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Simulation Research on Variable Frequency Control System of Hoist in Inland River Locks Based on Fuzzy PID

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Abstract. In view of the demand in the operation process of lock gate as “slow start-fast run-slow stop”, our study introduced the variable frequency control technology and established the opening and closing machine control system model. We conducted the closed-loop control simulation based on fuzzy PID to effectively suppress or eliminate the influence of error. Thus, the optimal control algorithm and strategy are obtained, and the precise control of the opening and closing process of the miter gate is realized.

1. Introduction

In the previous ship lock hydraulic steering system, the 50Hz power frequency motor is used in the hydraulic hoist of the gate, and the gate is always running at constant speed during the opening and closing process. At the moment of starting and stopping of the motor, the large acceleration of the gate and the gate weight itself will result in a great impact on the rotating parts, which causes easily damage of the mechanical parts.

In view of the Songhua River Dadingzi mountain ship lock, the intelligent variable frequency speed control device is used to control the speed of the hydraulic motor of the gate opening and closing machine. The "slow start-fast run-slow stop" variable speed operation can be achieved during the operation of the gate, which greatly increases the stability of the gate opening and closing and reduces the lash impact.

2. Frequency Conversion Control Technology of Hydraulic System

Hydraulic drive has been widely used in many fields due to its advantages of smooth transmission, high power ratio and convenient speed regulation. However, due to the low energy utilization ratio of the hydraulic drive system, the efficiency of the whole system is very low. Therefore, energy conservation has always been the main research topic in the field of hydraulic drive, which also has attracted widespread attention [1]. By changing the frequency of the power supply, the variable frequency speed regulation of the motor can be realized, so as to realize the speed regulation of the actuator and make the motor run efficiently all the time. The application of motor frequency conversion technology in the hydraulic system overcomes the shortcomings of the hydraulic system, reduces the energy loss of the hydraulic system, and further improves the efficiency of the system. Specifically, the background of the rise of variable frequency hydraulic technology is based on the following reasons [2]:

(1) the development of motor variable frequency speed regulation technology

With the continuous development of variable frequency motor speed regulation technology, it has been widely applied in many fields, and has achieved good energy saving effect. In some fields, the rate of electricity saving is even more than 40%.

(2) throttling governing hydraulic system has large energy loss and low efficiency.

In use of the traditional throttle speed control loop, the actuator always has a large overflow and throttle loss, which causes low power efficiency of the hydraulic system. Therefore, this design is only used in some small power hydraulic systems.

(3) shortcomings in volumetric speed control hydraulic system.

The principle of volume speed regulating loop is to control the speed of the actuator by changing the position control function of the variable mechanism and changing the displacement of the pump or motor. The proportional volume speed control loop is usually realized by adding electro-hydraulic proportional pilot valve on the basis of the original variable pump. That is to say, the electric mechanical converter and pilot valve are used to control the variable mechanism, so the electrical signals can be used to achieve various kinds of compensation, which can not only improve the control effect of the system, but also achieve a better energy saving effect [3]. Because the volume speed regulating loop has no throttling loss and overflow loss, it has higher power efficiency and is more suitable for high-power systems.

However, there are some shortcomings in the traditional speed control circuit. Firstly, the system needs a more complex variable displacement control mechanism, which requires a higher medium. Secondly, the swing angle of the inclined disk is limited in a certain range, so the speed range is limited; in addition, the motor speed is set at a certain value, in high speed low volume case, the wear of the system will be more aggravated and the system noise will be bigger; the efficiency of the motor varies with the load, the efficiency is very low in light load case; the variable pump is much noisier than the quantitative pump.

(4) the shortage of traditional energy saving hydraulic circuit

For the hydraulic equipment, the previous energy saving research is mostly considered from the point of view of the system itself, that is by reducing the power consumption of the hydraulic system itself, including the power loss of the loop and the power consumption of the hydraulic components.

In order to reduce the power consumption of the hydraulic components, it is necessary to further improve the efficiency of the components. Although a lot of research work has been done by the experts and scholars, it is difficult to improve the power efficiency of the components because of the restriction of the hardware structure. Improving the power efficiency of a single component does not make much contribution to the efficiency of the whole machine.

