Applied Mechanics and Materials *Online: 2013-11-15*
ISSN: 1662-7482, Vols. 462-463, pp 510-513
doi:10.4028/www.scientific.net/AMM.462-463.510

The Research of glass furnace commutation control system which is based on fuzzy neural network

Han Xue[1,a] , Chen Jian[2,b]

[1]Glass Rubs(Chongqing) Co., Ltd Chongqing, China

[2]College of Computer and Information Science & College of Software, Southwest University , Chongqing, China

[a]1468993603@qq.com, [b]j.hanchen@126.com

Keywords: fuzzy neural network; regenerative end fire glass furnace; commutation system

Abstract: In this article, a new combustion control program would be introduced, which is planned to use fuzzy neural network for intelligent analysis of temperature variation on end fire glass furnace. This program would be adapted to regenerative end fire glass furnace. The actual running of system indicates that the system is in good effect and suitable for the production technology very well.

Preface

The melting of glass is a complex physical-chemistry reaction, which is full of not only delays and inertia, but also is nonlinear. Affected by different factors, such as gas pressure, batch uniformity and insulating of furnace etc, this reaction becomes a complex thermal process. Thus, it is difficult to set an accurate mathematical model to control this complex process. However, as an important procedure in this reaction, the commutation system for regenerative furnace would not only affect the glass quality and the energy consumption but also concern about the environment protection and labor's protection.

Nowadays, the PID combustion control system is widely used in glass factory. This PID system could run very well in a small range around the working spot. However, when the melting process is in big undulation, the control effect becomes bad because of the delay and the changed parameters. With regards to this situation, the experience of operator's would be adapted to improve the control effect. This operation could work but is low efficiency. Considering the defects in this system, the fuzzy neural network control system is being introduced to realize the real-time monitoring and optimization of commutation in glass furnace [1]. This process is supported by field buss technology[2].

I. The technological procedure of commutation in glass furnace

The regenerative glass furnace is a square melting pot, which is used to melt the raw materials. In order to reduce the energy consumption and recover waste heat, there is a set of regenerator which has checker works in the end of furnace[3]. The gas and air are preheated through the checker works in one-side regenerator and burning in the furnace. The exhaust goes through the other side regenerator into flues. In this course, the waste heat in exhaust preheats the checker works in other-side regenerator. After some time (about 20minutes), the gas and air temperature of working-end regenerator's becomes lower and lower while the other-side's temperature increases gradually. At this time, it is necessary to do the commutation in order to recovery the waste heat and keep the stable furnace temperature. The interval of commutation depends on such factors that check bricks become overheat after long-time preheating as well as inhomogeneous temperature caused by long-time burning in one side[4].

The traditional commutation operates in accordance with the fixed time. The advantage of this operation is easy-done. But the disadvantage is obvious. We would express as follows. First of all, the interference on complex combustion procedure could not be considered in the operation of commutation on fixed interval. The experienced interval could not ensure the preheating could reach the optimal value. At the same time, if the temperature of air could not reach the expected value, the

combustion procedure would be changed which could cause the negative perturbation and reduce the furnace temperature. Secondary, because of the complex thermal process in the furnace, it is necessary to modify many data such as temperature, furnace pressure, secondary air flow and gas flow as well in order to keep a stable combustion system. However, during the commutation, there may be transient short of gas. It would be disturb the adjustment of all the parameters as above.

So in summary, there are so many nonlinear factors to influence the furnace temperature. It is almost impossible to set up a mathematical model in order to descript this process accurately. And it is also very difficult to set up any model to realize the control of furnace temperature. Today, as a typical intelligent control system, the fuzzy neural network system could be used to solve the complex control problem which could not be solved in traditional control system. The fuzzy neural network system could match the control system which is caused by nonlinear and uncertain factors very well.

II. The fuzzy neural network control system on commutation in glass furnace

The fuzzy control system is one kind of nonlinear control strategy which is based on the fuzzy reasoning. The fuzzy language is used to express the operation experience and inference rules in this system. The dimensional fuzzy reasoning rule is commonly used in fuzzy control system, in which the deviation and deviation change are input. Through quantification, fuzzy reasoning and defuzzification, the control value and control increment is output. In the commutation system of glass furnace, we adapt the rule of double input and one output. The input variable is the temperature deviation e and temperature deviation delta Δe. And the output variable is commutation frequency Vn. The fuzzy control system is as shown as Fig. 1.

