International Journal of Management, IT & Engineering
(ISSN: 2249-0558)

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Editorial Board

Title

DESIGN OF SMART HYBRID FUZZY PID CONTROLLER FOR DIFFERENT ORDER PROCESS CONTROL

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Abstract:

This paper develops a hybrid fuzzy PID controller for different order process control. A smart hybrid fuzzy PID controller which comes from smart combination of classical PID and fuzzy PID controller. Combination is done with the help of switching scheme that makes a decision upon the priority of the two controller parts; namely, the classical PID and the fuzzy constituents. The simulations done on various processes using the smart hybrid fuzzy PID controller provides 'improved' system responses in terms of transient and steady-state performances when compared to the pure classical PID or the pure fuzzy controller applications.

***Keywords*---**Fuzzy PID, PID controllers, Simulation, Smart hybrid controllers.

INTRODUCTION:

As PID is regarded as the standard control structures of the classical control theory, and fuzzy controllers have positioned themselves as a counterpart of classical PID controllers on the same dominant role at the knowledge-rich spectrum [1-2]. PID controllers are designed for linear systems and they provide a preferable cost/benefit ratio. However, the presences of nonlinear effects limit their performances. Fuzzy controllers are successful applied to non-linear system because of their knowledge based nonlinear structural characteristics. A fuzzy logic controller (FLC) makes control decisions by its well-known fuzzy IF– THEN rules. FLCs can be classified into two major categories: the Mamdani type FLC that uses fuzzy numbers to make decisions [3] and a Takagi– Sugeno (TS) type FLC that generates control actions by linear functions of the input variables. In the early years, most FLCs were designed by trial and error. Since the complexity of a FLC will increase exponentially when it is used to control complex systems.

Hybridization of these two controller structures comes to ones mind immediately to exploit the beneficial sides of both categories. The two control structures are combined by a switch[3-7]. In [8] a fuzzy switching method between fuzzy controller and conventional PID controllers is used to achieve smooth control during switching. The motive to design a new hybrid fuzzy PID controller

so that a further improved system response performance in both the transient and steady states have been achieved as compared to the system response obtained when either the classical PID or the fuzzy controller has been implemented.

Simulations are performed on MATLAB Simulink toolbox to illustrate the efficiency of the proposed method.

SMART HYBRID FUZZY PID CONTROLLER STRUCTURE:

Fuzzy PID controllers in literature can be classified into three major categories as direct action type, fuzzy gain scheduling type, and hybrid type fuzzy PID controllers [9-10].

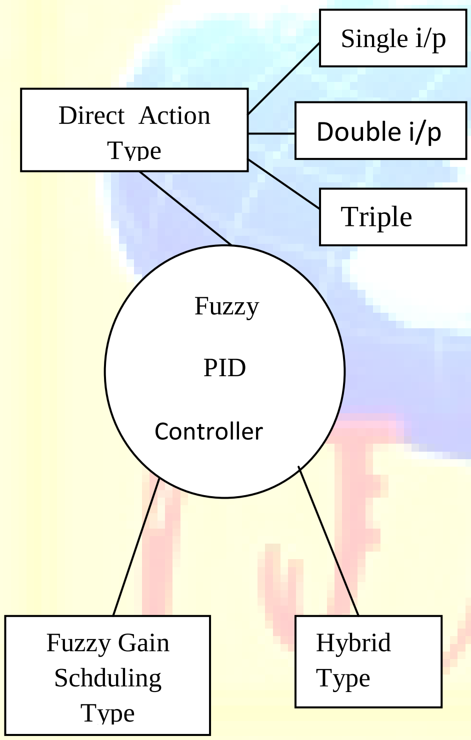

Fig 1: Classification of fuzzy PID controllers

The direct action type can also be classified into three categories according to number of inputs as single input, double input, and triple input direct action fuzzy PID controllers. The classification of fuzzy PID controllers can be seen in Fig. 1

The proposed hybrid controller that is given in Fig. 2 possesses two main parts: the classical PID and fuzzy PID controllers. A standard PID controller is also known as the “three-term” controller, whose transfer function is generally written in the “ideal form” as

$$G_{PID}(s) = K (1+ 1/T_I S + T_D S) \qquad (1)$$

where K is the proportional gain, K_I the integral gain, K_D the derivative gain, T_I the integral time constant and T_D the derivative time constant.

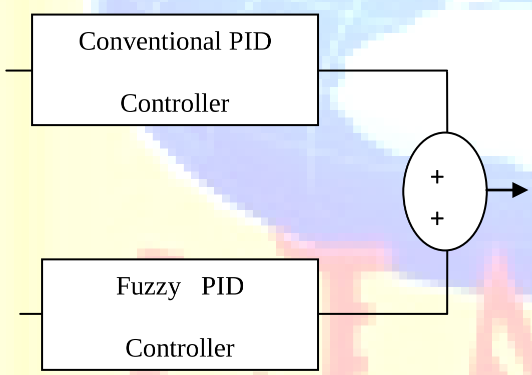

Fig 2: Block diagram of hybrid type fuzzy PID controller.

