Application of neural network regulator in cascade systems of regulation

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ABSTRACT

The purpose of research is scientific substantiation of the possibility and expediency of using of neural regulator in cascade systems. The object of research is cascade ACS. Multiplanimetric automatic control systems are used to improve the quality of regulation processes. Researches were performed for the most common class of cascade ACS - cascade-connected and also were performed simulations of neural controller. Methods of research included the use of advanced software on the basis of the package MatLab. Results of the research - comparative evaluation of cascade-connected ACS with and without the use of neural regulator.

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Introduction

Multiplanimetric automatic control systems are used to improve the quality of regulation processes.

Cascade-connected, which, like other cascade systems, has two circuits of regulation, situated one in another: secondary circuit SR in the main regulator circuit MR. The main value of the object of regulation is the input of MR, and intermediate variable signal is given to the SR input. MR exit is used to change the task for SR, which in turn acts on the regulators. The block diagram of the cascade-connected system is shown in Figure1.

The law of regulation of bypass cascade systems where main PI-controller provides a sufficiently rigid stabilization of the main variable $x(t)$ and secondary P-controller stabilizes an intermediate variable $x_{in}(t)$ is most often encountered in practice of regulation of technological processes. Moreover, in this case, the intermediate variable is not imposed rigid requirements on both static and dynamic processes of regulation and it can change its meaning within wide limits. In this case cascade system has relatively high stability and high quality of the transition process.

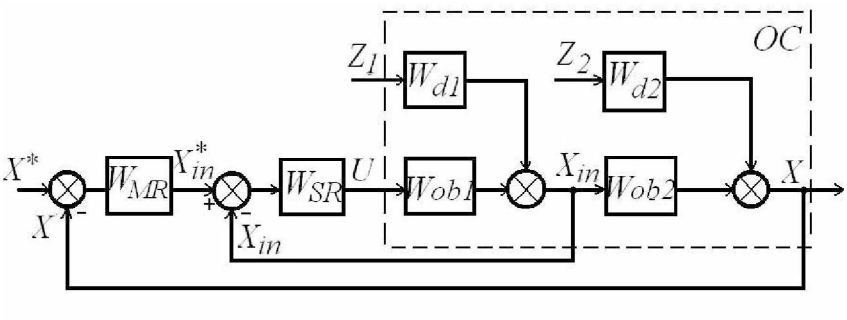

Fig.1

W_{MR} - the transfer function of the main regulator, W_{SR} - the transfer function of the secondary regulator, W_{ob1} - the transfer function of the first object, W_{ob2} - the transfer function of the second object, W_{d1} - the transfer function of the first disturbance, W_{d2} *- the transfer function of the second disturbance.*

The application of two PI-controllers in cascade ACS usually leads to a deterioration of stability and increases astatizm of the system in general. This is especially noticeable when the chosen criterion of optimality for transition process is near the limit of stability of the system.

But sometimes application of PI-controller as an auxiliary regulator for stabilization of an intermediate variable is appropriate and effective. Usually the PI controller in the intermediate circuit can be used if this circuit has a relatively small gain or the intermediate variable of control object imposed by such requirements as a smooth transient process control, narrow range of its change, lack of static errors, etc. Similar facilities are also widespread in the industry.

Also cascade systems are investigated by Chengyi Guo, who received the B.E. degree from the University of Electronic Science and Technology of China, Chengdu, in 1997 with Qing Song and Wenjian Cai.

In their research, the cascade control strategy is introduced for temperature control of air handling unit. Real-time experiment results demonstrate the performance of the cascade control scheme.

Methods of research

Based on the requirements for the cascade ACS we assume that the transfer functions of the object in the intermediate and main channels are respectively equal:

$$W_{0b1}(p) = \frac{K_1}{1+T_1 p} e^{-p\tau_1};$$

$$W_{0b2}(p) = \frac{K_2}{1+T_2 p} e^{-p\tau_2}.$$

where τ_1, T_1, K_1, - time delay, time constant and transfer coefficient of the object for the intermediate channel; τ_2, T_2, K_2 - time delay, time constant and transfer coefficient of the object for the main channel.

Most of the main circuits provide strict requirements for quality and affordability of static error and the internal circuit allows the presence of static error. Therefore, PI- regulator is used in the main circuit and the internal uses P-regulator. The scheme of cascade system, implemented in MatLab, is shown in Figure 2.

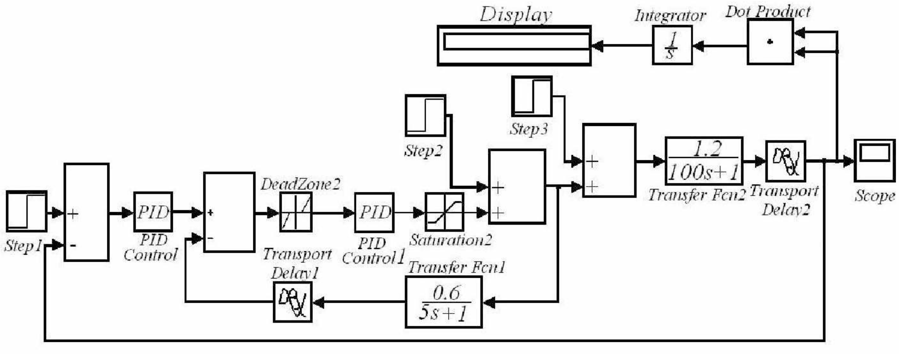

Fig.2

The main object of control $W_{0b2}(p)$ is represented by the product of aperiodic link and link of delay (in MatLab - Transfer Fcn2 and Transport Delay2); intermediate object $W_{0b1}(p)$ is also represented by the product of aperiodic link and link of delay - Transfer Fcn1 and Transport Delay1; P- and PI-controllers are represented by links PID Controller. Links of insensitivity and saturation are implemented through Dead Zone and Saturation.