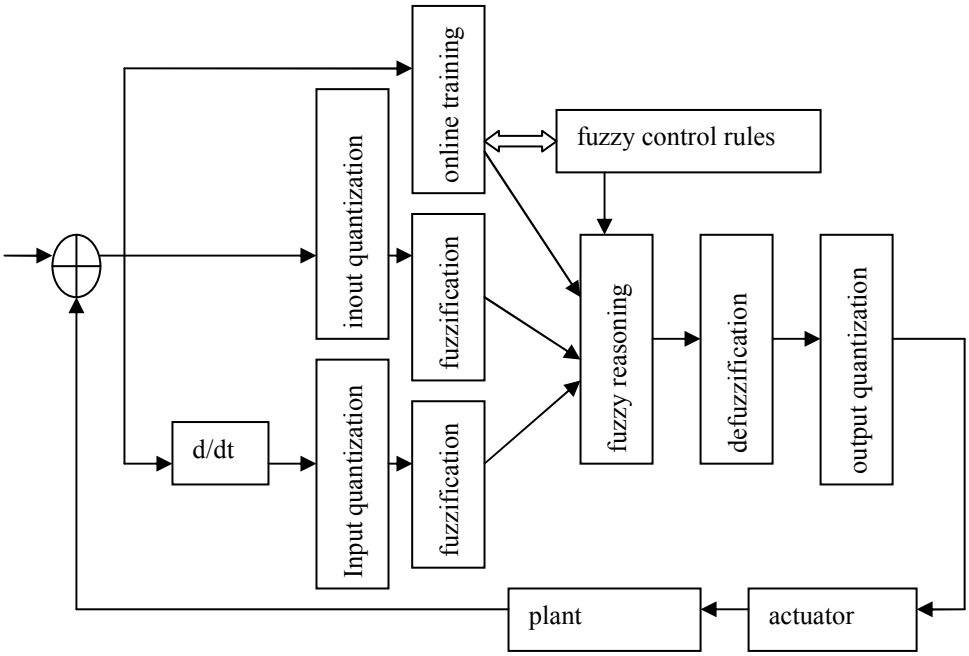

Fig. 1 The fuzzy control system

There are seven values (fuzzy sets) in input variable, such as negative large, negative middle, negative small, zero, positive small, positive middle and positive large as well. They are indicated as NL,NM,NS,ZO,PS,PM and PL. The values of Δe are negative large(NL), negative middle(NM), negative small(NS), zero(ZO), positive small(PS), positive middle(PD) and positive large(PL) as well. In fuzzy control system, the key is to set up logical fuzzy control rules. First of all, the object model would be set up and extracts the fuzzy control rules. Then, learning from the operator's experience and test result on-spot, the rules would be modified. Based on the modification, after online analysis the optimal rule is obtained[5]. The detail of optimization is described as follows. Firstly, we input the value of e and Δe and calculate with the model. All the rules Rk would be judged. The rules whose memberships are lower that that of threshold would be delete. Then the reserved rules still need to be optimized because of the same premises. The reversed rules are divided

into several groups (Rn). In the same group, the rule(R_i (1≤i≤n)) has the same premise. The procedure for optimization is as follows. First of all, in each group which has the same premise, rule Ri(j) is been chosen randomly. Secondly, the output $b_i(j) = u_\theta^{-1}(W_i(j))$ is been calculated by e and Δe. The total output V_n is been obtained by defuzzification. In the third step, the deviation is been calculated by the following formula.

$$ER_i(j) = \frac{WR_{i(f)}}{\sum_{k=1}^{m} WR_{i(j)}} \times \left(\frac{Vn - b_i(j)}{Vn_{\max} - Vn_{\min}} \right) \tag{1}$$

$WR_{i(j)}$ refers to membership of different rule $R_i(j)$, $Vn_{\max}$ and $Vn_{\min}$ refer to possible maximum output and minimum output. In the forth step, after the iteration, the actuator will get new e and Ve through the output. Then, the process repeats to get another output. Table 1 shows one of the output by fuzzy controller.

Table 1 Fuzzy control rules

e / Δe	NL	NM	NS	N0	PS	PM	PL
NL	PM	PM	PM	PS	ZO	NS	NS
NS	PL	PL	PM	PS	ZO	NS	NS
ZO	PM	PL	PS	ZO	NS	NM	NM
PS	PM	PM	PS	ZO	NS	NM	NL
PL	PL	PS	ZO	NS	NM	NL	NL

The module structure and algorithm play the key role in the system. The network controller is showed in Fig. 2.

