Design and Simulation of fuzzy PID controller based on Simulink

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Abstract. PID controller was widely used in various kinds of control process for its good stability and high reliability. But PID control system can not reach the expected effect for some nonlinear and time-varying characteristics of complex production process control. The fuzzy PID control method was put forward to solve the larger overshoot amount and a long time adjusting. A system of fuzzy control rule table was established after fuzzy inference. The PID parameters were changed in real time. And, the dynamic simulation was performed by using MATLAB (simulink) and the system was tested in the practical operation. The dynamic response and steady state properties of system were good.

Introduction

The conventional PID is widely used in process control for its simple structure, good reliability and high stability. At the same time, the conventional PID control is also a lot of defects. The most prominent problem is to set up and adjust the PID parameters. The conventional PID has no parameter adaptive ability and only corresponded to one system of Known model and parameters. And it was only suitable for that working condition once the parameters setting. Obviously, it was unable to meet the demand of practical production. The fuzzy PID control method was put forward. A system of fuzzy control rule table was established after fuzzy inference. The PID parameters were changed in real time. This system was more flexibility, adaptability and high control precision.

The Design of Fuzzy PID Controller

The Fuzzy PID controller was integrated of fuzzy controller based on conventional fuzzy controller.

The design of PID controller

In the design of conventional PID controller, the input variables were the deviation of E and the deviation rate of E_c. And the output variable was the control amount of U for controlling the perform structure. The control parameters of K_P 、 K_i 、 K_d were inputted by operator. The five-input-one-output mode was build. The principle diagram of PID control was shown in fig.1.

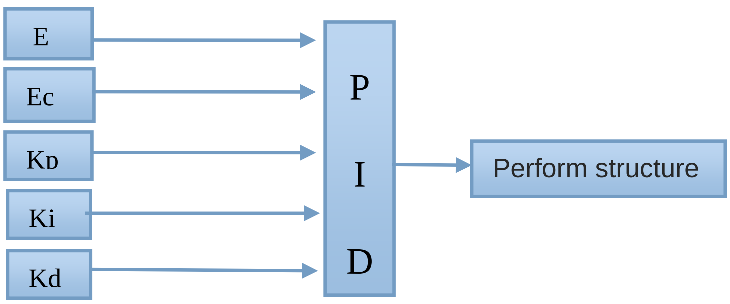

Figure 1 The PID control principle diagram

The design of fuzzy controller

Fuzzy controller contained a series of important steps: Fuzzy processing, fuzzy inference and anti fuzzy processing. The quality of fuzzy controller was mainly depended on the following factors: the structure of Fuzzy controller, the fuzzy rule base, the inference algorithm and the method fuzzy decision. The principle diagram of the fuzzy controller was shown in fig. 2.

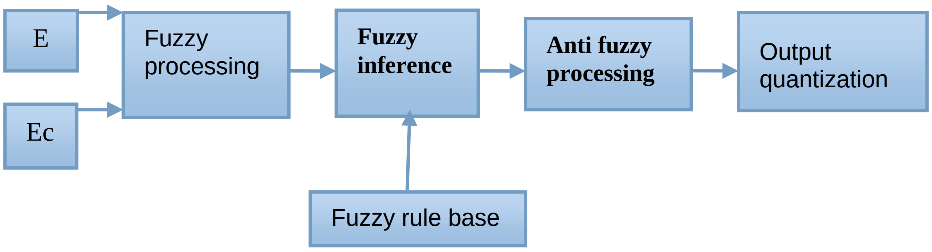

Figure 2 The principle diagram of the fuzzy controller

The design of fuzzy controller

The actual variable of input was converted into the variable of membership language after Fuzzy processing.

The fuzzy subsets of input variable and output variable were divided into positive board (PB), positive middle (PM), positive small (PS), zero (ZO) and negative small (NS), negative middle (NM) and negative board (NB). The corresponding domain range of input variables E and E_c was [-3,3]. The domain range of output variable K_P was [-1.2,1.2], K_i was [-0.12,0.12]， K_d was [-6,6].Than column factor was set according to the scene debugging. Sub triangle membership function was chose. The output variable membership function was shown in fig. 3.

