Research on the Design of Constant Pressure Water Supply System Based on PLC

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In this paper, the author researches on the design of constant pressure water supply system based on PLC. The combination of computer technology and PLC control technology could effectively and rapidly test the present water supply system's parameters and performance; meanwhile it could also modify the software to test other parameters at any time according to customer's demands. This study adopted modular design, usually used in system design, to divide the system's functions into modules, thus revealing the design concepts of the complex system. The control model and the approximate mathematical model are also established. The frequency converter with built-in PID module to realize the closed loop speed control system. The water flow with frequency pump mutual investment security supply and variable frequency pump grading adjusting water supply mode can not only ensure the lowest safe water flow and also high flow constant pressure water supply and energy saving. This paper discusses the two motor mutual investment reserves for minimum security of water supply idea and implementation method, discusses a variety of effective supply states and the switching conditions of four pumps parallel water supply mode. This paper also discusses the PLC control software program flow, electrical control scheme, PLC software, PID parameter setting, motor relay protection setting and some other issues in depth.

1. Introduction

Along with the high speed development of Chinese economy, industrial enterprise production scale expands unceasingly, Industrial enterprise on production process control precision improves constantly, and enterprise water supply system is developing very quickly. At the same time, soft and hardware infrastructure construction of water supply system also need higher request. And this system is an important part of industrial enterprise's reliability and stability. Water supply system affects industrial enterprise production safety continuity. Because low efficiency and automation level, the traditional methods of industrial enterprise like the pump pressurization water supply and the jar etc. are difficult to satisfy the needs of current industrial production. Based on the requirement of water supply in an industrial enterprise, a system by using variable frequency and controlling, which is composed of low voltage electrical equipment transducer, PLC, pumps, motors is designed to. This system has functions of automatic work frequency operation, automatic constant pressure operation and the function of long-range control by hand (He and Chen, 2016).

2. Communication test and system functional module

The water supply test system in this study was mainly divided into two parts, hardware design and software design which were independent but also closely interconnected. This study took a holistic consideration to match the two parts so as to create a highly efficient and convenient water supply test system (Montalvo et al., 2008; Stokes and Horvath, 2006).
Analysis of test control system:
(1) Display Function
The measurement system could display all the crucial default parameters and real-time parameters in the forms of graphs, diagrams, etc. This could show the whole state of the test system.
(2) Function of Real-time Control

The test system could send control orders to the operating units at any time. The orders could control all the phases of the test and produce a report of the parameters and data in the test. The user could use all the adjustment equipment, such as the buttons, to control all the phases and process of the test, like setting the rotating speed and moment of force, etc.

(3) Alarming Function (Wilhite et al., 2009).

If something went wrong with the equipment, or the tested parameters were beyond the default parameters, the test system could warn the operators in the forms of light or electrical signals and point out the failure area.

(4) Data Management Function

The test system could collect, store, display the test data which could be inquired, produce reports with these data and print the reports. The uses could find data they wanted, such as parameter record, curve record, and etc. Meanwhile, the database could also be retrieved and printed.

This system adopted PLC as the IC of parameter collection and process control, and the control system consisted of several equipment and one PLC. (Refer to Figure 1) this kind of system is usually used when the component equipment is not far away from each other and closely related. However, if one subjects was changed, the all the subjects must be stopped which was one of the disadvantages of centralized control system. But this system in the study could totally meet the test demands.
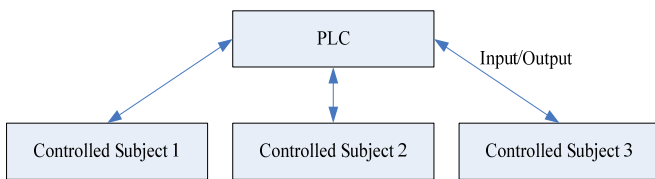

