

Simulation Design of Level Cascade Control System for Double-capacity Water Tanks

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Abstract: As a typical representative of process control, double-capacity water tank level control is a common automation control system used to control the level of two tanks to achieve level stabilisation and control, which is widely used in various fields of industrial production. Liquid level control is the key to the performance of the whole control system due to the existence of hysteresis and other problems in the control. Serial control of the sub-loop has a rapid control role, it can effectively overcome the impact of the disturbance into the sub-loop, improve the dynamic characteristics of the object, so in order to achieve better control performance, this design uses serial control to achieve the level of double-capacity water tank fixed value control. Double-capacity water tank level series control system to the tank level as the controlled quantity, first of all, the characteristics of the tank, the establishment of its mathematical modelling, and then the use of MATLAB on the simulation of the tank as well as PID parameter adjustment, and finally through the response curve to analyze the control performance of the system. The simulation results show that the double-capacity water tank level series control performance is good, the system can achieve the level of static-free regulation, and anti-interference ability is strong, with good dynamic and steady state performance.

Keywords: Double-capacity water tank, Cascade control, PID, Simulation.

1. Introduction

With the continuous development of industrialisation and urbanisation, level control systems have become an important part of modern production. In the actual production of industry, the accuracy and control effect of liquid level control directly affects the production cost of the factory, economic benefits and even the safety factor of the equipment. Double-capacity tank level cascade control system to achieve stable control of two tanks level to meet the production and life needs, is a common level control system, widely used in a variety of liquid storage and delivery areas. Although there have been many researches on liquid level control system, there are still some problems in practical application, such as low control accuracy, poor stability, slow response time and so on[1]. Therefore, in-depth research and optimisation of the double-capacity tank level cascade control system is needed to improve the performance and stability of the system. This paper focuses on the simulation implementation of the double-capacity water tank level cascade control system, and focuses on the influence of the control algorithm on the system control performance.

2. Modelling

2.1. Characteristics of the object

The overall structural block diagram of the second-order double-capacity level control object is shown in Figure 1. Take the level H_2 of the middle water tank as the main parameter and the level H_1 of the upper water tank as the subparameter, the output of the main regulator is the given value of the subregulator, the main loop is a fixed-value control system, and the sub-loop is a follower control system. The change of water inlet Q_1 first makes the upper tank level H_1 change, the inflow of Q_1 on the controlled variable H_2 influence process is more indirect and complex, which also exposes the weakness of the single-loop control is poor, and the control of the series control system is superior to make up

for these shortcomings, and make the outflow H_2 tend to stabilise[2-3].

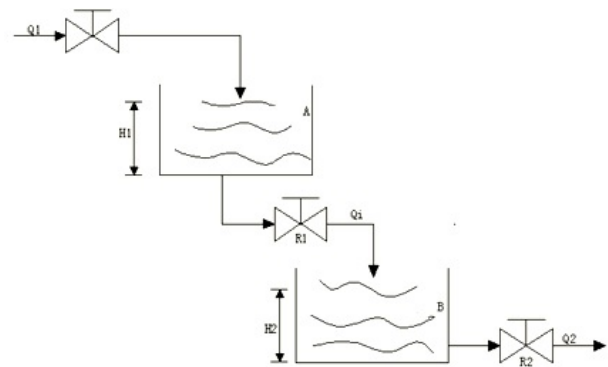


Figure 1. Second-order double-capacitance level control object

The purpose of the serial control system is to make the system have good dynamic and steady state performance, ensure the control quality of the main controlled quantity, and realise non-differential regulation. When there is a disturbance in the sub-loop, because the time constant of the main controlled object is larger than that of the sub-loop, the sub-loop has already made a quick response when the main controlled quantity is not reflected, which eliminates the influence of the disturbance on the main controlled quantity in a timely manner. In addition, if the perturbation acts on the main controlled object, the existence of the sub-loop greatly reduces the time constant of the subcontrolled object, thus speeding up the response of the system and improving the dynamic performance.

From the above figure, it can be seen that the object under test consists of two tanks connected in series, which is called a double-capacity tank. According to the principle of single-capacity tank characteristic test, it can be seen that the mathematical model of double-capacity tank is the product of

two single-capacity tank mathematical model, i.e., the mathematical model of double-capacity tank can be described by a second-order inertia link[4-5]:

$$G(s)=G1(s)G2(s)=\frac{k_1}{T_1s+1} \cdot \frac{k_2}{T_2s+1} = \frac{K}{(T_1s+1)(T_2s+1)} \quad (1)$$

Where $K = k_1k_2$, is the amplification factor of the double-capacity tank, and T_1 and T_2 are the time constants of the two tanks, respectively.

