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Design of the Algorithm on the Flue Gas Desulfurization Controller

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Abstract

In view of the low speed and precision of the flue gas desulfurization system, this paper presents a hybrid method with parameter self adjustment. Through the analysis of the control system of flue gas desulfurization of flue gas and the transfer function of the object, and established the control system of flue gas desulfurization, perturbation models obtained a new flue gas desulfurization of the mixed sensitivity controller algorithm, simulation by Matlab show that this algorithm has certain advantages compared with at present commonly used algorithm.

***Keywords**: Flue gas desulfurization controller; Mixed sensitivity; Self-adjusting parameters; Data Collection; Correction accuracy*

1. Introduction

In today's increasingly serious environmental pollution, the problem of environmental protection is getting more and more attention. The smoke and exhaust gases generated by the industrial manufacturing resulted in decline in air quality, increase haze and other effects [1]. For flue gas containing sulfur pollutants emission source increasing, how to solve the content of sulphur in flue gas is the top priority now. At present, the flue gas desulfurization system is the empirical method to adjust the PID parameters to control the effect of the flue gas desulfurization [2], but the ordinary PID control has a slow adjustment speed, the accuracy is not high, for the big lag link control effect is not good and so on shortcomings [3].

2. System Working Principle

The FGD control system is a closed-loop control system. Monitoring the content of sulfide in flue gas by on-line monitoring instrument and the signal is transmitted to the controller. Controller based on the system setting content with real-time content, after the control algorithm to calculate the output signal, the real-time control of permanent magnet synchronous motor the material delivered to the bunker then the bunker into the boiler to reflect and achieve control of sulfide content in the flue gas. The system block diagram is shown in Figure 1.

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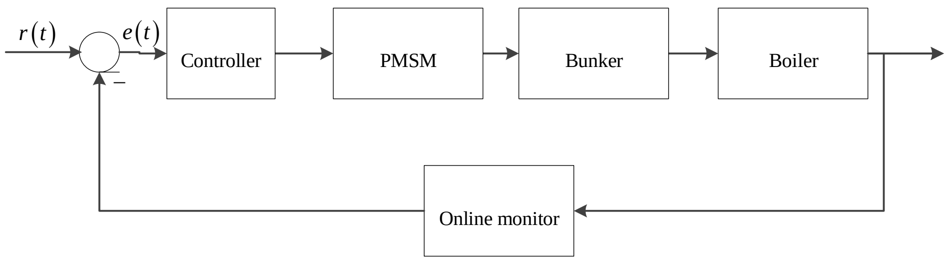

Figure 1. Block Diagram of Flue Gas Desulfurization Control System

3. Establish the Model of Flue Gas Desulfurization Control System

Flue gas desulphurization control system under the application of permanent magnet synchronous motor as a bunker actuators, control limestone motor control bin frame for quantity. Permanent magnet synchronous motor control precision decided to limestone to the accuracy of quantity, the control accuracy of the limestone directly influences the cost of the material and the stability of the system,so control the speed of permanent magnet synchronous motor is the key point of this algorithm. Permanent magnet synchronous motor current loop ACR control of the object is the two inertia link [4], the current loop ACR structure diagram shown in Figure 2.

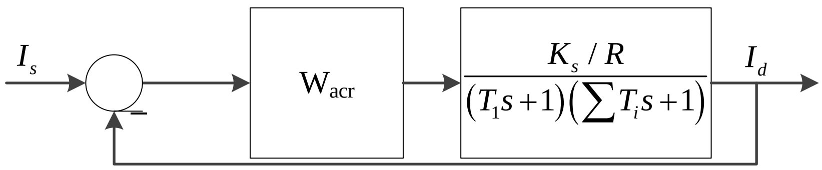

Figure 2. ACR Structure Diagram of Current Loop

Among them, T1s, Tis for the current loop of the filter time constant, Ks/R for the current loop gain. In order to correct the current loop into a typical I system, the PI regulator should be used. The transfer function of the PI regulator is:

$$Wasr(s) = \frac{K_i(\tau_i s+1)}{\tau_i s} \tag{1}$$

Formula (1), Ki is the current regulator scaling factor, $\tau_i$for the current regulator lead time constant. Select the PI controller parameters such that τ_i= T_i, the current loop zero to eliminate the large inertia of the controlled object pole, a simplified diagram of the current loop ACR structure is shown in Figure 3.

