PID algorithm

To analyze the experimental results, the data corresponding to the curve in the Fig. 4 and Fig.5 is import to the Excel with the import function of Labview PictureBox. The data shows that the first adjusting time is 12 seconds and the second adjusting time is 14 seconds using the traditional PID algorithm and that the first adjusting time is 37 seconds and the second adjusting time is 25 seconds using the single neuron adaptive PID algorithm. The data also shows that the pressure difference has small fluctuation using the single neuron adaptive PID algorithm in steady stage and that the steady-state error is one half of that using the traditional PID algorithm.

4 Conclusions

The traditional PID and single neuron adaptive PID separately is used to control the secondary pump in the pressure difference control experiments in this article. The experiment results show that traditional PID control has faster response in the period of dynamic responses and the single neuron adaptive PID control has less steady-state errors in the steady period. Therefore, in the view of steady-state performance, because less steady-state errors cannot lead to larger temperature fluctuation which makes sure the comfort in the air-conditioning room, the single

neuron adaptive PID is more suitable for the secondary pump control than traditional PID.

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