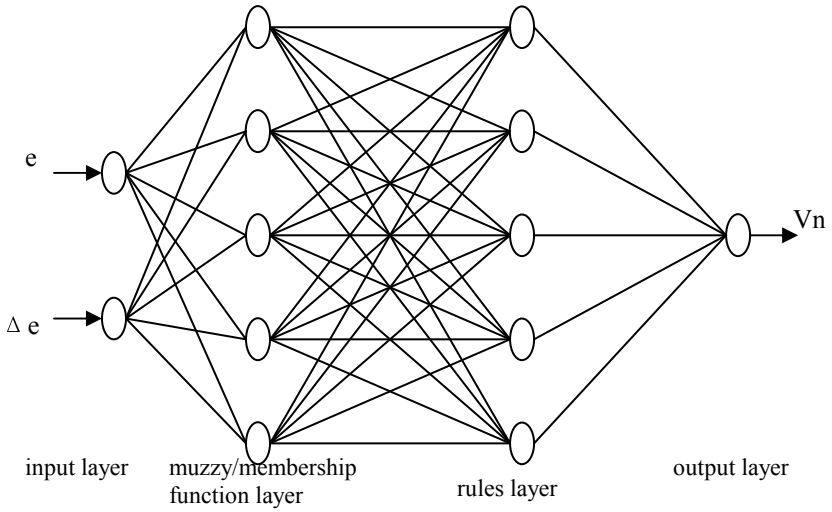

Fig. 2 The fuzzy neural network controller

This network is made up of four layers of neurons, which are input layer, membership function layer, rule layer and defuzzification output layer. In the first layer, the temperature deviation e and the deviation delta Δe would be transfer to neurons in second layer after quantization. The transfer function is indicate as

$$I_i = \begin{cases} e \\ \Delta e \end{cases} \quad O_i = kI_i \tag{2}$$

I_i refers to first input value and O_i refers to output value. "i" refers to the node number in each layer. In the second layer, the input parameters would be fuzzificated. The Gaussian membership function would be adapted in this calculation. The transfer function is indicate as

$$I_i = -\frac{(u_{ij} - m_{ij})^2}{\sigma_{ij}^2} \qquad O_i = u_{ij} = e^{-\frac{(u_{ij}-m_{ij})^2}{\sigma_{ij}^2}} \tag{3}$$

u_{ij} refers to fuzzy set membership function and m_{ij} and σ_{ij} refer to the mean and variance of fuzzy set. In the third layer, the rule would be calculated the membership, that is to calculate the rule membership according to the output of the second layer. The formula is showed as follows:

$$W_k = \frac{\sum_i u_{ij} e^{-\alpha_i u_{ij}}}{\sum_i e^{-\alpha_i u_{ij}}} \tag{4}$$

The transfer function for this layer is $I_i = u_{ij}, O_i = W_k$. The forth layer is defuzzification layer. The output of each rule in fuzzy set is indicated as

$$b_k = u_v^{-1}(W_k) \tag{5}$$

v refers to Collection of linguistic variables. The accurate output for commutation could be calculated by the formula as follows:

$$Vn = \frac{\sum_k W_k u_v^{-1}(W_k)}{\sum_k W_k} \tag{6}$$

In this layer, the transfer function is $I_i = W_k \quad O_i = Vn$.

III. The operation situation and result of system

By adapting the field bus technology and fuzzy neural network control system, the intelligent fuzzy neural network temperature control system is set up on the regenerative end fire furnace for production temperature control. With the dispersed node, the fuzzy control is realized effectively and the holistic character has improved a lot. After the strategy of fuzzy neural control, the recovery interval of furnace temperature is been shorten half of the original. The fluctuation of furnace temperature is improved obviously and the tolerance of temperature change is controlled under ±4℃. Compared to PID system, the fuzzy neural network commutation program could not been interfered less by experience factors. Thus, this system would make sense on quality control and reducing energy consumption.

References

[1] Ishigami H, Fukuda T and Shibasta T, et al. Structure optimization pf fuzzy neural network by genetic algorithm [J]. Fuzzy set and systems,1995, 71(3): 257-264

[2] Dempf D, List T. On-line data reconciliation in chemical plants [J] .Computer Chemical Engineering, 1988, 22:1023-1025

[3] North-west Light Industry College. Glass Technology . China Light Industry Press, ISBN: 7501901791, 2006-9

[4] Berenji HR, Khedhar P. Learning and turning fuzzy logic controllers through reinforcements[J]. IEEE Transaction On Neural Networks,1992. 3(5): 724-740 .