The other is to improve the mechanical efficiency by designing a reasonable hydraulic circuit to minimize the loss of pressure and flow in the loop, and to improve the efficiency by adopting different pressure adaptive control loop, flow adaptive control loop and volume control loop.

Another form of well-designed hydraulic circuit is to achieve energy recovery during the braking process, such as the various forms of secondary regulation hydraulic systems and accumulator circuits. Although there are many kinds of energy saving hydraulic circuits, there is only one purpose, which is to reach the required power, maximize the power efficiency and save energy. However, the hydraulic system that only considers energy saving still has shortcomings.

First, this energy saving hydraulic circuit is mostly very complex, for example, the pressure, flow and power of hydraulic circuits need more complicated mechanisms.

Second, the system has higher requirements for the components themselves, such as different types of accumulators, variable pumps, secondary regulation elements, etc.

Third, there are many high oil-mediums required processes and parts in the system. Poor reliability and failure rate also bring a lot of difficulty to system maintenance.

Fourth, because the system design process is only confined to the energy saving hydraulic circuit, the efficiency characteristics of the motor are rarely taken into account. When selecting the motor, the model parameters of the system are usually determined by the maximum power required by the load in the working cycle. However, during the actual operation process, the motor is mostly in the state of under load operation. Thus, the overall efficiency of the motor is low, and the power efficiency of the whole system is greatly limited.

Frequency conversion speed adjustment is easy to realize the positive and negative rotation of the motor. The operation of opening and closing of the gate only needs to output two normally open contact instructions to the frequency converter without changing the contactor. Due to improper commutation, the problem of burning motor can be avoided perfectly. The gate starts at low speed at the time of opening and closing with low frequency, which can reduce instantaneous impact and protect the mechanical elements of the gate. The accelerate time and decelerate time can be set arbitrarily, so the acceleration and deceleration processes are relatively gently. In addition, when the two gates are closed, the speed difference between the two gate motors can be adjusted in real time as required, so it is very convenient to realize the synchronous control of gate closing.

3. Simulation of Open and Close Machine Control System

3.1. Closed Loop Simulation based on PID

The experimental data is used to establish a simple model for the variable frequency drive control system of hydraulic hoist, and the simulation of PID closed loop control is carried out on the model. The parameters obtained are used to control the actual hydraulic hoist [4][5][6].

The experimental data obtained are processed and shown in Figure 1.

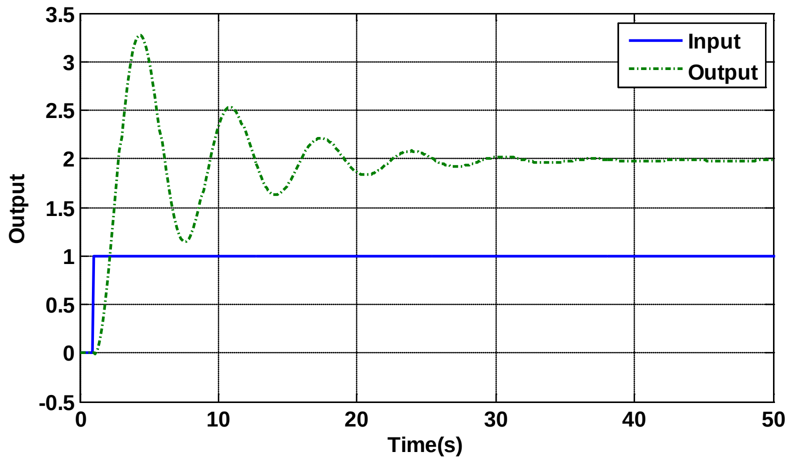

Figure 1. Experimental data

The transfer function, which is obtained by the MATLAB based simple model of the frequency conversion drive control system, is shown as follow:

$$\frac{-0.1519s+1.9821}{1.0613s^2+0.28s+1}$$

Simulink simulation model is shown in figure 2.

