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# HYBRID FUZZY PD CONTROL OF TEMPERATURE OF COLD STORAGE WITH PLC

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**ABSTRACT**

The cold storages are the industrial equipments for storing food, vegetables and other things in low temperature. Characteristics of the cold storage for their volume have a big lag and are difficult to control. So, traditional PID controls are not adaptive to control them. One of methods which can overcome the problems is using a fuzzy control for them. But it is known that the differential input which is needed in the fuzzy controller is difficult to realize and easy to producing oscillating. A nonlinear tracking differentiator (TD) is substitute for a usual differential input; therefore hybrid fuzzy PD (proportional and derivative) controls which include two nonlinear tracking differentiators have been presented. In this paper, the hybrid fuzzy PD control for cold storages with PLC is proposed to improve the system performances. The paper is focus on the realizations of the control algorithms specially. The application of the system in the fields proved the control system related with the paper is correct and effective.

**Keywords:** *Cold Storage, Fuzzy PD Control, Tracking Differentiator, PLC, Refrigerator*

## 1. INTRODUCTION

There are many cold storages applied in the world for storing food, vegetables and other things in very low temperature. One of most important parameters with them is the temperature. The refrigerators are used to control the temperature of theirs. With the development and improvement of industrial control levels, the refrigerators for cold storages are used wider in productive practice and required better control characteristics. But for the sake of the big volume of cold storages and several point distributions of the refrigerators and sensor, the control of temperature of cold storages is very difficult. In order to study the problems, some papers have been published. The fundamental factors to control the temperature of a cold storage are to sense the information of the temperature; different configurations of the cold storages require different controllers. The embeded-systems [1] can be used for a single cold storage, and distribution systems [2] have been used for lots of cold storages. In order to obtain the good control properties, some control algorithms must be used. PID algorithm was used generally [3], and several intelligent algorithms, such as simulated-human control [4] and fuzzy control [5] have been adopted better. It is noted that the above controllers are not suitable to the application because of reliability of control systems. So the programmable controllers (PLC) as the main control equipment and fuzzy control algorithms were adopted in the paper. Additionally, PLC can realize the other control functions of the system easily.

As we known, traditional PID controls are not adaptive to control them. One of main methods which can overcome the problems is using a fuzzy control. But it is known that the differential input which is needed in the fuzzy controller is difficult to realize and easy to producing oscillating. A nonlinear tracking differentiator (TD) is substitute for a usual differential input. Therefore hybrid fuzzy PD controls have been presented. But, a hybrid controller can provide better system performance over a simple fuzzy controller alone.

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In this paper, hybrid fuzzy PD control for cold storages is proposed to improve the system performance. The paper is focus on the realizations of the control algorithms specially.

The paper is organized as following: section 2 deals with the design of hybrid fuzzy PD controller, section 3 presented realizing techniques of the controller with PLC. Section 4 introduces the application of control system with PLC presented. Section 5 gave some summary.