Fuzzy PI type control is known to be more practical than fuzzy PD type, since it is difficult for the fuzzy PD to remove the steady state error. The fuzzy PI type control is, however, known to give poor performance in the transient response for higher order process due to the internal integration operation.

To improve the performance of the fuzzy PI type and fuzzy PD type at the same time we want to design a fuzzy controller that processes the fine characteristics of the PID controller only by using the error and the rate of change of error as its inputs [11]. A PID type fuzzy controller structure that simply connects the PD type and the PI type fuzzy controllers together is shown in Fig. 3. The inputs are the classical error (e) and the rate of the change of error (e').

These rules are expressed as: If { e is ZR and e' is ZR}, then { u is ZR}.

The output of the PID type fuzzy controller is

$u_c = \alpha u + \beta \int u dt$

$= \alpha(A + PK_e e + DK_d e') + \beta \int (A + PK_e e + DK_d e')dt$

$= \alpha A + \beta At + (\alpha K_e P + \beta K_d D)e + \beta K_e P \int edt + \alpha K_d De'$

These equivalent control components are repeated as follows:

Proportional: $\alpha K_e P + \beta K_d D$

Integral: $\beta K_e P$

Derivative: $\alpha K_d D$

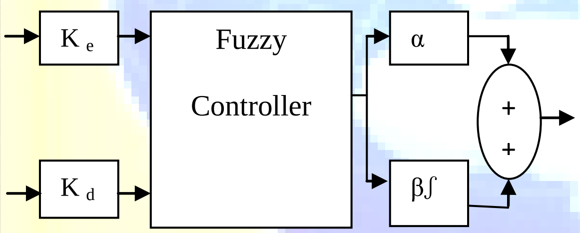

Fig 3: The Fuzzy PID Controller structure

Triangular membership functions are used for input variables as it is shown in Fig. 4. For the output variable u, singleton membership functions are defined as in Fig. 5. The fuzzy PID controller rule base composed of 49 (7x7) rules as shown in Table 1. The control surface of the fuzzy PID controller is also given in Fig. 6.

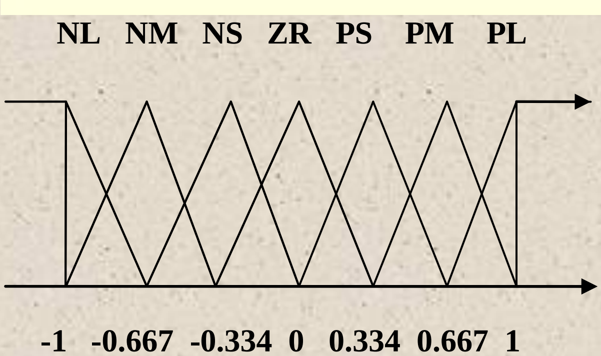

Fig 4: The membership functions of e and e' .

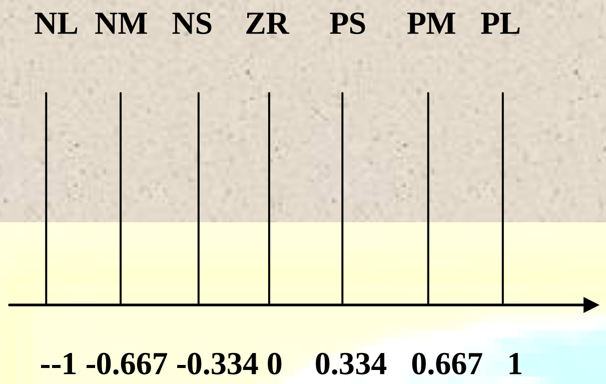

Fig 5: The membership functions of u.

TABLE1 A GENERAL FUZZY CONTROLLER RULE

E/E	*NL*	*NM*	*NS*	*ZR*	*PS*	*PM*	*PI*
PL	ZR	PS	PM	P1	P1	PI	PI
PM	ns	ZR	PS	PM	P1	P1	PI
PS	nm	ns	ZR	PS	PM	P1	P1
ZR	nl	nm	ns	ZR	PS	PM	P1
NS	nl	nl	nm	ns	ZR	PS	PM
NM	nl	nl	nl	nm	ns	ZR	PS
NL	nl	nl	nl	nl	nm	ns	ZR

The Matlab Simulink simulation model of the proposed intelligent hybrid PID controller is shown in Fig. 7. The parameters of the PID controller are denoted by K, TI, and TD. As encountered in the literature, these stand for proportional gain, integral and derivative time constants, respectively. The parameters of the fuzzy controller are defined as K_e, K_d, α , and β .

