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# SHIP BOILER STEAM PRESSURE CONTROL SYSTEM BASED ON BP-PID CONTROL

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## Abstract:-

*The control of steam's pressure is the key link of boiler power plant, its control performances influence the rotate speed of steam turbine directly. Boiler steam's pressure has the characteristics of time-varying, nonlinearity, large inertia and large hysteresis. The traditional PID control method does not have the ability of self-adaptability, and it is difficult to meet the system's requirements. In order to solve the problem, this paper design a boiler steam pressure control system based on BP-PID control. A second-order mathematical model with time delay of boiler steam's pressure is used as the controlled object, the PID controller and the PID controller based on BP neural network are used to control it.The whole process is simulated by MATLAB software.The simulation results show that when the PID controller based on BP neural network is adopted, the response curve has no oscillation, no overshoot and short transition time, the control effect is better than traditional PID controller.*

**Keywords:-***Boiler steam's pressure, PID, BP neural network*

**CLC number: TP217**

## 0 INTRODUCTION

Traditional boiler steam pressure control system mainly uses simple PID control method to control boiler steam pressure. The method is simple in calculation and fast in response. However, due to the characteristics of non-linearity, time-varying, large inertia and large time delay, the control effect is not good. At present, in theory, experts at home and abroad have carried out a series of studies on the use of intelligent control strategies to control the combustion system of boilers. In reference [1-3], a boiler steam pressure fuzzy controller is designed, which combines fuzzy control with PID control. The steam pressure is controlled within a certain range by setting the input and output of the fuzzy controller and the control rules. This method can improve the stability of the system to a certain extent, but its control rules are difficult to determine, so it has not been widely used. Document [4] Using the functional equivalence of fuzzy system and RBF neural network, RBF neural network replaces fuzzy control, which makes up for the defect of fuzzy control in rule selection and improves the control accuracy of the system. However, the number of hidden neurons of RBF neural network increases with the increase of training samples, thus increasing the network complexity and the system calculation load. Document [5-6] combines the merits of fuzzy control, neural network control and immune algorithm, and proposes a fuzzy immune neural network PID controller for marine boiler steam pressure system, which further optimizes the dynamic performance of the system. The system is more complex, the number of layers of fuzzy rules and neural networks is difficult to choose, and different choices have a greater impact on the final results, so it is very important. It is difficult to be used in actual industrial production. Document [7-8] synthesizes three improved strategies, i.e. boundary self-adjustment of decision variables, Gauss mutation of decision variables and volatile factor of adaptive pheromone, and designs a hybrid improved ant colony algorithm. The method is applied to the process of function optimization, which improves the speed of the system. However, the situation that the ant colony algorithm is easy to fall into local optimum cannot be improved obviously, and the accuracy of the system is not high.

In this paper, BP neural network is used to optimize the traditional PID control. After analyzing the problems in the control of boiler steam pressure in the literature mentioned above, BP neural network is introduced. On this basis, a boiler steam pressure control system based on BP neural network PID is designed. The simulation results show that, under the control of BP neural network PID controller, the system has no oscillation, no overshoot and fast transition time, and has good dynamic response characteristics.

## 1 Boiler Steam Pressure Control System and Model

### 1.1 Boiler Steam Pressure Control System

Boiler steam pressure control system is a complex industrial system. Its control object has many characteristics, such as non-linearity, time-varying, large inertia, and large time-delay and so on. Steam pressure control is a key link of boiler power plant, and the quality of control will directly affect the speed of steam turbine. Therefore, accurate and timely control of boiler steam pressure is particularly important.
The tasks of the steam pressure control system for marine boilers can be summarized as the following three points:
①The pressure and temperature of steam produced by boiler combustion can meet the needs of steam equipment;
②Economic combustion;
③Safe operation.

Whether the amount of steam consumed by steam equipment is balanced with the amount of steam produced by the boiler is expressed by steam pressure. Whether it is too low or too high, it will cause certain damage to the conduit and steam equipment. The pressure and temperature of steam correspond to each other, and controlling its temperature is theoretically to control its pressure. Therefore, the primary task of the system is to keep the steam pressure and temperature in the main pipe within a certain range.

Only by maintaining a reasonable air-oil ratio can the boiler be economically burned. If the air is insufficient, the fuel will not be fully burned, which will cause a lot of heat loss; if the air is excessive, the combustion efficiency will be reduced, and a lot of heat loss will be in the flue gas. Therefore, we should try our best to ensure that the air and fuel are in the best proportion and improve combustion efficiency, so as to achieve the goal of reducing pollution, energy saving and consumption reduction.

The third task is to ensure the safe operation of the system. Operators'personal safety should always be the first.