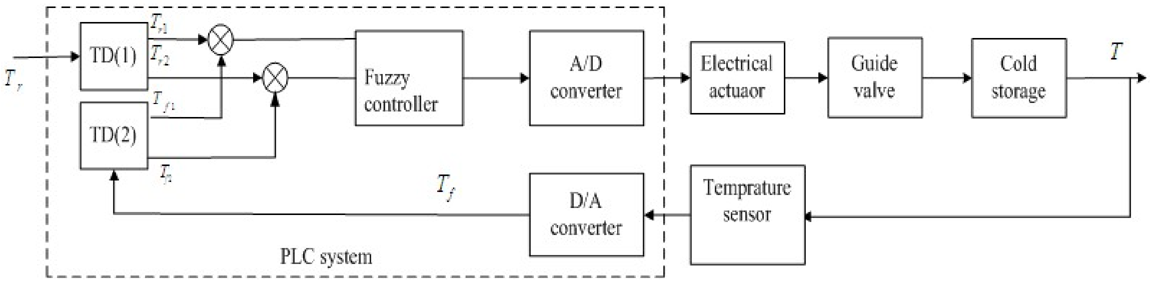

*Figure 1: The System Block*

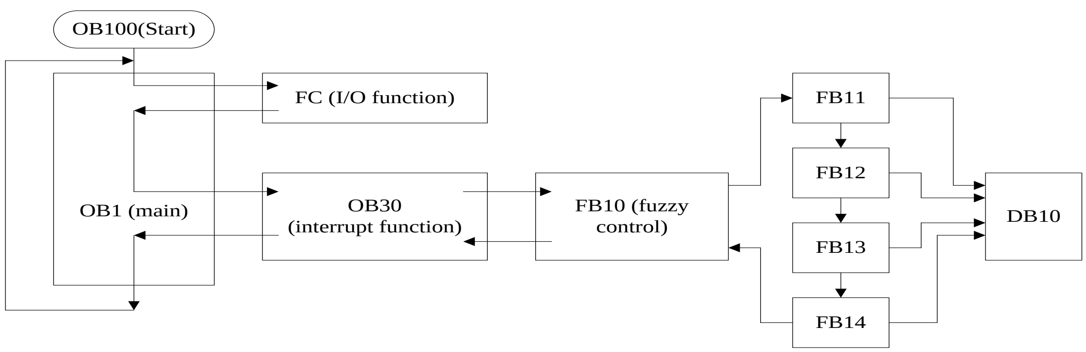

*Figure 3: The Diagram Of Structure For Software*

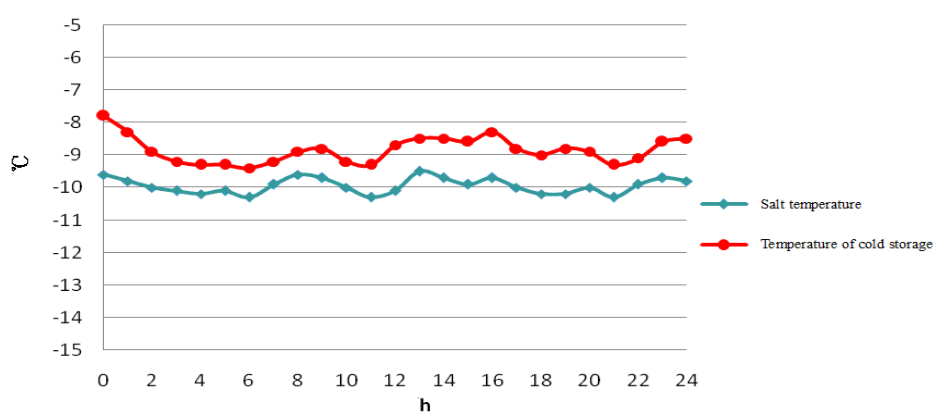

*Figure 4: The Diagram Of Temperature*

## 2. DESIGN OF HYBRID FUZZY PD CONTROLLER

The characteristics of the cold storage for their volume are big lag and difficult to control. The temperature of the cold storage is controlled by refrigerator. There are two methods of controlling refrigerating media in refrigerator, which are using a suction guide valve or controlling flow speed of refrigerating media to control the speed of impeller in the centrifugal refrigerator directly. In the system of ours, the first control method was used in order to make use of exiting equipments. There is a suction guide valve in the input of the refrigerator to control refrigerating capacity for the change of refrigeration load. So, the mathematic relation

