Oil Contamination Cleaning Control System Based on PID

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Abstract

Aiming at the practical engineering problem of oil contamination cleaning in ships and seas, S7-300 PLC is taken as the core of control system. Based on the double cycle proportional control theory in PID controller, the auto-oil contamination cleaning spray equipment control system is built. It can achieve the flow ratio control and can be automatically adjusted according to the preset ratio of the two liquids and the total flow, which meet the predetermined requirements and has good stability and dynamic characteristics.

Keywords

PLC; PID; ratio control; automatic adjustment; double circulation.

1. Introduction

In oil and chemical industries, the control of flow ratio is very common, while the traditional control of flow ratio is achieved by manual operation, labor efficiency is low, and the work intensity is high; and due to external factors affecting the staff, the material ratio is uneven. Frequently, the quality is not up to standard, causing waste of resources [1-4]. When the surface of the sea is polluted by oil, if it cannot be cleaned up in time, it will cause serious damage to the ecosystem. In view of the shortcomings of traditional operation, this paper is based on Siemens S7-300 PLC, according to the design of the dual-cycle PID control system, to achieve the ratio of two liquids and total flow control, with good stability and dynamic characteristics.

2. System Control Structure Overview

This article is based on the actual engineering problems carried out in the study, the engineering examples used in Figure 1, the purpose is to two different liquids (oil dispersants, tap water), the two pipelines were transported to the same pipeline, After a certain proportion of modulation, the high-pressure liquid is discharged. For the control requirements, the control system selects Siemens S7-300 PLC as the control core. After setting the total flow rate and the ratio of the two flow rates, the result is transferred to the FB 41 module of the PLC through calculation, and the information returned by the flow sensor passes through the PLC. The A/D conversion module converts the sensor value into a digital quantity within the PLC. The PID control module then processes the set value and the returned value, causing the actual value to change to the set value, and finally by the D/A. The module is converted into a control current value and transmitted to the electronically controlled ball valve for control.

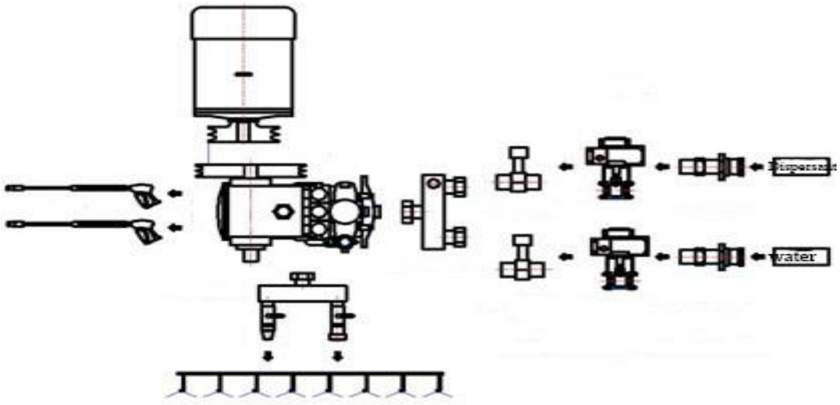

Figure 1. Project example diagram

3. System Working Principle

3.1 Double Cycle Proportional Control System

The properties of the PID control system are determined by the technical parameters and the machine conditions. In order to obtain the desired control effect, the system controller that is most suitable for the site needs to be selected. Common controller types are continuous controllers, fixed value controllers, cascade controllers, hybrid controllers, proportional controllers, secondary controllers, etc. [5].

The PID control system used in this article is a double-cycle proportional control system, which is one of the proportional controllers. Its structure is shown in Figure 2.