Figure 1: Centralized Control System

Because the man-machine interface resources of PLC controller were limited, therefore, extra equipment should be added in the design to offset this problem. In this study, a industrial computer was utilized which was applicable in industrial environment characterized with intense dust, strong noises, and strong electric-magnetic field, etc. Meanwhile, this industrial computer had sufficient software resources, strong man-machine interface, whose system functions and resources could be updated to meet different demands and its windows operating system could be sued to control the test (Filipe and Ramos, 2009).
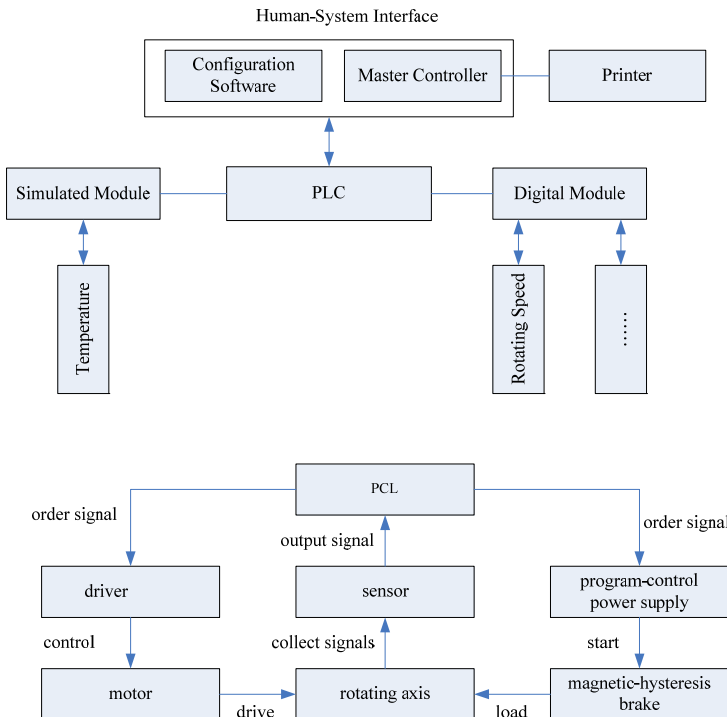

Figure 2: Control System Structure and the structure of the PLC control system

This study clearly took a scheme that was characterized by PLC as the core of master control and the combination of master controller with PLC. In this water supply test design, PLC sent order signals to the driver to start the water supply, then the program-control power was started to control-hysteresis brake so as to simulate the load size, and the sensor collected the signals from the rotating axis and sent them back to PLC for processing. Finally, the resulted data were displayed, processed and managed by the master controller. The structure of the PLC control system was shown as Figure 2.

In this system design, the master controller and PLC were its host computer and core of control respectively, which were connected by data link equipment. The host computer had the real-time functions, including display, sending orders, parameter setting, and controlling the display; while the functions of PLC were collecting data, controlling test equipment, and shifting, etc. The test system could control all the test processes smoothly and control several test parameters at the same time. The system could also effectively and rapidly collect, converse and store, display the data. Besides, the system could check itself when it was working, and man could check the system as well. The function of PLC is clear, and its structure is shown in Figure 2.

3. Detail design for software and hardware

The software and hardware of water supply test system controlled by PLC were design independently, whose compatibility should be ensured. The steps of PLC controlled were as follows: analyzing control demands, distributing I/O ports, hardware design, software design, debugging on the scene. Apart from meeting the design tasks and demands and conforming to the present production process, the system design should serve the purposes of safety, reliability, easy operation, convenient maintenance, and being economical and practical.

Considering the functional demands of water supply test system, this test system adopted Siemens's PLC chip, S7-200, as it's CPU, which has been widely used and has a stable performance track record. Siemens Co. Ltd. is the world's leading electrics company with semiconductor as its core competitiveness and is one of the biggest electrics equipment providers, who have advanced automatic control technology and experience and a relatively big share of the PLC market. The S7-200 PLC could satisfy the whole system design's needs of A/D and D/A conversions, I/O ports, water supply ports. Besides, its cost performance, reliability, and stability, among other things were superior to its fellow products.

The algorithm based on SQP theory can be expressed as following (Dean, 2009).

$$f^{(\alpha)}(x0) = \frac{df(x)}{dx^\alpha}\bigg|_{x=x_0}$$
$$= \lim_{\delta_x \to 0} \frac{\Delta^\alpha(f(x)-f(x_0))}{(x-x_0)^\alpha}$$

(1)

For $0<\alpha\leq1$ where

$$\Delta^\alpha(f(x)-f(x_0)) \cong$$
$$\Gamma(1+\alpha)\lim_{x\to\infty}\Delta(f(x)-f(x_0))$$

(2)

And local fractional integral of $f(x)$ defined by Eq.3.

$$_aI_b^{(\alpha)}f(t) = \frac{1}{\Gamma(1+\alpha)}\int_a^b f(t)(dt)^\alpha$$
$$= \frac{1}{\Gamma(1+\alpha)}\lim_{\Delta t \to 0}\sum_{j=0}^{j=N-1} f(t_j)(\Delta t_j)^\alpha$$

(3)

