Design of Fuzzy PID with Expert Control for a Temperature Process

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Abstract:**The aim of this paper is to design an expert fuzzy PID controller for a temperature process. By using a combination of fuzzy PID controller and expert control many problems like non linearity, time variance and large time delay in the temperature process can be solved. Fuzzy algorithm is used to adjust the PID parameters and expert control reduces temperature shock near the set value. Fuzzy PID is used when error is higher than the set value else expert control will be selected. By using fuzzy PID with expert control we get fast response and overshoot can be completely eliminated.**

Keywords: Expert control; Fuzzy PID control; Temperature control

I. INTRODUCTION

Some of the disadvantages of temperature process are non linearity, large delay and time variance. So it is important to find an accurate method to control the temperature. Recently, Fuzzy PID control has been widely used in temperature processes because of its simplicity, practicality, flexibility, stability, high precision and robustness. As the control rules and membership functions of fuzzy controller are artificially set, it is difficult to meet the requirements of real-time control, so expert system came into being. The expert controller makes the system, reach the stable state in a shorter time. In this paper, fuzzy PID with expert control is designed for a temperature process. Expert fuzzy PID controller has got many advantages compared with a normal fuzzy PID control because expert control requires just a few set of rules for the control action to be performed whereas Fuzzy PID control requires more set of rules for the control action to be performed. Expert Fuzzy systems are usually applicable in linear - non linear systems.Expert fuzzy systems can also be used for financial systems and pattern recognition. Expert systems are one of the largest applications of Artificial Intelligence. Expert systems use the knowledge of human experts. Fuzzy logic is a form of many valued logic.

II. SYSTEM DESCRIPTION

A. Temperature process

Fig.1 shows the block diagram for a temperature process.

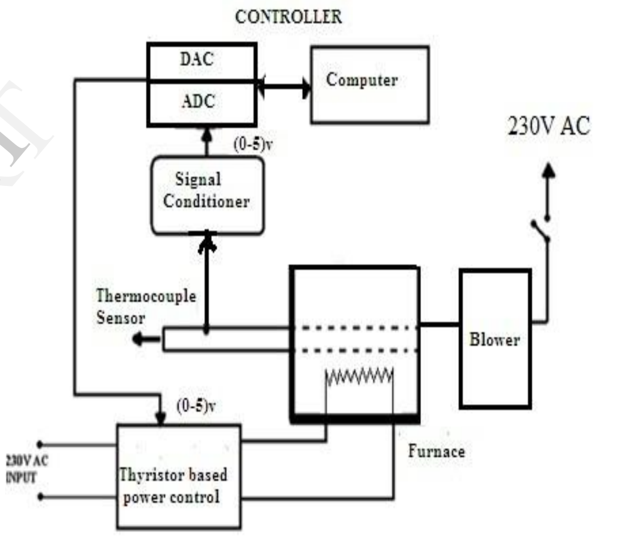


Fig. 1 General Block diagram for a temperature process.

The temperature process is a nonlinear process. Air is drawn from the atmosphere using a centrifugal blower. It is driven past a heater grid and through the length of a tube back to the atmosphere. The air in the tube is heated to the desired temperature level, and the aim of this control equipment is to measure the air temperature, to compare it with the set value and to generate a control signal that determines the amount of power to be delivered to the correcting element. Here the temperature is sensed by the thermocouple and its output will be in milli volt, so the output should be amplified to 0-5 V. The process temperature is then given to the PC where control action is implemented. The process temperature is then compared with the set point and the error is given to the controller. This control signal acts as the gate pulses or trigger for the SCRs in the thyristor based power control circuit where there are two back to back connected SCRs that control the 230 V given to the heater. By controlling voltage given to SCR (0-5V) the temperature of the air can be controlled.

B. Block diagram for Expert System

Fig. 2 shows the block diagram for proposed method.