### 1.2 Mathematical Model of Steam Pressure of Boiler

Generally, the marine steam pressure system consists of five links: furnace, evaporation heating surface, superheater, main pipe and steam equipment. The schematic diagram of boiler steam pressure can be shown in Figure 1.
In Figure 1, $M$ ($kg/s$) is the amount of fuel consumed per unit time in the furnace and the input of the system. $P_M$ is the steam main pipe pressure, the pressure at the outlet of the superheater, and the output of the system. $K_M$ is the fuel valve amplification factor. $\square_M$ is the delay time. $C_b$ is the coefficient of heat storage, that is, the amount of evaporation that can be huff and puff from the drum and the evaporating heating surface when the pressure changes $1MPa$. $P_b$ is drum pressure and Superheater inlet pressure. $R_{gr}$ is the dynamic resistance of superheater. $C_M$ ($kg/Mpa$) is the capacity coefficient of the main pipe. $\square_r$ is the opening of the control valve, $K_T$ is the static amplification coefficient of the control valve, *and RT* ($Mpa\square s/kg$) is the dynamic flow resistance coefficient of the steam equipment.

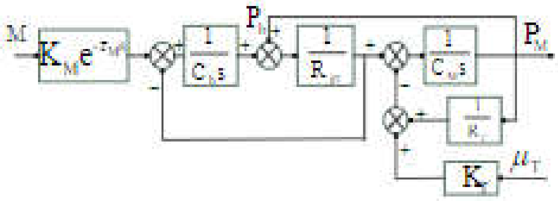


**Fig.1 Boiler steam pressure system principle diagram**

Under the disturbance of fuel oil, there are two kinds of dynamic models for steam pressure system of marine boiler:
(1) When the steam consumption is constant, the opening of the regulating valve of the steam equipment $\square_T$ change, the dynamic model of steam pressure of marine boiler can be expressed as follows:

$$W_M(s) = \frac{P_M(s)}{M(s)} = \frac{K_M(C_M R_{gr} + 1)e^{-\tau s}}{s(C_M C_b R_{gr} s + C_b + C_M)} \qquad (1)$$

(2)Variation of steam consumption, opening of regulating valve of steam equipment $\square_T$ when unchanged, and the dynamic model of steam pressure of marine boiler can be expressed as follows:

$$W_M(s) = \frac{K_M R_T e^{-\tau s}}{C_M C_b R_{gr} R_T s^2 + C_b R_{gr} s + C_M R_T s + 1} \qquad (2)$$

Taking case (1) as an example, according to the design parameters of a marine boiler, the following approximate mathematical models are obtained through continuous experiments:

$$G_M(s) = \frac{1.2e^{-\tau s}}{25.5s^2 + 68.25s} \qquad (3)$$

**2 PID Controller Based on BP Neural Network**

**2.1 Simple PID Controller**

The structure of the PID control system is shown in Figure 2.

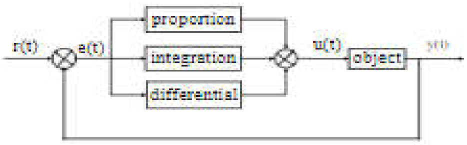


**Fig.2 Structural schematic diagram of PID control system**

Given input signal $r(t)$ and output signal $y(t)$ , the system constitutes a deviation:

$$e(t) = r(t) - y(t) \qquad (4)$$

Deviation $e(t)$ is first worked out by proportion, integral and differential, and then linear combination is used to obtain the control quantity:

$$\begin{aligned} u(t) &= K_P[e(t) + \frac{1}{T_I}\int_0^t e(t)dt + T_D\frac{de(t)}{dt}] \\ &= K_P e(t) + K_I\int_0^t e(t) + K_D\frac{de(t)}{dt} \end{aligned} \qquad (5)$$

The transfer function is:

$$G(s) = \frac{U(s)}{E(s)} = K_P[1 + \frac{1}{Ts} + T_D s] \qquad (6)$$

Among them, $K_P$ is the proportional coefficient, $T_I$ is the integral time constant and $T_D$ is the differential time constant. The PID controller has simple structure, convenient calculation, strong anti-interference ability and reliability, and has been widely used in the field of modern control. At the same time, the setting of its parameters is very important. The combination of parameters directly determines the final control effect.

**2.2 Design of PID Controller Based on BP Neural Network**

Boiler steam pressure has the characteristics of non-linearity, time-varying, large inertia and large lag. It is difficult to give a specific mathematical model, and the parameters of the PID controller are difficult to determine. Therefore, a PID controller based on BP neural network is introduced to improve the dynamic performance of the system by setting parameters online.

Combining the principle of PID control and BP neural network, using the self-learning ability of BP neural network, the parameters of the PID controller are set directly in the neural network. By adjusting its own weights, the neural network grasps the control intensity of proportion, differential and integral, and obtains the optimal parameter combination of the PID controller, so that the expected control effect of the PID controller can be achieved.

The PID controller based on BP neural network consists of two parts:

(1) PID controller (adjustable parameters) directly controls the controlled object;

(2) BP neural network, according to the state of the system, chooses the appropriate adaptive algorithm, tunes the three parameters of the PID controller, and achieves the best combination of the PID.