With $\Delta_i t = t_{j+1} - t_j$ and $\Delta t = \max\{\Delta t_1, \Delta t_2, ..., \Delta t_j, ...\}$, where for j=1, 2, …, N-1, [t_j, t_{j+1}]and t_0=a, t_N=b. Active set methods (ASM) are considered as one of the most effective techniques for solving small to medium scale nonlinear problems. In this work we will focus on ASM for solving convex QP problems depicted in (3) in which case the Hessian G is at least positive semi definite and therefore any local solution of the QP is also a global minimizer. ASM solves system (3) by reducing it into the following equality constrained QP. If f(x) is defined on the real line $-\infty < x < \infty$, its local fractional Hilbert transform, denoted by $f_x^{H,\alpha}$(x) is defined by

$$H_\alpha\{f(t)\} = \hat{f}_H^\alpha(x) = \frac{1}{\Gamma(1+\alpha)}\oint_R \frac{f(t)}{(t-x)^\alpha}(dt)^\alpha$$

(4)

Where x is real and the integral is treated as a Canchy principal value, An active set method starts by making an initial guess of the optimal active set $f_x^{H,a}(x)$, usually, if this guess turns out to be incorrect, it repeatedly uses gradient and Lagrange multiplier information to swap indices in and out of the current estimate of A(x*).Although the simplex method is principally considered as active set approach for solving LP problems, active set methods for QP differ from the simplex method in that the search may not always progress from one vertex of the feasible region to another. Some iterates (and, indeed, the solution of the problem) may lie at other points on the boundary or interior of the feasible region. That is:

$$
\frac{1}{\Gamma(1+\alpha)} \oint_R \frac{f(t)}{(t-x)^\alpha}(dt)^\alpha
$$
$$
= \lim_{\varepsilon \to 0}[\frac{1}{\Gamma(1+\alpha)} \int_{-\infty}^{x-\varepsilon} \frac{f(t)}{(t-x)^\alpha}(dt)^\alpha +
$$
$$
\frac{1}{\Gamma(1+\alpha)} \int_{x+\varepsilon}^{\infty} \frac{f(t)}{(t-x)^\alpha}(dt)^\alpha]
$$

(5)

To obtain the inverse local fractional Hilbert transform, write again Eq. (4) as

$$
\hat{f}_H^\alpha(x) = \frac{1}{\Gamma(1+\alpha)} \int_{-\infty}^{\infty} \frac{f(t)}{(t-x)^\alpha}(dt)^\alpha
$$
$$
= \frac{1}{\Gamma(1+\alpha)} \int_{-\infty}^{\infty} f(t)g(x-t)(dt)^\alpha
$$
$$
= f(x)*g(x),
$$

(6)

The equation of motion is as follows:

$$
\partial_j(C_{ijkl}\partial_k u_l + e_{kij}\partial_k \varphi) - \rho \ddot{u}_i = 0
$$

(7)

Under the linear theory, that is:

$$
\partial_j(e_{ijkl}\partial_k u_l - \eta_{kij}\partial_k \varphi) = 0
$$

(8)

The linear equation can be expressed into the following simplified forms:

$$
L(\nabla,\omega)f(x,\omega) = 0, \; L(\nabla,\omega) = T(\nabla) + \omega^2 \rho \mathsf{J}
$$

(9)

Since the vectors $L(\nabla,\omega)$ are linearly independent for all $T(\nabla)$, the strictly convex inequality constrained QP can be solved by solving the following KKT system via the range space or null space procedures elaborated in (9). Consider the Lagrangian expression for the equality constrained problem depicted in (9), In which,

$$
T(\nabla) = \begin{Vmatrix} T_{ik}(\nabla) & t_i(\nabla) \\ t_k^T(\nabla) & -\tau(\nabla) \end{Vmatrix}, \; \mathsf{J} = \begin{Vmatrix} \delta_{ik} & 0 \\ 0 & 0 \end{Vmatrix}, \; f(x,\omega) = \begin{Vmatrix} u_k(x,\omega) \\ \varphi(x,\omega) \end{Vmatrix}
$$

(10)

Consider delay, the L can be expressed as:

$$
L^0 = \begin{Vmatrix} C_{ijkl}^0 & e_{kij}^0 \\ e_{ikl}^{0T} & -\eta_{ik}^0 \end{Vmatrix}
$$

(11)

These functions can be expressed in the following form:

$$
C(x) = C^0 + C^1(x), \; e(x) = e^0 + e^1(x), \; \eta(x) = \eta^0 + \eta^1(x), \; \rho(x) = \rho_0 + \rho_1(x)
$$

(12)

The value with superscript of 1 represents the difference below:

$$
C^1 = C - C^0, e^1 = e - e^0, \; \eta^1 = \eta - \eta^0, \rho_1 = \rho - \rho_0
$$

(13)