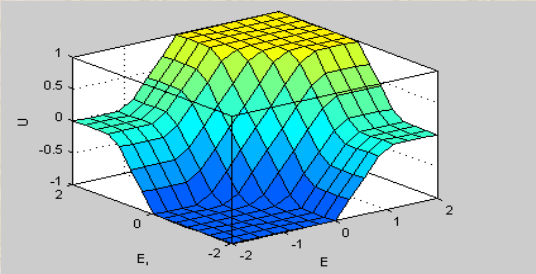

Fig 6: The control surface of the fuzzy PID controller

A switching & blending mechanism firstly decides the dominant one of the two controller structures; namely, classical and fuzzy controllers on the basis of priority. The outputs of the fuzzy PID controller and the classical PID controller are then multiplied by either one of the functions 1-g(e) and g(e).

1-g(e) and g(e) are the weighing factors . They quantify the level of the activity of the contributing controller and help us to achieve a reasonable trade off between the actions generated by the individual controllers. Since the function g(e) has to be positive valued, it has been selected as $g(e)=e^2$. Consequently the hybrid controller's output becomes either

$$U_{HYBRID} = (1-g(e)).U_{PID} + g(e).U_{FUZZY} \qquad (2)$$

Or

$$U_{HYBRID} = g(e).U_{PID} + (1-g(e)).U_{FUZZY} \qquad (3)$$

It is obvious that when the error is large the controller output multiplied by f(e) is activated more than the other controller part. The switching part of the mechanism tries to catch the bigger one of the control efforts of the two main controller parts. The idea behind this is that higher control effort should produce faster system response.

SIMULATIONS RESULTS:

The following simulations are done in order to see the performance of the proposed hybrid fuzzy PID controller.

A. *Simulation 1*

In the first simulation, the following first-order process model with a dead-time is considered:

$$G_1(s) = \frac{1}{s+1}e^{-0.2s} \qquad (4)$$

The corresponding system responses and controller outputs are given in Fig.8 and Fig. 9, respectively. The controller parameters of the classical PID controller are set to K=2, T_I=0.25, T_D=0.025 in order to have a small rise time. On the other hand, the fuzzy PID controller has the following parameters: $\alpha = 0.05$, $\beta = 4.5$, K_e=1, K_d=0.56.

B. *Simulation 2*

The second simulation is performed on a second-order process plus dead-time with the transfer function given as follows:

$$G_1(s) = \frac{1}{(s+1)(s+2)}e^{-0.2s} \qquad (5)$$

The controller parameters of the classical PID controller are set to K=0.01, T_I=0.014, T_D=1 to have a smooth response with a small overshoot. On the other hand, the fuzzy PID controller has the following parameters: $\alpha = 0.2$, $\beta = 1.1$, K_e=1.5, K_d=0.2. The corresponding system responses and controller outputs are given in Fig.7 and Fig. 8, respectively.

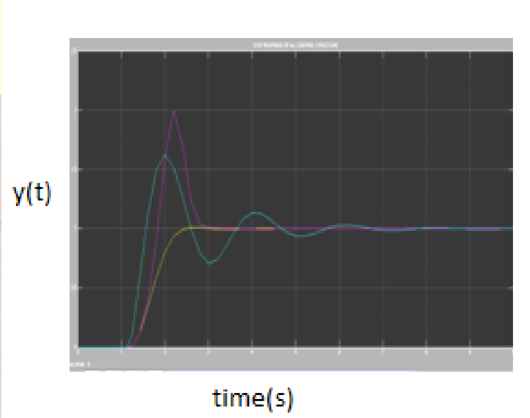

Fig 7: The step responses of all control structure

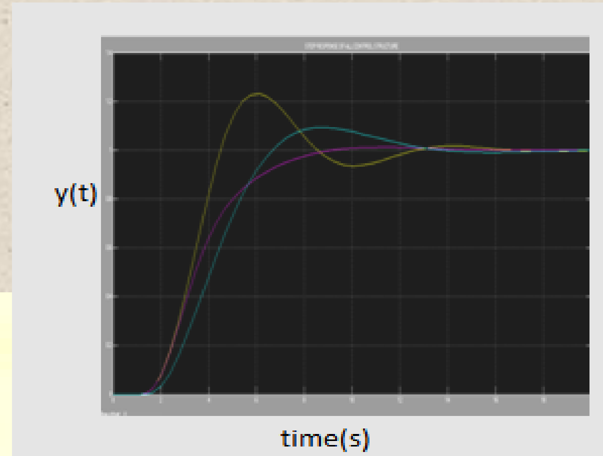

Figure 8: The step responses of all control structures

CONCLUSION:

In this design methodology that includes the classical PID and the fuzzy controllers are improved, thus a new smart hybrid controller has been achieved. A switching & blending mechanism that depends on some function of actuating error is presented. Simulations are done on various processes using the new hybrid fuzzy PID controller have provided improved system responses in terms of transient and steady-state responses. Here, only two of these simulations are given and the proposed hybrid fuzzy PID controller is compared to the pure classical PID or the pure fuzzy controller applications. All of the simulation results have shown that the proposed hybrid structure has provided an effective performance on system response.

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