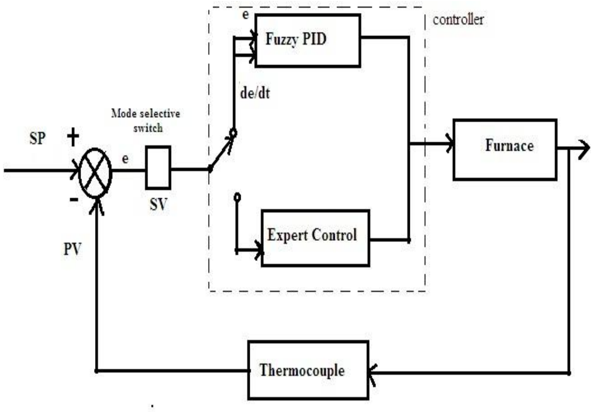


Fig. 2 Block diagram for proposed method

Where,

SP:	Set Point
SV:	Set Value
PV:	Process Value

The temperature in the heating furnace is measured using thermocouple, and is compared with the set point. Thus, we get the error *e* and the change in error *ec* which are the input parameters. Then we give a set value to the mode selective switch, and that set value will be the maximum possible error tolerable by the system. According to the set value, either the fuzzy PID control or the expert control will be chosen. When the error *e* is greater than the set value, the fuzzy PID control will be selected and when the error *e* is less than the set value, the expert control will be selected. Thus, the temperature can be controlled according to the real-time error *e* and error change rate *ec*. By using Expert fuzzy PID control, overshoot in the response can be nullified to a greater extend [2].

III. CONVENTIONAL CONTROLLER DESIGN

Fig.3 shows the open loop temperature response

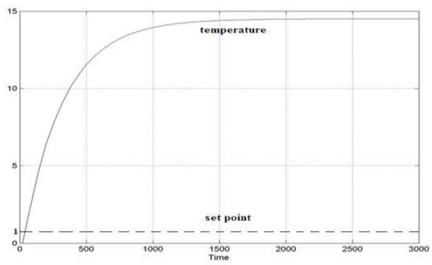


Fig.3 Open loop temperature response

For the design of conventional P, PI, PID controllers, open loop test is to be performed. From the open loop response, we can find the tuning parameters for P, PI and PID mode.

Here Zeigler Nichols tuning method is used for controller design [4].

The transfer function obtained from the open loop response is:

$$\frac{14.5e^{-30s}}{300s+1}$$

From the response we find that:
Kp = 14.5
t1 = 130 s
t2 = 270 s
T = (t2-t1)*1.5 = 210
td = t2 – T = 60

For a Proportional controller:

Kc=T/(td*Kp) (1)
=0.2413

For a Proportional Integral controller:

Kc=0.9T/(td*Kp) (2)
=0.2172
Ti=3.33td=199.8
Ki= Kc/Ti (3)
=1.087*10^-3

For a PID controller [5]:

Kc=1.2 T/(td*Kp) (4)
=0.2896
Ti=2td=120
Ki=Kc/Ti=2.41*10^-3 (5)
Td=0.5 td=30
Kd=Kc*TD=8.688 (6)

From the above responses we find that:
For proportional controller though there is no overshoot, but an offset is present and for PI and PID controllers the settling time is more. So we go for Fuzzy PID controller [1]. For that let us look into the creation of the rule base for Fuzzy PID.

IV. FUZZY PID TUNING

Let,
NH – Negative High
NM – Negative Medium
Z – Zero
PM – Positive Medium
PH – Positive High
E – Error
DE – Change in error.

The following tables shows the tuning rules for fuzzy PID. Table 1 shows the tuning rules for Kp.

TABLE 1: TUNING RULES FOR KP

Where,

	NHDE	NMDE	ZDE	PMDE	PHDE
NHE	Kpb1	Kpm3	Kpm2	Kpm1	Kpm1
NME	Kpm3	Kpm2	Kpm1	Kps3	Kps3
ZE	Kpb1	Kpm2	Kpm2	Kpm1	Kps3
PME	Kpm3	Kpm1	Kps3	Kps2	Kps2
PHE	Kpm2	Kps3	Kps3	Kps2	Kps2

Kps – Kp small
Kpm – Kp medium
Kpb – Kp big

Now let us see the tuning rules for Ki. Table 2 shows the tuning rules for designing Ki.