The whole function can be simplified into the following integral equation set:

$$
f(x,\omega) = f^0(x,\omega) + \int_V S(x-x')(L^1 F(y')
$$
$$
+\rho_1 \omega^2 \mathbf{g}(R)T_1 f(y')]S(y')dy'
$$

(14)

The PLC adopted in this system design had MPI (Multiple Point Interface) and DP ports, among other ports, which could still not satisfy the demands of the modernized water supply test system. Therefore, this system should add extra I/O ports to enhance the system design's advantages. As a result, SM332, SM322, SM321 were added to the system in this study. Meanwhile, in order to improve the system's anti-interference ability around the I/O module, RC filter circuit was added to the system, which had no impact on the system. When the digital signal drove the electrics equipment, with a small volt and current, a relay should be added to control the strong-volt equipment.

As a specifically designed development tool by Siemens for S7-200CN, STEP-Micro/WIN V4.0 was developed based on windows which had a friendly interface, strong functions to allow system programming and resources distribution. It not only allowed all kinds of programming, but also monitored the real-time operating programs of the users. The PLC of S7-200 series had rich programming languages, which at present included function module, sentences forms, T-shape graphs, and etc. It could use some kind of language order, and also use several languages. The host computer and programmer could use it to program function order.

When programming, in order to make the programming easy and capable of inquiry and modification, the position in memory was marked, and the uses of function modules were noted.The hardware of this study were Siemens equipment, therefore, the compatibility of programs was pretty good. The programming languages were based on the real needs, such as order diagrams, framework texts, T-shape graphs. The essence of this test was to test the I/O port's digital signals. In general, PLC programs were modular which were made up of different modules. The module types and functions are shown in Table 1.

Table 1: Module Types and Functions

Module Types	Module Names	Module Functions
Logical Modules	OB	Operating system and user programs' ports & decide users' program structure
	FC	Programmed by users & no sub-function and memory
	FB	Programmed by users & memory and sub-function
	SFB	Stored in CPU operating system & system function module
	SFC	Stored in CPU operating system & system function module
Data Modules	DB	Store data & shared by all modules

PLC programming and computer programs had similarities so that after the designers drew out the framework, they just need to program the corresponding function orders in the modules. First of all, the test of power supplies was the basic of the whole test which must be done at the beginning of the whole test. Secondly, the inverter must be checked. Started the delay-timer, when the rising edge was approaching, the delay-time began to time, and the position of SD was "1"; the falling edge was blocked, and the delay-timer was stopped to wait for the next rising edge. At this time, if nothing was wrong with the power supply, then the switch was kept open, ensuring normal power supply to inverter. Check and record the inverter's output signal and cut the circuit when the test was over, then sending orders to change the internal parameters to its default settings. When something urgent happened in the test, press the related button, then the PLC would stop the orders in the shortest time to top the inverter.

When PLC framework of program module was confirmed, its programming was the same with computer programming, inputting correspondent codes in fixed modules to realize PLC framework programming. As shown in Figure 4, these were the components of the test system.
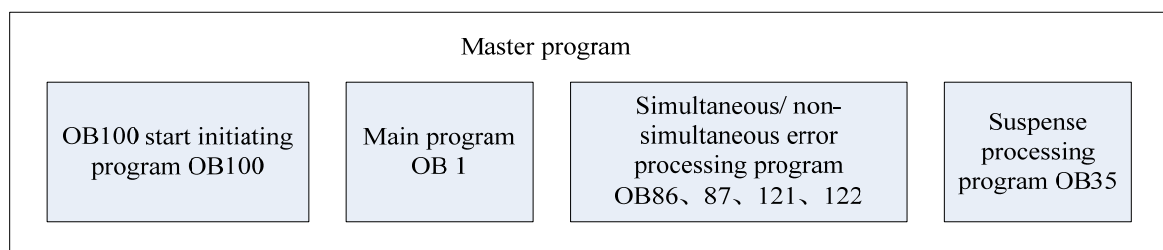

Figure 4: The components of the test system

4. Conclusion

Water supply system affects industrial enterprise production safety continuity. Because low efficiency and automation level, the traditional methods of industrial enterprise like the pump pressurization water supply and the jar etc. are difficult to satisfy the needs of current industrial production. In this paper, the author researches on the design of constant pressure water supply system based on PLC. This paper discusses the two motor mutual investment reserves for minimum security of water supply idea and implementation method, discusses a variety of effective supply states and the switching conditions of four pumps parallel water supply mode. This paper also discusses the PLC control software program flow, electrical control scheme, PLC software, PID parameter setting, motor relay protection setting and some other issues in depth. The experiment result shows the proposed method can improve the overall performance.

Acknowledgments

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