**Design of Constant Pressure Water Supply PID Control System Based on SIEMENS S7-200**

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**Abstract**

In modern water supply system, the water level should be kept stable, so that the fluctuation of water pressure will be small. But in practical application, with the increase of water intake by users, the water level will drop and the water pressure of water tower will fluctuate, which is not conducive to the stability of water supply system. To solve this problem, we use Siemens S7-200 PLC as the controller and PID as control algorithm. A closed-loop control system is designed to keep the water level stable by taking the pump speed as input and the liquid level as output.

**Keywords**

Water supply systems, PID control, S7-200 PLC, closed-loop control system.

1. **Introduction**

In modern water supply systems, as water flows out, the level of the tower drops and the pressure at the bottom of the tower decreases, so that when water is delivered, the floors that could have been delivered are likely to be unacceptable. In order to solve this problem, we need to keep the water level of the water tower basically constant. Siemens S7-200 PLC has a lot of advantages in PID regulation. So we rely on the principle of PID control and use S7-200 as a tool to control the frequency of the inverter, and then control the speed of the motor to maintain the relative stability of the water level.

2. **General Plan for Achieving Constant Pressure Water Supply**

At the beginning, the motor is manually started to discharge water into the water tower. When the water level is 70% of the full water level, the PID regulation is turned on, and the PLC controls the frequency converter to automatically adjust the water level. The water level is detected by the level sensor. The sensor sends the detected level to the analog input and output module EM235 of PLC. After comparing the actual level with the set level, the inverter is controlled by the analog output port AQW0 of EM235, and then the motor speed is controlled.

3. **PID Control**

3.1. **PID Control Principle and Characteristics**

In engineering practice, the most widely used regulator control law is proportional, integral, differential control, referred to as PID control, also known as PID regulation. PID controller has been published for nearly 70 years. It has become one of the main industrial control technologies because of its simple structure, good stability, reliable operation and easy adjustment. When the structure and parameters of the controlled object can not be fully grasped, or the precise mathematical model is not enough, other control theories are difficult to use, the structure and parameters of the system controller must rely on experience and field debugging to determine, which is the most convenient application of PID control technology.
That is, when we do not fully understand a system and the controlled object, or can not effectively measure the means to obtain system parameters, the most suitable PID control technology. PID control, in practice, PI and PD control. The PID controller is the system error. It uses proportional, integral and differential to calculate the control volume to control.

3.1.1. Proportional (P) Control

Proportional control is one of the simplest control methods. The output of the controller is proportional to the input error signal. When proportional control is applied, the system output steady-state error (Steady-state error).

3.1.2. Integral (I) Control

In integral control, the output of the controller is proportional to the integral of the input error signal. For an automatic control system, the steady-state error is stored after it enters the steady state, which is called the system with Steady-state Error for short. To eliminate steady-state error, the integral term must be introduced into the controller. The integral term error depends on the time integral, and the integral term increases with the increase of time. In this way, even if the error is very small, the integral term will increase with time, which pushes the output of the controller to increase and further reduces the steady-state error until it is equal to zero. The proportional plus integral (PI) controller can make the system steady without any steady-state error.

3.1.3. Differential (D) Control

In differential control, the output of the controller is proportional to the differential of the input error signal. The automatic control system may avoid oscillatory instability during the process of error adjustment. The reason is that there are large inertial components (links) or delay components, which have the function of restraining errors, and the changes always lag behind the error changes. The solution is to "advance" the change of inhibition error, that is, when the error is close to zero, the inhibition error should be zero. That is to say, it is often not enough to introduce only the "proportion" term in the controller, and the proportion term is only used to amplify the error amplitude, but it is necessary to add the "differential term" at present, which can predict the trend of error change. Thus, with the proportional plus differential controller, the control effect of restraining error can be equaled to zero in advance, which is negative and avoided. Serious overshoot of controlled quantity. For the controlled plant with large inertia or lag, the proportional plus differential (PD) controller can improve the dynamic characteristics of the system during regulation.

3.2. PID Algorithm Implementation Process

PID algorithm is a commonly used closed loop control algorithm. PID is proportional, integral and differential. The sum of the standard PID control value and the deviation (the difference between the set value and the actual value), the integral of the deviation to time and the differential of the deviation to time can be expressed in the following formula:

\[
M(t) = K_c \left( e + \int_0^t edt + \frac{de}{dt} \right) + M_0
\]

(1)

M (t) is time function and is the output of PID control loop, Kc is the gain of the PID control loop. e is the error, M0 is control deviation and the initial value of the control loop.

It can be seen from the above formula that PID control consists of three parts of proportional integral derivative. The bigger the proportion coefficient, the stronger the control effect, and the faster the system reaction speed. But the bigger the proportion coefficient, the bigger the overshoot of the system, which leads to the system oscillation. The integral part is mainly used to eliminate the accumulation error of the control system and make the system become a static error free system. Differential links are related to the deviation rate of change, the greater the
deviation rate of change, the stronger its control effect, in order to suppress the increase of deviation. Because the computer is a digitized working tool, it is necessary to discretize the continuous function, and the equation 1 is discretized as:

\[ M_n = K_c e_n + K_I \sum_{i=1}^{n} e_i + K_D (e_n - e_{n-1}) + M_0 \]

(2)

\[ M_n = K_c e_n + K_I e_n + K_D (e_n - e_{n-1}) + MX = MP_n + MI_n + MD_n \]

(3)

Mn is the calculated value of the loop output at the nth sampling time, Kc is the loop gain, en is the loop deviation at the nth sampling time, KI is the integral coefficient of the control loop, KD is the differential coefficient of the control loop, and Mo is the initial value of the control loop. The integral term in Eq. 2 includes all the sampling errors from the first sampling period to the current sampling period. It is not necessary to save all the sampling period errors when calculating, just save the integral preceding term MX.