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between the temperature of cold storage and the suction guide valve can be defined [4 ].For such control process, the mathematical model of the cold storages can be approximately reduced to first-order inertia plus time delay model expressed as below:

$$G(s) = ke^{-ts}/(Ts+1) \quad (1)$$

which T is the time constant and t is the pure delay time. Formula (1) can be simplified approximately as the second-order system model:

$$G(s) = k/\left[(Ts+1)(ts+1)\right] \quad (2)$$

As we known, if a traditional PID controller is applied to the formula (2), the parameters of the controller are difficult to choose, and the unmodelling characteristics of object are not to control. Therefore, the fuzzy controls were used to improve the control characteristics of system. In order to get the easy realization, hybrid fuzzy PD controls were designed for the ease of differential controller in physical level. The hybrid fuzzy PD consists of two nonlinear tracking differentiators. The nonlinear tracking differentiator TD ( Ⅰ ) whose input $T_r$ and tracking differentiator output is $T_{r1}$ and $T_{r2}$ is designed as [6-8]

$$\dot{T}_{r1} = T_{r2} \quad (3)$$

$$\dot{T}_{r2} = -R_r sat(T_{r1} - T_r + \frac{T_{r2}|T_{r2}|}{2R_r}, \delta_r)$$

(4)

which a nonlinear saturation function $sat(A, \delta_r)$ is defined as

$$sat(A,\delta_r) = \begin{cases} \operatorname{sgn}(A), & |A| > \delta_r \\ \dfrac{A}{\delta_r}, & |A| \le \delta_r, \delta_r > 0 \end{cases} \quad (5)$$

in which $\operatorname{sgn}(\cdot)$ is a standard sign function.

Similarly the nonlinear tracking differentiator TD(Ⅱ) whose input $T_f$ and tracking differentiator output is $T_{f1}$ and $T_{f2}$ can be obtained.

Using the output signal of the above speed differentiator, the fuzzy controller input signals are represented as

$$e(t) = K_e(T_{r1}(t) - T_{f1}(t)), \quad (6)$$

$$c(t) = K_c(T_{r2}(t) - T_{f2}(t)) \quad (7)$$

which $K_e$ and $K_c$ are the scaling gains.

So the close-loop control structure which includes the hybrid fuzzy PD controller is shown in Fig 1. It consists of fuzzy PID controller, D/A converter, electrical actuator, suction guide valve, cold storage, temperature sensor and A/D converter.

Fuzzy PID controller is designed as follow. Supposes the two-dimensional fuzzy reasoning input fuzzy language variable is E and C, the output fuzzy language variable is U. Set language variable E to be 6, namely {negative big (NB), negative middle (NM), negative small (NS), positive small (PS), positive middle (PM), positive big (PB)}.The fuzzy language variable C of change rate of linguistic value deviation is 5, namely {negative big (NB), negative small (NS), zero (Zero), positive small (PS), positive big (PB)}; output fuzzy language variable U will be 5, namely {zero (Zero), positive micro (PW), positive small (PS), positive middle (PM), positive big (PB)}. Rule explanation: Take the rule "IF E=PB and C=Zero then U=PB" as an example, if E is (PB) and the change rate C of deviation is a zero, in order to obtain the quick speed of response, should enlarge the control quantity, namely U=PB. Altogether 30 sentences form the input output relations curved surface fuzzily in Matlab, as shown in Figure 2.

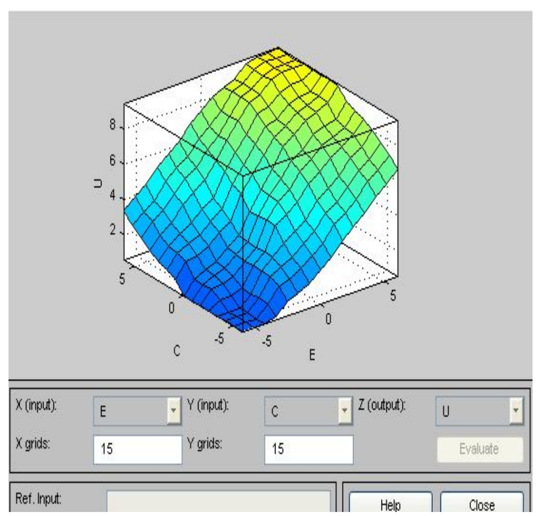


*Figure 2: The Input Output Relations Curved Surface*

## 3. REALIZATIONS OF FUZZY PID CONTROLLER BY A PROGRAMMABLE CONTROLLER (PLC)

Programmable controllers (PLC) are a most widely application in the industrial control