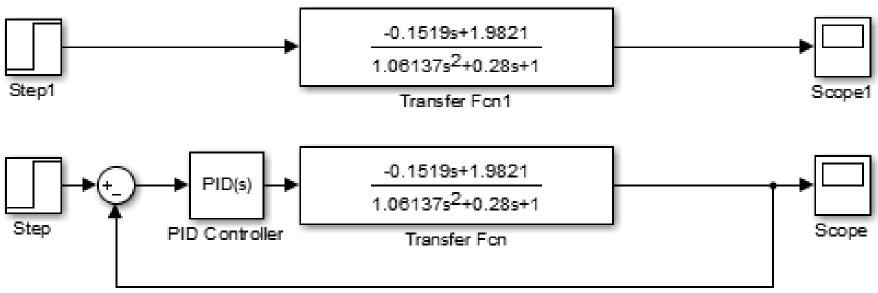

Figure 2. Simulink Simulation Model

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The step response curve of the model is shown in Figure 3.

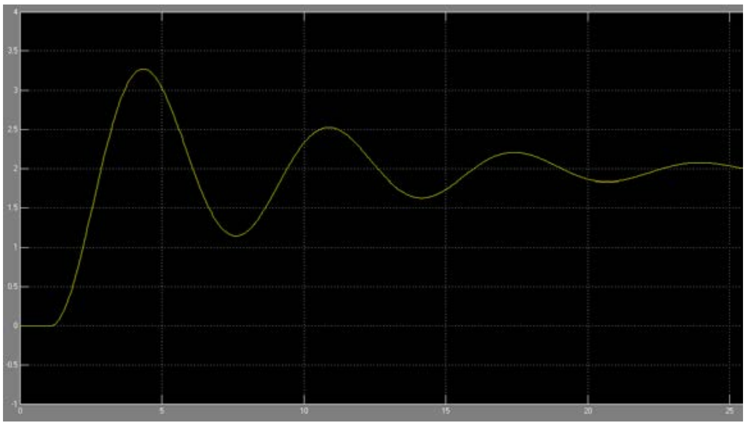

Figure 3. Step Response Curve

The step response of the PID closed loop control is shown in Figure 4.

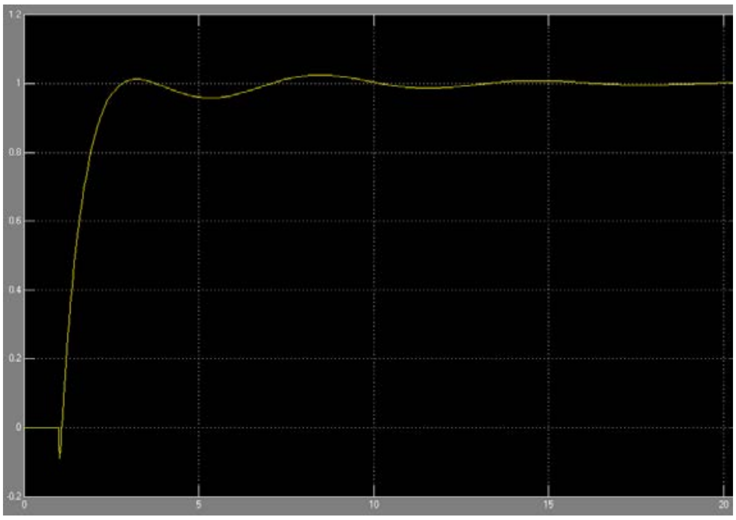

Figure 4. PID Controlled Step Response Curve

Through the simulation and experimental research, it is known that the PID control can accurately and quickly control the hydraulic hoist. However, because the hydraulic hoist models are different at different stages, the parameters of scale, differential and integral can not be fixed. Three main parameters need to be modified at each time. It is not only a waste of time, but also difficult to obtain the optimal parameters. So it is necessary to use fuzzy control and PID to realize the opening and closing machine control[7][8][9].

3.2. Closed Loop Simulation based on Fuzzy PID
The simulation model of fuzzy PID control for variable frequency drive control system of hydraulic hoist is established by Simulink, as shown in Figure 5.