In the formula, MX is the preceding integral term, MPn is the proportion of the nth sampling time, MI_n is the integral term of the nth sampling time, and MDn is the differential term of the nth sampling time.

The proportional term can be written as:

\[ MP_n = K_c e_n (SP_n - PV_n) \]

(4)

The SPn in the formula is the given value at the time of sampling at n, and PVn is the value of the process variable at the time of sampling n.

The integral term is proportional to the deviation and can be written as:

\[ MI_n = K_I e_n + MX = \frac{K_c T_d (SP_n - PV_n)}{T_i} + MX \]

(5)

TS is sampling period, TI is integral time constant, and the differential term is proportional to the deviation rate.

\[ MD_n = K_d (e_n - e_{n-1}) = \frac{K_c T_d (PV_n - PV_{n-1})}{T_s} \]

(6)

KD is the differential time constant and PVn-1 is the process variable value at the sampling time of n-1. For me or ID control with zero gain, if the integral time differential time is specified as positive, it is a positive action loop, and if it is specified as negative, it is a reaction loop.

3.3. Parameter Tuning of PID Controller

The tuning of PID controller parameters is the core of control system design. It is charged with the characteristics of the process to determine the proportionality coefficient, integration time and differential time of the PID controller. There are many ways of tuning PID controller parameters. There are two main categories: one is the theoretical calculation setting method. It determines the controller parameters based on the mathematical model of the system and theoretical calculation. The data calculated by this method may not be used directly, but also must be adjusted and revised in engineering practice. Secondly, the engineering tuning method, which mainly relies on engineering experience, is carried out in the direct control system test,
and the method is simple and easy to master. It is widely used in engineering practice. The method of PID controller parameter engineering is mainly composed of critical ratio method, response curve method and attenuation method. Each of the three methods has its own characteristics, the common point is that the test, and then the engineering empirical formula to tune the controller parameters. However, the parameters of the controller need to be adjusted and perfected in actual operation. Generally speaking, it is a critical proportion method. Using this method, the tuning steps of PID controller parameters are as follows:

1. First select a sufficiently short sampling period to allow the system to work.
2. Only the proportional control link is added until the critical oscillation occurs in the system response to the input step. The proportional amplification coefficient and the critical oscillation period are recorded.
3. The formula is calculated to the PID controller parameters under a certain degree of control.

Since the 1930s, automation technology has made amazing achievements, and has played a key role in industrial production and the national economy. Automation level has become an important symbol to measure the modernization level of all walks of life. At the same time, the development of control theory has gone through three stages: classical control theory, modern control theory and intelligent control theory. The earliest and most typical examples of classical control are centrifugal flying hammer governor control of steam engine; the typical examples of modern control are gun control, Apollo moon landing; intelligent control examples are fuzzy automatic washing machine, etc.

4. Control System Design

The control program uses Siemens S7-200 programming software V4.0 STEP 7 MicroWIN SP9, PID control instructions as shown in Figure 1:

![PID control instructions](image)

<table>
<thead>
<tr>
<th>address offset</th>
<th>parameters</th>
<th>data format</th>
<th>parameters type</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>process variable PVn</td>
<td>double, real</td>
<td>input</td>
</tr>
<tr>
<td>4</td>
<td>set value SPn</td>
<td>double, real</td>
<td>input, output</td>
</tr>
<tr>
<td>8</td>
<td>output Mn</td>
<td>double, real</td>
<td>input</td>
</tr>
<tr>
<td>12</td>
<td>gains Kc</td>
<td>double, real</td>
<td>input</td>
</tr>
<tr>
<td>16</td>
<td>sampling time Ts</td>
<td>double, real</td>
<td>input</td>
</tr>
<tr>
<td>20</td>
<td>Integral time Ti</td>
<td>double, real</td>
<td>input</td>
</tr>
<tr>
<td>24</td>
<td>differential time Td</td>
<td>double, real</td>
<td>input</td>
</tr>
<tr>
<td>28</td>
<td>integral front term MX</td>
<td>double, real</td>
<td>input, output</td>
</tr>
<tr>
<td>32</td>
<td>process variable PVn−1</td>
<td>double, real</td>
<td>input, output</td>
</tr>
</tbody>
</table>
We take the TBL address as VB100, according to the PID control requirements to select the address values: VD104 is 0.7, VD112 is 1.0, VD116 is 0.1, VD120 is 30, VD124 is 0. SIEMENS STL programming language is as follows:

**Main program:**

```
LD I0.0    MOVB 10, SMB34
O Q0.0    ATCH INT_0:INT0, 10
AN I0.1    ENI
= Q0.0    interrupt:
LD Q0.0    LD SM0.0
EU ITD AIW0, AC0
CALL SBR_0:SBR0 DTR AC0, AC0
```

**Subprogram:**

```
/R 32000.0, AC0
LD SM0.0    PID VB100, 0
MOVR 0.7, VD104 MOV  VD108, AC1
MOVR 1.0, VD112 *R 32000.0, AC1
MOVR 0.1, VD116 ROUND AC1, AC1
MOVR 30.0, VD120 DTI AC1, AC1
MOVR 0.0, VD124 MO VW AC1, AQW0
```

**5. Conclusion**

The control scheme has been applied to the actual constant pressure water supply system of water tower, which can keep the actual water level at 70% of the full water level and can work stably.

**References**