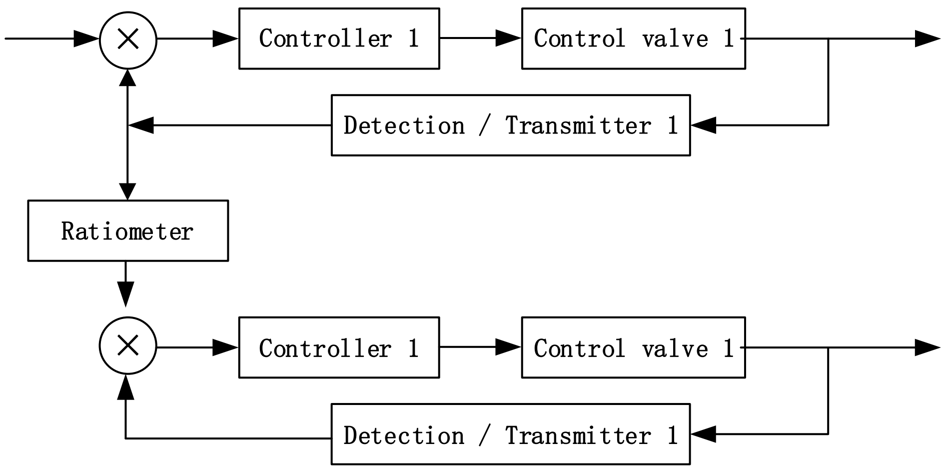

Figure 2. Double-cycle proportional controller

Based on the single-cycle proportional control system, an additional closed-loop proportional control system is added, and the single-cycle proportional control system becomes a double-cycle proportional control system [6]. The double-cycle proportional control system is more complex than the single-cycle proportional control system. The required controllers, actuators, and detectors need to be doubled. However, for actual production, the production efficiency and quality are very important. Therefore, the system is Stability and accuracy requirements are high. The multi-cycle proportional control system can calculate the set value of the second closed-loop control by the first closed-loop control process quantity. The multi-cycle proportional control system can realize the anti-disturbance and fixed value control of the master and slave momentum, so that the master and slave momentum are relatively stable, so that the total material is relatively stable and the total system load is relatively stable.

3.2 The Basic Idea of PLC Analog Closed-Loop Control System

A typical PID analog quantity closed-loop control system is shown in Figure 3, where the portion of the dashed box is achievable with a PLC. In the closed-loop flow control system described in this article, the pressure in the main pipeline is monitored by a flow sensor, and the flow transmitter converts the simple voltage signal output by the sensor into a 4 to 20 mA current signal of the standard range and then sends it to the PLC analog quantity. The input module obtains a digital quantity Pv(n) proportional to the flow rate after A/D conversion, and the CPU compares it with the flow reference value and calculates the error according to a certain control law (PID control algorithm), and the operation is performed. The result (digital quantity) is sent to the analog output module, and after D/A conversion, it becomes the standard current signal Pv(t), which is used to control the output frequency of the PID controller, and then control the opening degree of the electronically controlled ball valve Mv(t), to achieve closed-loop control of the flow C (t) [7].

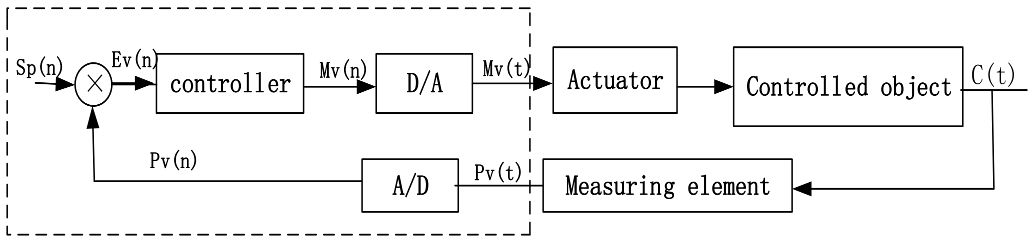

Figure 3. Scheme diagram of PLC analog quantity closed-loop control system

3.3 FB41 PID Control Module

Siemens S7-300 series provides users with powerful, easy to use, high degree of integration of the analog closed-loop control, the CPU comes with a dedicated function block to achieve PID control, all models of the CPU can use FB41-FB43 And FB58 and FB59 function blocks for temperature control. Figure 4 shows the "CONT-C" block diagram of the FB41 function block [7].