TABLE 2: TUNING RULES FOR KI

	NHDE	NMDE	ZDE	PMDE	PHDE
NHE	Kis3	Kis2	Kib2	Kim1	Kim1
NME	Kis3	Kib2	Kim1	Kim2	Kim2
ZE	Kis3	Kib2	Kib2	Kim1	Kim1
PME	Kis2	Kim1	Kim2	Kim3	Kim3
PHE	Kis2	Kim2	Kim2	Kim3	Kib1

Where,
Kis – Ki small
Kim – Ki medium
Kib – Ki big

The tuning rules for designing Kd is shown in the Table 3.

TABLE 3: TUNING RULES FOR KD

	NHDE	NMDE	ZDE	PMDE	PHDE
NHE	Kdm3	Kds2	Kds2	Kds3	Kdm3
NME	Kdm2	Kds3	Kdm1	Kdm1	Kdm2
ZE	Kdm3	Kds3	Kds3	Kdm1	Kdm2
PME	Kdm2	Kdm1	Kdm1	Kdm1	Kdm2
PHE	Kdm2	Kdm2	Kdm2	Kdm2	Kdm2

Where,
Kds – Kd small
Kdm – Kd medium
Kdb – Kd big

From the three set of tables we can see that Fuzzy PID requires nearly 25 set of rules and still overshoot is present in the response and also the response is slow [3].

V. EXPERT FUZZY TUNING

Let,
VL – Very Low
L – Low
H – High
M – Medium
VH – Very High

The tuning rules for expert fuzzy are shown in the table 4.

TABLE 4: TUNING RULES FOR EXPERT FUZZY

e	VH	H	M	L	VL
o	PB	N	NB	P	Z

Where,
PB – Positive Big
P – Positive
Z – Zero
N – Negative
NB – Negative Big
e – Error
o – Output

Expert Fuzzy which I have used here required just 5 set of rules for the output to settle. Expert fuzzy thus have nullified the overshoot and produced a fast response [7].

Thus in the experimental set up used for the temperature control first the system works using fuzzy PID and then shifts to expert control and thus nullifies the overshoot and produces a fast response. Setting rules for conventional fuzzy PID is a difficult task whereas setting the rules for expert fuzzy is quite easier.

VI. RESULTS AND DISCUSSION

Fig.4 shows the response for different controllers.

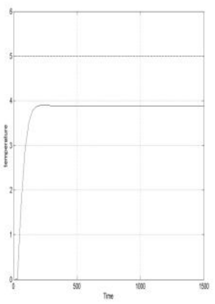
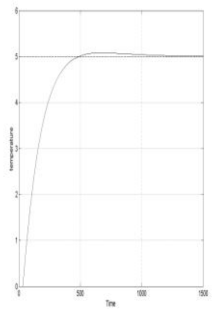
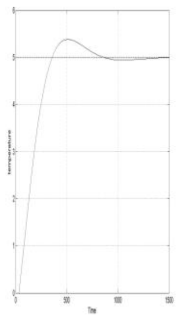
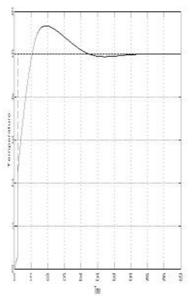
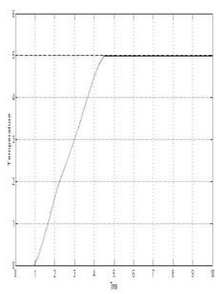
1.P controller 	2. PI controller 
3.PID controller 	4.Fuzzy PID controller 
5. Expert - Fuzzy PID controller 	

Fig. 4: Responses for different controllers.

From the responses, we find that an offset is present for the Proportional controller. Settling time is more for PI and PID controllers. By using Fuzzy PID settling time gets reduced [6]. But overshoot is present. Thus using expert fuzzy PID controller we get a fast response without overshoot.

VII. CONCLUSION AND FUTURE WORK

The expert fuzzy PID method is thus the combination of Fuzzy PID with Expert control which regulates the temperature of the heating furnace, and thus an expert fuzzy PID controller is designed. This controller has several advantages which includes high precision of using the fuzzy control and fast response of using the expert control. Simulation results reveal that the expert fuzzy PID controller is superior to conventional PID controller in terms of the overshoot and speed of response. As a future enhancement, expert fuzzy PID control for a temperature process can be implemented in real time.

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