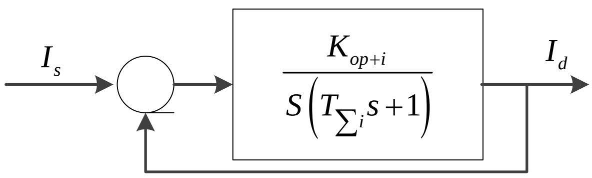

Figure 3. ACR Structure of Current Loop

Among them, the open-loop amplification coefficient K_{op+I} and the time constant $T_{\sum I}$ respectively:

$$K_{op+i} = \frac{K_i K_s \beta}{\tau_i R} \tag{2}$$

$$T_{\sum i} = T_s + T_{oi} \tag{3}$$

Speed loop ASR of permanent magnet synchronous motor is designed according to Ⅱ type system, and the structure of the speed loop of permanent magnet synchronous motor is shown in Figure 4.

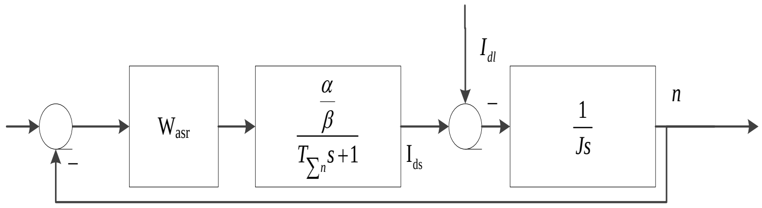

Figure 4. ASR Structure of the Permanent Magnet Synchronous Motor Speed Loop

The J is the moment of inertia. In order to correct the speed loop into a typical Ⅱ type system, the speed regulator should also be used in the PI regulator and Its transfer function is:

$$W_{asr}(s) = \frac{k_n(\tau_n s + 1)}{\tau_n s} \tag{4}$$

Formula (4), K_n is the ratio of the speed regulator amplification factor; τn of the speed controller lead time constant. Thus, the open-loop speed control system functions as:

$$W_n(s) = \frac{K_{op+n}(\tau_n s + 1)}{S^2(T_{\sum n} s + 1)} \tag{5}$$

In the formula (5), τ_n for the speed regulator lead time constant, select the 0.06s, $T_{\Sigma n}$ the speed loop time constant, select the 0.01s, K_{op+n} is the ratio of the speed regulator amplification factor. Permanent magnet synchronous motor current double closed loop control block diagram is shown in Figure 5 [5].