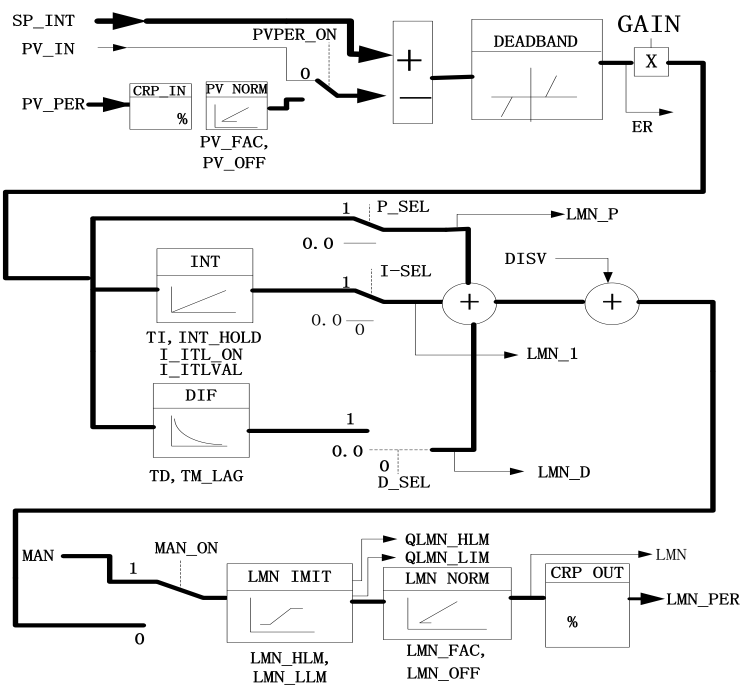

Figure 4. FB41 “CONT-C” Block Diagram

4. PLC Programming

4.1 PLC Work Flow Chart

System work flow chart shown in Figure 5, in this system, the need to be Siemens S7-300 PLC as the core control element, through the input of the total pipeline flow and ratio (tap water Q2; dispersant Q1), to automatically The electric control ball valve of each pipeline performs opening degree control, and the flow rate of each pipeline and the total pipeline pressure are fed back to the PLC through the sensor, thereby real-time monitoring and adjustment of the flow rate of each pipeline and the total pipeline pressure.

4.2 PLC Hardware Configuration and I/O Points Allocation

The Siemens S7-300 PLC adopts the modular configuration mode. The hardware configuration table is shown in Table 1. The biggest feature of the programming software STEP 7 is that it provides some data blocks for each function block (Function Block-FB). The definition of blocks and partitions is more clear, rigorous, and more powerful. The system's I/O statistics are shown in Table 2.

4.3 PLC Control Address Allocation

The definition of each symbol and address of the PLC program in the control system is shown in Table 3, including the call address in the middle of the system for internal data conversion. Many of these intermediate variables are used for data conversion in the PLC program. The actual interface variables include 2 sensor inputs, 3 digital inputs, 2 PLC analog outputs, 2 PLC digital outputs, and 2 upper outputs. The machine shows 3 values (the data is stored in the MD register) and the upper computer has 3 inputs (the data is stored in the MD register).

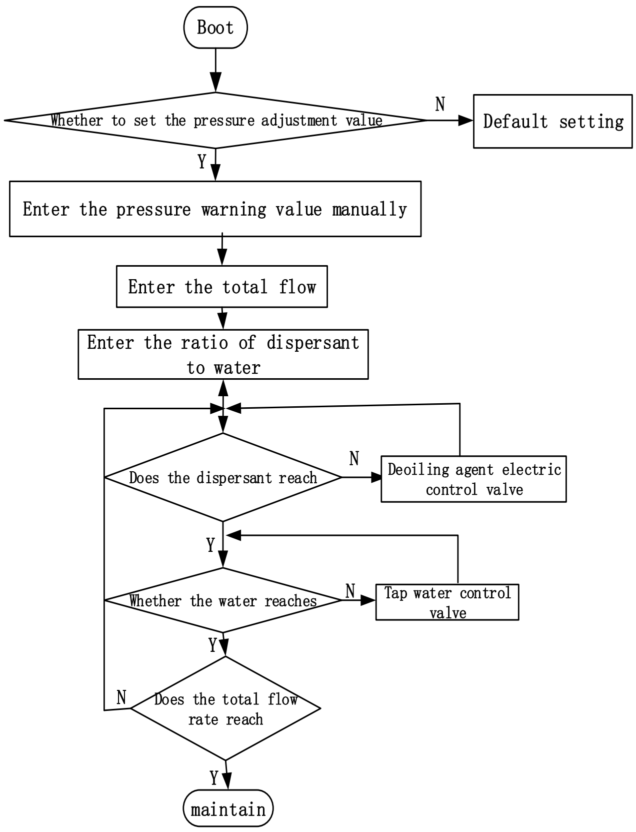

Figure 5. System Workflow

Table 1 PLC hardware configuration table

PLC module	Module name		Specification	Order number
CPU	CPU 300		314C-2 DP	6ES7 314-6CF00-0AB0
PS	PS 307	2A		6ES7 307-1BA00-0AA0
DI/DO	SM 323	DI8/DO8		6ES7 323-1BH00-0AA0
AI	SM 331	AI8×12Bit		6ES7 331-7KF01-0AB0
AO	SM 332	AO2×12Bit		6ES7 332-5HB01-0AB0

Table 2. System I/O Statistics

Input signal			Output signal		
name	symbol	address	name	symbol	address
start up	SB1	I0.0	pressure	YL	PIW276
stop	SB2	I0.1	motor	KM	Q0.0
emergency stop	SB3	I0.2	Warning light	BJ	Q0.1
flow1	L1	PIW272	Electric valve 1	D1	PQW288
flow2	L2	PIW274	Electric valve 2	D2	PQW290