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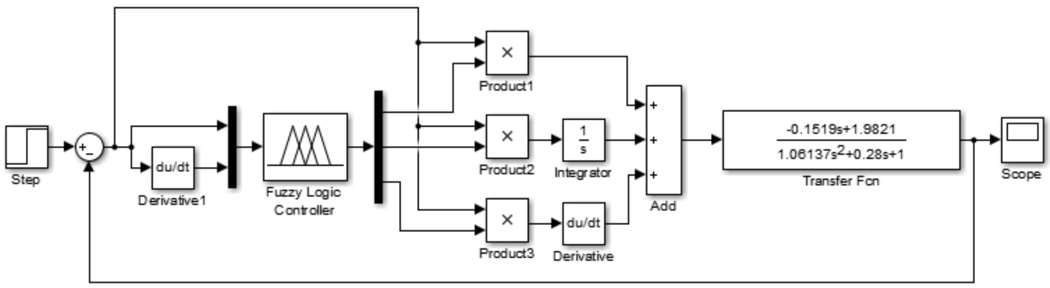

Figure 5. Fuzzy PID Control Model

The fuzzy rules for PID parameters are mostly the triangle rules. The three control surfaces are shown in Figure 6.

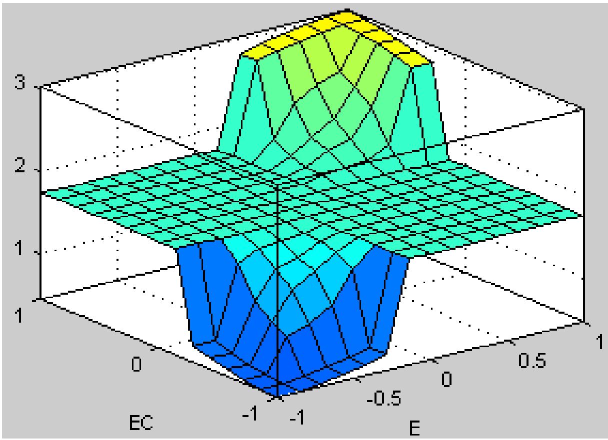

Figure 6. Fuzzy Control Strategy Surface

The step response curve of fuzzy PID control is shown in Figure 7.

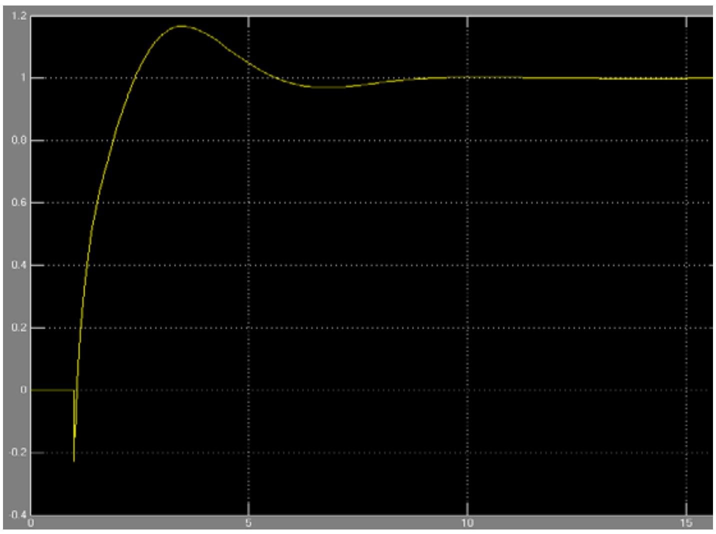

Figure 7. System Step Response Curve based on Fuzzy PID

Compared the PID control based step response curve with the fuzzy PID control based step response curve, it can be seen that the control effect by the classic PID control may be better than the

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fuzzy PID control in case of reasonably setting PID parameters. But for the changing system, the fuzzy PID control advantage is obvious. As long as the estimation model of the system is known and the PID parameters' field are given, the fuzzy adaptive algorithm can automatically match PID parameters and realize closed loop control of hydraulic hoist. Through the verification of hydraulic open and close machine experiment, the characteristics of flexible control, high applicability and high accuracy of fuzzy PID control can be obviously proved.

4. Conclusion

The result proves that the variable frequency hydraulic system based on fuzzy PID control has better control effect on gate opening and closing. In actual use, it can meet different requirements of overshoot, stability, response speed and other performance indicators, and has better operation performance.

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