2.2. Modelling of the object

In the experiment, a step signal is input to the upper water tank to make its level leave the original equilibrium state. After a certain adjustment time, the tank level re-entered the equilibrium state. Using the curve fitting method of MATLAB, the experimentally measured data were fitted, and the transfer function of the water tank was calculated through the tangent method, resulting in a MATLAB curve fitting diagram shown in Figure 2:

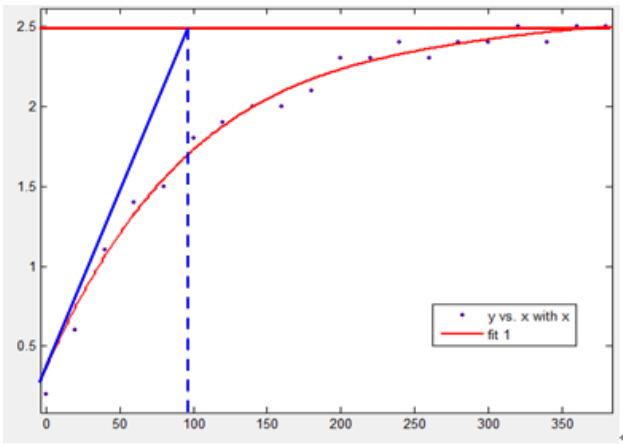


Figure 2. Fitted curve of the upper tank

In the experiment, the lower tank generates a step signal to make its liquid level leave the original equilibrium state. After a certain adjustment time, the tank level re-entered the equilibrium state. The curve fitting method of MATLAB is used to fit the experimentally measured data, and the transfer function of the water tank is calculated through the tangent method, resulting in a MATLAB curve fitting diagram shown in Figure 3:

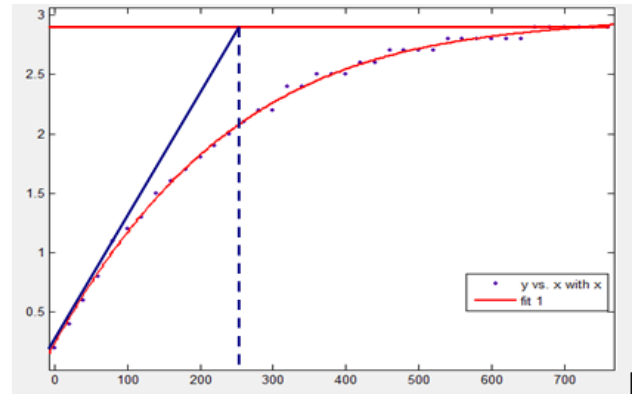


Figure 3. Fitted curve of the lower tank

According to the curve using tangent graphing method to calculate the upper and lower tank characteristic parameters, from the upper and lower tank transfer function to the double-capacity tank transfer function is:

$$y = \frac{0.083}{98.7s+1} \times \frac{0.097}{244.2s+1} \quad (2)$$

2.3. PID control algorithm

The PID algorithm is one of the most widely used algorithms in industrial applications, which can automatically correct the control system accurately and quickly in the control of closed-loop systems. PID control is a linear combination of proportional, integral, and differential deviations to form a control quantity, which can be used to bring the controlled variable in the control system to the desired value or to stabilise it within the desired range[6]. The PID control algorithm can be expressed as follows:

$$U(t) = Kp[e(t) + \frac{1}{Ti} \int_0^t e(t) + Td \frac{de(t)}{dt}] \quad (3)$$

The PID control algorithm is representable in the form of a transfer function:

$$G(s) = \frac{U(s)}{E(s)} = kp(1 + \frac{1}{Tis} + Tds) \quad (4)$$

3. Simulation Results

The series level control system is simulated using Simulink tool and the system simulation is shown in Fig 4:

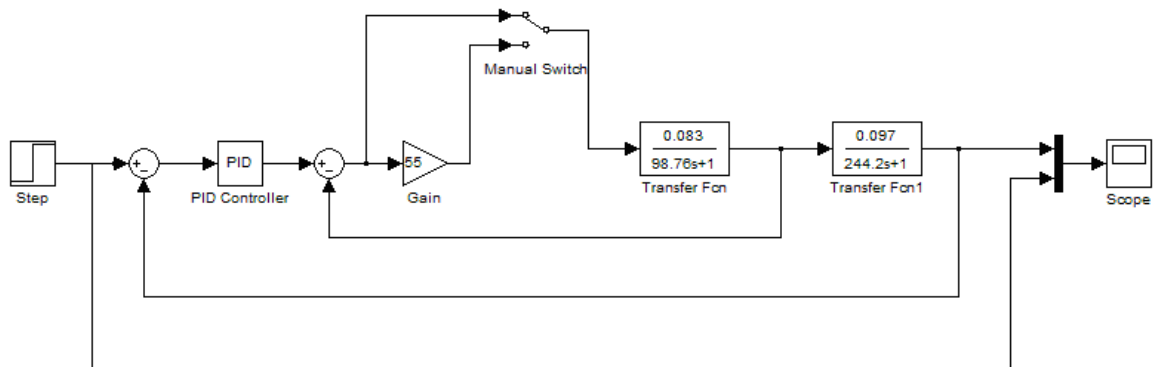


Figure 4. Simulation of the serial control system

In order to verify the superiority of the series control system of the dual-capacity water tank, a single-pole, double-throw switch is added to the system simulation block diagram, which can be used to derive two different control systems, a control system with added sub-loop control, i.e., the series control system, and a single-loop control system without sub-loop control, respectively. Double-capacity tank level control

system using PID control algorithm to achieve constant value control of the tank level, PID control parameters using the trial and error method for parameter calibration, after repeated trial and error, to get the proportional time constant of 250, the integral time constant of 2 seconds, the differential time constant of 5 seconds, the simulation curve is shown in the following figure:

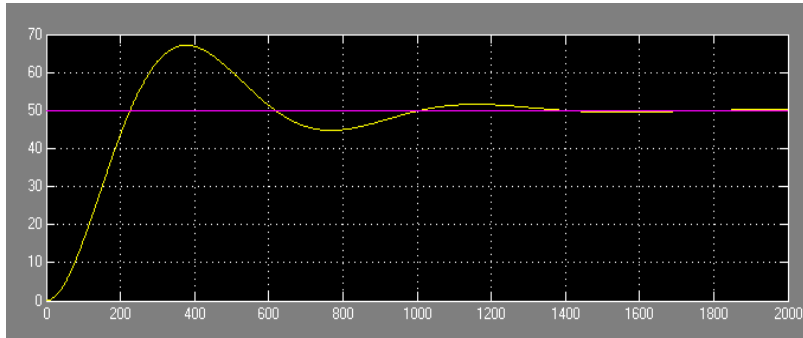


Figure 5. Single-loop PID control waveforms

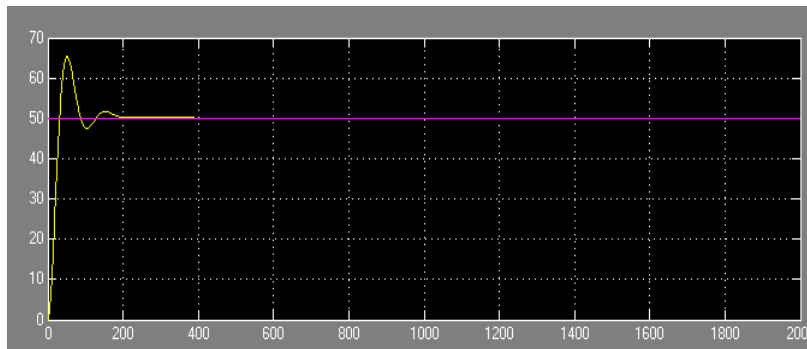


Figure 6. Cascade control PID control waveforms

From the above two graphs, it can be seen that under the action of the same PID control parameters, the regulation time of the series control is about 200s, and the regulation time of the single-loop PID control is about 1450s, and the overshoot, volatility, and steady-state error of the series control are smaller compared with that of the single-loop control, which

can be seen that the rapidity, stability, and accuracy of the series control are better than that of the single-loop control system. In order to verify the anti-disturbance capability of the serial control, a disturbance signal is added to the control loop for simulation, and the system simulation structure is shown in Fig. 8:

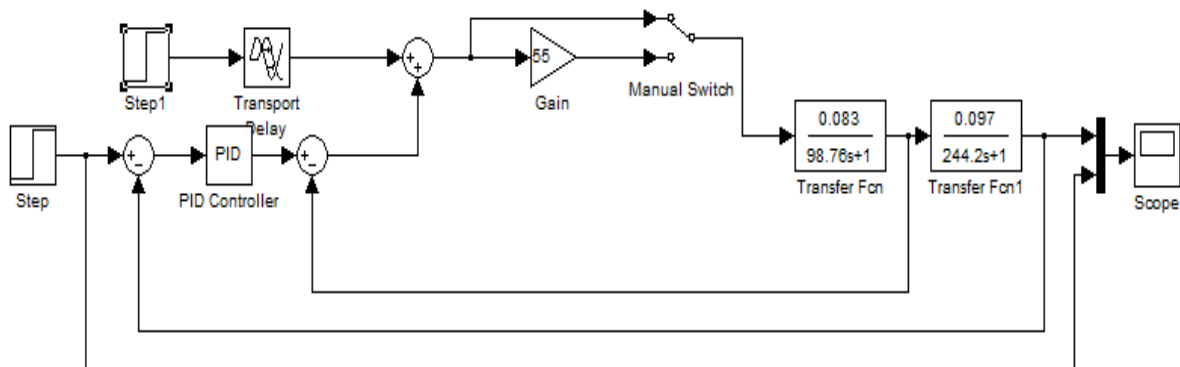


Figure 7. Simulation of a series system with added perturbation

The effect of the perturbation on the waveform is analysed in the original unchanged system to compare the effect of the

perturbation on the control performance of the system, and the waveforms of the two control loops are shown below:

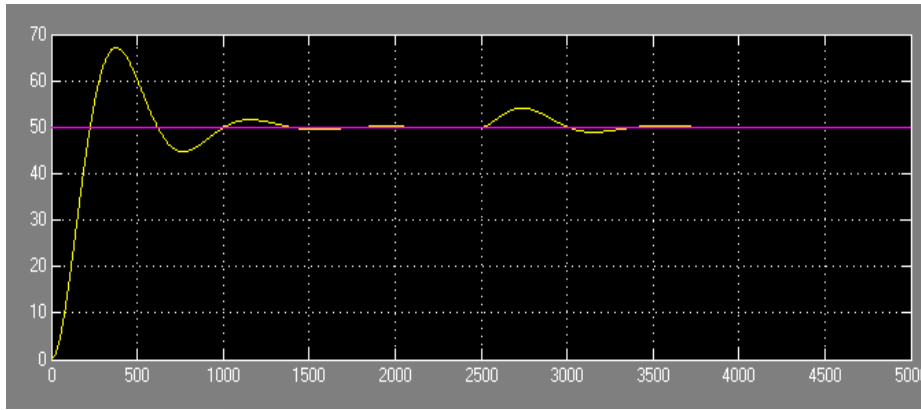


Figure 8. Single-loop PID control waveform with added perturbation

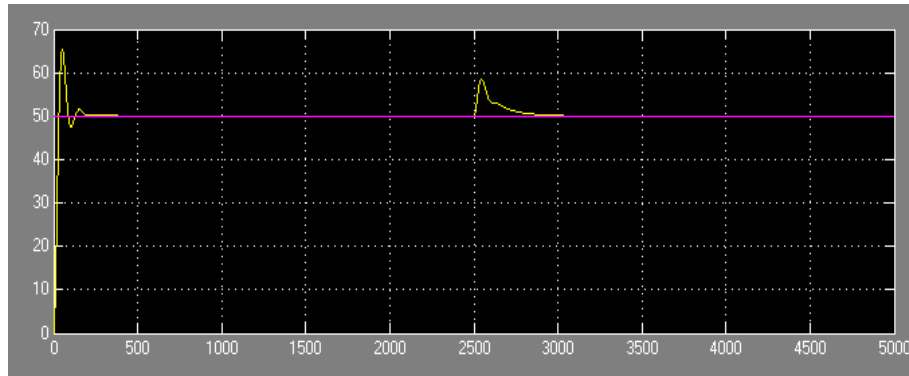


Figure 9. Series loop PID control waveform with added perturbation

From the above two graphs, it can be seen that after the perturbation is added at 2500 seconds, the system with simple loop control takes a longer time to return to the smooth state from the perturbation, while the time for the series system is very short, and it can be seen that the perturbation has less effect on the series system, which proves the superiority of the control performance of the series system.

4. Conclusion

Through the above simulation results can be obtained, compared with the use of conventional single-loop control, the use of series-level control to achieve the level of dual-capacity tank fixed-value control system has a good performance in terms of dynamic characteristics, steady-state characteristics and anti-interference characteristics, suitable for industrial production, can effectively improve the real-time, accuracy and smoothness of the production process.

Acknowledgment

This work is supported by Natural Science Foundation of Inner Mongolia (2022MS06014) and Research Program of Science and Technology at Universities of Inner Mongolia

Autonomous Region (NJZY22210).

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