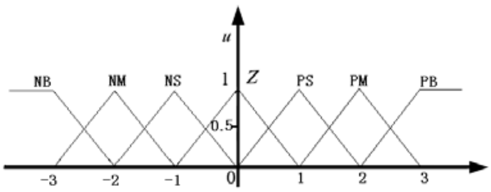

Figure 3 The output variable membership function

The establishment of fuzzy rule base

According to variable determination of membership language and actual debugging experience, the adjustment rule of the parameters K_P 、 K_i 、 K_d was described as follows which correspond to different inputs of E and E_c.

i) K_P was taken large value and K_d was taken small value when E was big. The response speed of control system accelerated. System overshoot increased when integral coefficient value was too large. So, K_i was equal to zero or taken small value.

ii)Considering the system overshoot, the value of K_P Should be reduced s when E was middle. The value of K_d and K_i should be appropriate.

iii)When E was small, the value of K_P and K_i Should be increased which was advantageous to reduce the steady error of the system. The value of K_d was most critical.

The Modeling of Fuzzy PID Controller

In process control, the system often needed to be test and adjust several times for better effect. Sometimes it is dangerous and no economic to test and adjust. This problem can be well solved by simulation software.

The system module was established and fuzzy rule was edited by using MATLAB.

Table 1 the fuzzy rule base of K_P 、 K_i 、 K_d .

ec	*e*						
	NB	NM	NS	Z	PS	PM	PB
NB	PB	PB	PM	PM	PS	PS	Z
NM	PB	PB	PM	PM	PS	Z	Z
NS	PM	PM	PM	PS	Z	NS	NM
Z	PM	PS	PS	Z	NS	NM	NM
PS	PS	PS	Z	NS	NS	NM	NM
PM	Z	Z	NS	NM	NM	NM	NB
PB	Z	NS	NS	NM	NM	NB	NB

ec	*e*						
	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NM	NM	Z	Z
NM	NB	NB	NM	NM	NS	Z	Z
NS	NM	NM	NS	NS	Z	PS	PS
Z	NM	NS	NS	Z	PS	PS	PM
PS	NS	NS	Z	PS	PS	PM	PM
PM	Z	Z	PS	PM	PM	PB	PB
PB	Z	Z	PS	PM	PB	PB	PB

ec	*e*						
	NB	NM	NS	Z	PS	PM	PB
NB	PS	PS	Z	Z	Z	PB	PB
NM	NS	NS	NS	NS	Z	PS	PM
NS	NB	NB	NM	NS	Z	PS	PM
Z	NB	NM	NM	NS	Z	PS	PM
PS	NB	NM	NS	NS	Z	PS	PS
PM	NM	NS	NS	NS	Z	PS	PS
PB	PS	Z	Z	Z	Z	PB	PB

The establishment of fuzzy controller module

Enter the FIS editor after input“fuzzy” in the command window of MATLAB. Set the input variable values to 2 and the output variable values to 3. Choose“mamdani” as Fuzzy algorithm and fuzzy inference algorithm. The fuzzy controller was named ‘mohuguizeji33’. The fuzzy editor was shown in fig. 4:

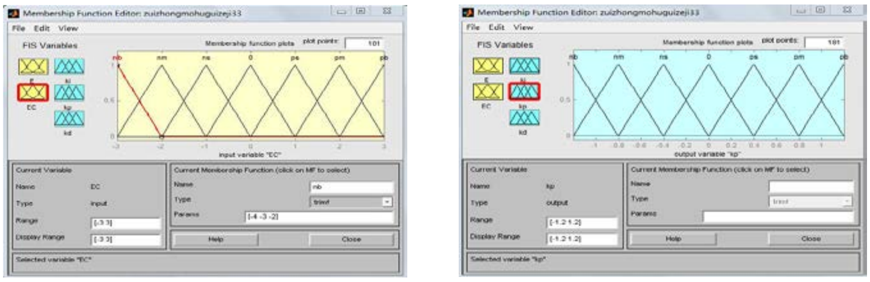

Figure 4 The fuzzy editor of FIS

Setting of membership function

Double click the variables icon of input or output in FIS editor interface. Enter the interface of membership Function Editor after

Set the variable membership functions of E, E_c, K_P, K_i and K_d. Each variable membership functions were shown in fig. 5.