The structure of PID control system based on BP neural network is shown in figure 3.

The algorithm steps can be summarized as follows:

(1) Analyse the controlled object, design the structure of BP neural network and initialize it: Give the initial weights of each layer network, select the appropriate inertia factor and learning rate, and set $k$ to 1;

(2) Sampling input$r(k)$ and output $y(k)$ , calculating error $e(k)=r(k)-y(k)$ ;

(3) Normalized processing is selected as the system operation status of network input;

(4) The input and output of each node of the neural network are calculated;

(5) Calculate the output $u(k)=u(k-1)+\Delta u(k)$ of the PID controller, juxtapose $k=k+1$ and return to step 2.

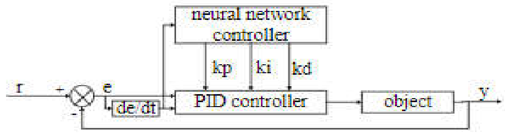


**Fig.3 Structure chart of PID control system based on BP neural network**

After learning and training, the output of BP neural network meets the requirement, and the weights of each layer of network are determined. It can be concluded that the BP neural network is finished, and the neural network that completes the learning work can be used to identify and predict, thus giving the PID controller with the optimal combination of parameters.

**3 simulation results**

Taking $G_M(s)=\dfrac{1.2e^{-\pi}}{25.5s^2+68.25s}$ as the mathematical model of boiler steam pressure and step function $rin$ ($t$)=1as the input signal, the traditional PID controller and the PID controller based on BP neural network are used to control it respectively. Finally, three parameters of the PID controller are selected by experiential trial and error method, namely $K_p=0.9$, $K_I=0.01$ and $K_D=35$ .

Response curves of traditional PID controller

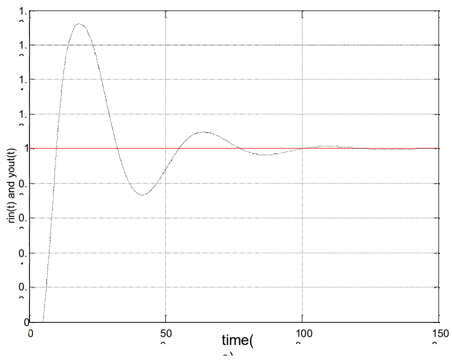


**Fig.4 Response curve of traditional PID control algorithm**

Figure 4 shows the response curve of the traditional PID control algorithm. Its adjustment time$t_s$ □877$s$, overshoot□%□74%, slow response of the system, and accompanied by a larger shock. It can be seen that the traditional PID controller cannot control the boiler steam pressure well.

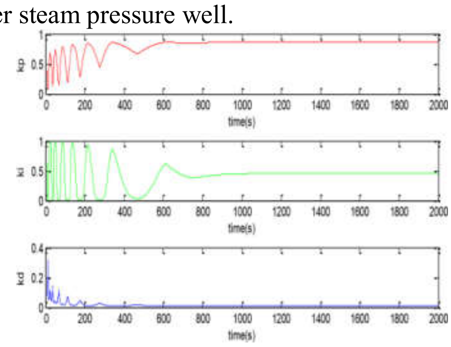


**Fig.5 changing curve of PID Parameters in training**

**Fig. 5 shows the change curve of PID parameters in the training of BP neural network**.

After the training, $K_P=0.887$ , $K_I=0.472$ , $K_D=0.001$ .

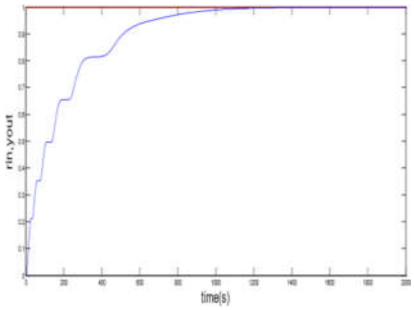


**Fig.6 Input-output curve of the optimized system**

Fig. 6 is the input-output curve of the system corresponding to the PID controller based on BP neural network. Its adjustment time $t_s$ =877$s$, overshoot $\delta\% = 0$; and no oscillation, output can quickly follow the input, the system response is fast and stable. It can be seen that the PID controller based on BP neural network is superior to the traditional PID controller in dynamic response.

## 4 Conclusion

This paper designs a PID controller based on BP neural network. After detailed analysis of boiler steam pressure system and PID controller based on BP neural network, the mathematical model of boiler steam pressure is established. The mathematical model is simulated by using traditional PID controller and PID controller based on BP neural network through MATLAB software. The simulation results show that the PID controller based on BP neural network can use the self-learning ability to get the optimal combination of PID parameters, shorten the adjustment time, reduce overshoot and eliminate vibration, and its control performance is obviously better than that of simple PID controller.

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