Network of direct transfer FF was chosen for the implementation of neural regulator. Since the inner circuit doesn't provide specific requirements for accuracy, the use of a neural network controller is unreasonable. Therefore neural network controller is used to replace the PI-controller of the main circuit.

Function newff designed to form a multilayer neural network of direct transfer with given training and settings functions, using the method of back propagation.

The function has the following syntax: <network name> = newff ([<ranges of input values >] [<number of neurons in the recurrent layer> <number of neurons in the output layer>] {<activating function of recurrent layer> <activating function of output layer>}.

net=newff([-2 2; -1 2], [15 1], {'satlins' 'purelin'})

Thereafter the training of network can be carried out by using the function train:

[net,tr]=train(net,P,T)

Results of study are illustrated in Figure 3.

During the 27 epochs the criterion of quality of education has reached value 0.856844.

Implementation of the cascade system with neural network regulator in MatLab is shown in Figure 4.

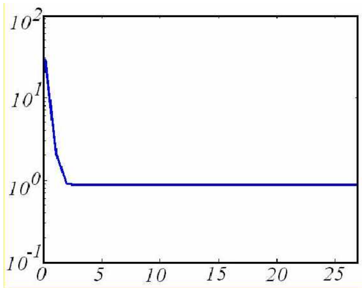

Fig.3

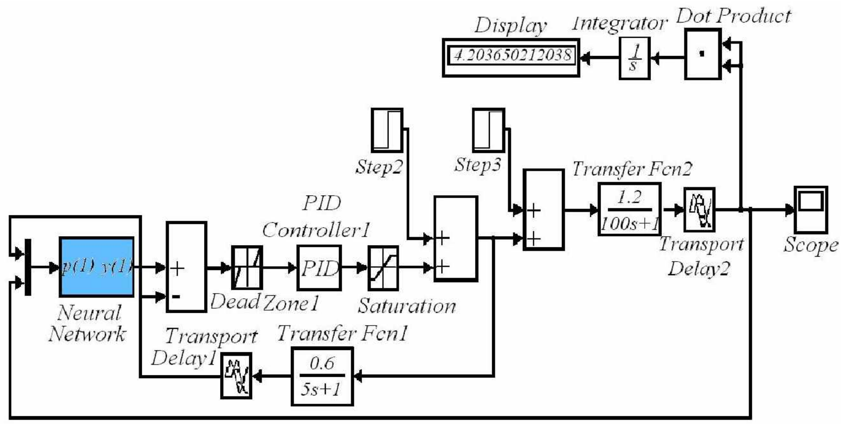

Fig.4

Results and discussion

Some of the most comfortable for evaluating the quality of transient processes are the integral quality criteria, especially when using the computer modeling. This are generalized indexes which actually give an estimate of the area under the curve of the transition process, and then the requirement of reduction of deviation and duration of the transition process is clearly formulated. There are such integral criteria: linear, quadratic, upgraded quadratic. In this paper quadratic integral criterion is used:

$$\int_0^{t_n} (\Delta x)^2 dt$$

The transient processes of the cascade ACS without and with neural network regulator are given in Figures 5 and 6 respectively.

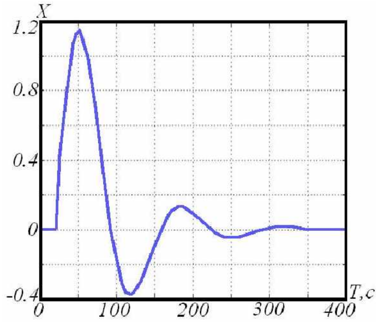

Fig.5

The integral-quadratic criterion I is equal to 50,81 (units)^2·sec.

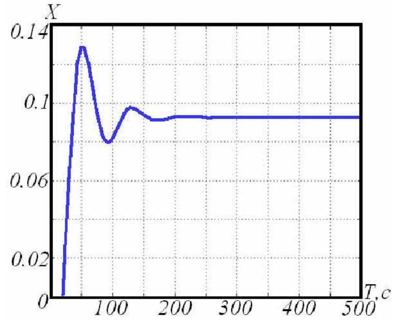

Fig.6

The integral-quadratic criterion I is equal to 4,2 (units)^2·sec.

Conclusions

As a result of replacement of PI-controller of the main circuit on the neural network controller obtained improvement integral-quadratic criterion in 12 times at a ratio $T_1/T_2 = 0.05$. In despite of the creation and study of neural regulator is more difficult than setting of PI-regulator, but there is no need to find the PI-controller settings for various internal circuits. The disadvantage of cascade ACS with neural network regulator is static error.

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