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environments. They have an advantage of high function and easy programming. Especially, they can easily realize very complex control algorithms in one or several instructions. Further, in the application of controllers, the reliability of them is one of the best properties. Generally programmable controllers have the better reliability than other controllers.

During programming of PLCs, usually, sequential function chart (SFC) is draw first, and the ladder logic diagram is draw second. But, for the complexes control states, the integrated programmings are mixed and not clear. So, some PLC use module programming, that is task of programming are divided several parts, such as function block and data block.

So, hybrid fuzzy PD controller is realized by a programmable controller (PLC) of CPU 333 in series S7-300 with type of module programming. Its program flowchart is shown in the Fig 3. Main program module OB1 completes the function and the function block as well as signal and data transmission. Function module FC completes A/D sampling, carries on D/A output and other processions. The circulation interrupt organization block for selecting time gap is OB30 of 1s. Function module FB10 completes the entire fuzzy control function. The background data block DB10 which corresponds with function module FB10, mainly saves the quantification factor and the goal temperature, the survey temperature and so on other parameters. FB10 is composed of four sub-procedures FB11, FB12, FB13, FB14; FB11 completes TD (1) control function; FB12 completes TD (2) control function; FB13 realizes summing function; FB14 completes fuzzy control processing.

The function of FB14 includes carrying on fuzzy processing, realizing the fuzzy control list inquiry function, completing clear processing. The core technology is the fuzzy control questionnaire inquiry procedure. In the fuzzy control list, fuzzy control value U saves in block data DB10 according to from rank to column and from the left towards right visiting way order. The data type is integer (INT).The first address is DB0, is in turn DB2, DB4 ......DB58 (the U regular number is 30).If the conventional look-up table method of judgment sentence is uses, it will be able to cause the procedure statement to be many and to be tedious, therefore the indicator addressing table of look-up method in STEP7 will be used. In order to simplify the design, input element in the fuzzy universe of discourse is set to increase 6, finally [0, ......12].The base address of control quantity is 0, the displacement address is 2×(13×Xi+Yj), by Xi, Yj may determine the absolute address of the control quantity is 2×(13×Xi+Yj), obtains the U fuzzy value through the indicator variable which in the address saves.

## 4. RESULTS OF EXPERIMENTS

The system designed has been used in the field. It is the one parts of a whole industrial applicable control system with PLC. The prototype system related with parts presented consists of PLC, electrical actuator, guide valve of refrigerator and temperature sensor. In the application, refrigerating Medias uses salt water and the salt water inlet temperature is about minus five degrees. In order to confirm the control effect of the system, the record of the temperatures in salt water outlet and in the cold storage during 24 hour were have made, as shown in Figure 4. It is note that the temperature of salt water outlet with the refrigerator is undulated minus ten degrees and the temperature of cold storage is undulated minus nine degrees, and the margin of fluctuation was not all big, which confirms the control system designed the validity.

## 5. SUMMARY

The hybrid fuzzy PD control with PLC for cold storages was presented. Its application in the industrial case was completed. The application proves the controller presented is effective and correct. It has the properties of two: the algorithm presented is better fit to the case of the cold storages and easy realized. Therefore the system response is speeded up, the output vibration is reduced. So, it has some value of application, and makes some good effect of using fuzzy control algorithm.

It is believed that control systems with PLC are main trends of development for control systems. The future work is making much application of control algorithm for real control system with PLC, such as how to divide control task to several modules and how to program ladder logic diagram from control algorithms.

## ACKNOWLEDGMENT

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