Table 3. Control System Symbol Table

Symbol	Address	Data type
CONT_C	FB 41	FB 41
SCALE	FC 105	FC 105
UNSCALE	FC 106	FC 106
SB1	I 0.0	BOOL
SB2	I 0.1	BOOL
SB3	I 0.2	BOOL
YLXS	MD 20	REAL
LL1XS	MD 24	REAL
LL2XS	MD 28	REAL
TOTAL	MD 32	REAL
RATIO	MD 36	REAL
YLBJ	MD 40	REAL
FLOW1	MD 54	REAL
FLOW2	MD 58	REAL
F1SC	MD 64	REAL
F2SC	MD 68	REAL
L1W	MW 50	WORD
L2W	MW 52	WORD
CYC_INT5	OB 35	OB 35
L1	PIW 272	INT
L2	PIW 274	INT
YL	PIW 276	INT
D1	PQW 288	INT
D2	PQW 290	INT
KM	Q 0.0	BOOL
BJ	Q 0.1	BOOL

4.4 PLC Ratio Control

The ratio calculation program is one of the core programs of this design and acts as a ratio comparator in the entire double closed loop control system. Therefore, the calculation of the flow ratio ratio plays an extremely important role in this system. The basic requirement of this design is to input the total flow rate and the ratio of water to the oil-removing agent from the host computer. The opening of the electronically controlled ball valve of the two sub-pipes can be controlled separately to achieve the flow control. So the calculation process is as follows [8]:

$$K = \frac{K2}{K1} \tag{1}$$

$$K1 + K2 = 1 \tag{2}$$

(1), (2) The two equations can be solved by equations (3) and (4):

$$K1 = \frac{1}{K+1} \tag{3}$$

$$K2 = \frac{K}{K+1} \tag{4}$$

Dispersant flow rate:

$$Q1 = \frac{Q\alpha}{K+1} \tag{5}$$

Water flow:

$$Q2 = \frac{QK\alpha}{K+1} \tag{6}$$

Where K is the proportional coefficient; Q is the total flow, L/min; Q1 is the dispersant flow, m3/h; Q2 is the water flow, m3/h; K1 dispersant ratio; K2 water ratio; α is the unit conversion Coefficient (α=3/50, from L/min to m3/h).

4.5 FB41 Module Configuration

In the S7-300 PLC, the FB41 PID control module to set the flow rate feedback is set as follows:Set the hardware interrupt cycle of the OB35 organization block in the CPU hardware setting to 100 ms; create the OB35 organization block, call the FB41 function block therein, and establish the data block DB41 (flow 1 data), DB42 (flow 2 data) as the background Data module; set MAN_ON value to 0 (BOOL), enable closed loop, do not receive manual value; set PEPER_ON value to 1 (BOOL), enable peripheral input variable; set CYCLE value to T#100 ms(TIME) Set the sampling period (FB41 call cycle), the value should be consistent with the interrupt cycle of the OB35 organization block; set the SP_INT value to the standardized MD54 (FOLW1, the MD58 of flow 2 is the same); set the PV_PER peripheral input Value port access MW50 (flow transmission value, MW52 same); set TI value T#200 ms, ie integration time is 200 ms; set LMN output port to access MD60 (valve output, MD64 is the same); The rest of the parameters are the default settings (PI control parameters can be set and optimized in the on-site debugging). The flow PID control in the program is as follows, where Q1:Q2=1:3.

```
A M 0.3
= L 20.1
BLD 103
A M 0.2
= L 20.2
BLD 103
CALL "CONT_C" , DB10
```

```
COM_RST :=
MAN_ON  :=L20.1
PVPER_ON:=L20.2
P_SEL :=
I_SEL :=
INT_HOLD:=
I_ITL_ON:=
D_SEL :=
CYCLE :=T#100MS
SP_INT :="FLOW1"
PV_IN :=
 PV_PER :="L1W"
MAN :=
GAIN :=
TI :=T#200MS
TD :=
TM_LAG :=
DEADB_W :=
LMN_HLM :=
LMN_LLM :=0.000000e+000
PV_FAC :=
PV_OFF :=
LMN_FAC :=
LMN_OFF :=
I_ITLVAL :=
DISV :=
LMN :="F1SC"
LMN_PER :=
QLMN_HLM:=
QLMN_LLM:=
LMN_P :=
LMN_I :=
LMN_D :=
PV :=
ER
```

5. Conclusion

In this paper, according to the FB41 PID function block of Siemens S7-300 PLC, the proportional control of the flow rate is achieved by using a double-cycle control structure, and the water and the cleansing agent flow according to the preset ratio and flow rate. The liquid sprayed by the spray gun is more uniform and achieves a better oil-purifying effect. This system is widely used in an environmental protection division in Shandong due to its superior stability, dynamic characteristics, and high working efficiency.

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