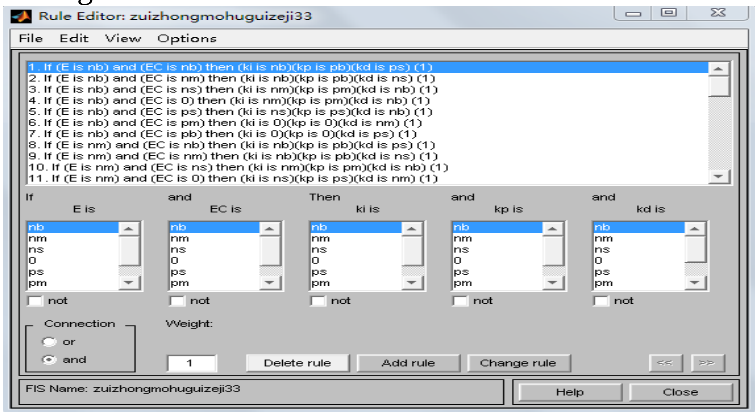

Figure 5 The variable membership functions of E, E_c and K_d

Editing the fuzzy rule base

Click the fuzzy rule module in the interface of the fuzzy controller window. Input and edit the fuzzy rule base. The fuzzy rule base was edited according to table 1 and shown in fig. 6.

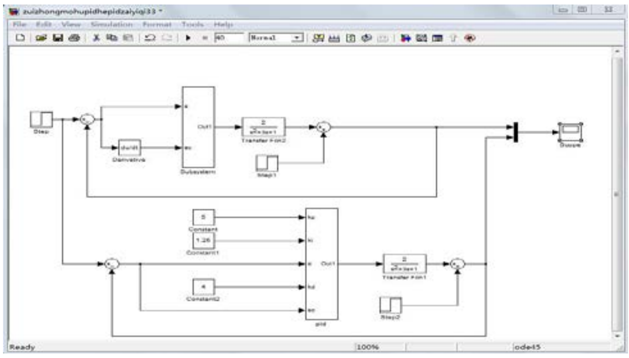

Figure 6 The fuzzy rule base

The Establishment and Simulation of Fuzzy PID Controller Block Diagram

Simulink toolbox could provide corresponding modules for the simulation block diagram. Input "fuzzy" in the command window of MATLAB. The block diagrams of regular PID controller, fuzzy controller and embedded fuzzy PID controller were established. The fuzzy PID controller block diagram was shown in fig. 7.

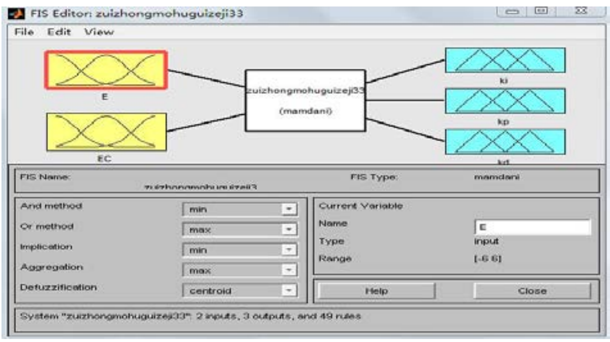

Figure 7 The fuzzy PID controller block diagram

In the simulation process of fuzzy PID controller, the transfer function of controlled object was set as $G_S = \frac{2}{s^2 + 3s + 1}$. For the robustness analysis of controller, the disturbance was added at 15s. The fuzzy rule base “mohuguizeji33” was imported into the working interval under export File project. The fuzzy controller module was inserted.The simulation result of fuzzy PID controller was shown in fig. 8.

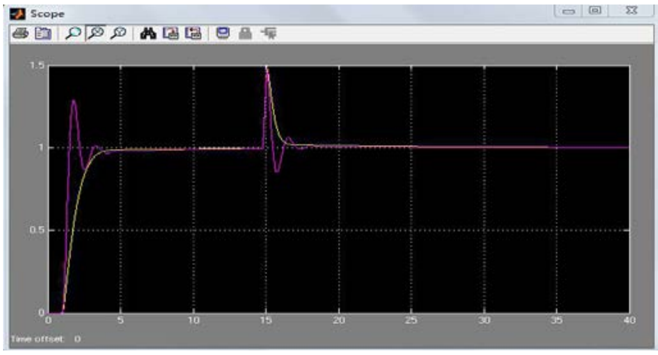

Figure 8 The simulation result of fuzzy PID controller

The simulation curve of traditional PID controller was shown by purple curve. The simulation curve of fuzzy PID controller was shown by yellow curve. The adjustment time of fuzzy PID controller was shorter. Controller was more stable into steady state. The overshoot of fuzzy PID controller was much smaller than that of traditional PID controller. The fuzzy PID controller recovered faster and the convergence time was smaller under the external disturbances.

Conclusion

According to the analysis of simulation result with MATLAB, the advantage of traditional PID controller was preserved in fuzzy PID controller. PID parameters were adjusted by PID controller according to the real-time working state. It has a good adaptability and control effect in the actual production.

Acknowledgement

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