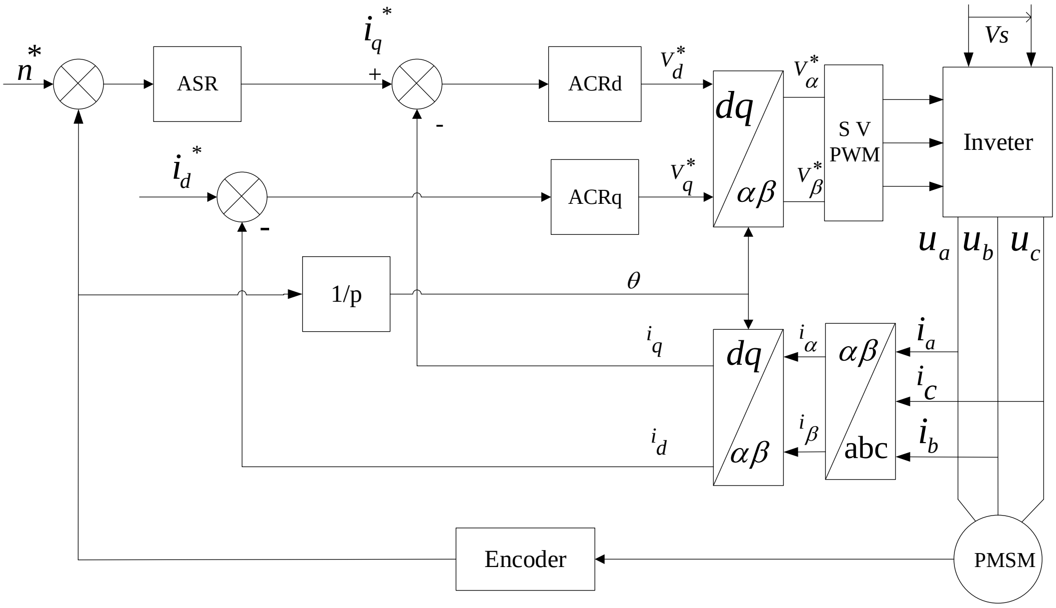

Figure 5. PMSM Current Double Closed Loop Control Diagram

In order to avoid the interference caused by the uncertainty of the flue gas desulfurization control system, the model of the lue gas desulfurization control system is set up as shown in Figure 6.

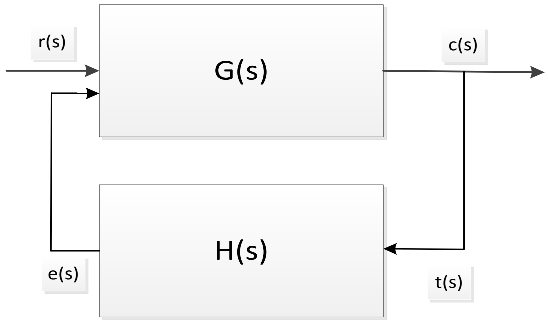

Figure 6. Standard Type Diagram of Flue Gas Desulfurization

Wherein G (s) of the controlled object is fixed, r (s) for the external input signal, c (s) is the system output signal, e (s) is the control output signal, t (s) is a measure of the output signal, H (s) is the controller [6].

$$\begin{cases} \dot{x} = Ax + B_1 r + B_2 e \\ \dot{c} = C_1 x + D_{11} r + D_{12} e \\ \dot{t} = C_2 x + D_{21} r + D_{22} e \end{cases} \tag{6}$$

Formula (6), x is the state variable, r, e, c, t is the corresponding signal vector dimension; A, B_1, B_2, C_1, D_{11}, D_{12}, C_2x, D_{21}, D_{22} are constant matrices; Generalized controlled object G (s) is

$$G(s) = \begin{bmatrix} G_{11} & G_{12} \\ G_{21} & G_{22} \end{bmatrix} = \begin{bmatrix} A & B_1 & B_2 \\ C_1 & D_{11} & D_{12} \\ C_2 & D_{21} & D_{22} \end{bmatrix} \tag{7}$$

Open loop transfer function:

$$\begin{bmatrix} c \\ t \end{bmatrix} = G(s)\begin{bmatrix} r \\ s \end{bmatrix} = \begin{bmatrix} G_{11} & G_{12} \\ G_{21} & G_{22} \end{bmatrix} \tag{8}$$

Function of the feedback loop:

$$e = H(s)t \tag{9}$$

By the formula (6), (7), (8), (9) can be derived from t to u the closed loop transfer function:

$$T_{ds} = G_{11} + G_{12}H\left[I - G_{22}H(S)\right]^{-1}G_{21} \tag{10}$$

In the practical application of G (s) are fixed controlled object, in this article, the mathematical model of flue gas desulfurization is the controller. To achieve the required performance control system must be such that the system is stable, reasonable controller H (s) is designed especially important [7].

4. Control Algorithm and Simulation Results

Because of the closed-loop control functions directly affect the performance of the system, so using the weighted sensitivity function as the control system transfer function [8], it can be expressed as

$$\|U\|_\infty < \gamma \tag{11}$$

In the formula (11), γ is an infinite small value, U is a controller for the system, and the system achieves a stable state when the type (11) is satisfied. Actual control system design, direct numerical meet this condition is more complex, using the normalization process [9], that function can be expressed as

$$\|w_p U\|_\infty < 1 \tag{12}$$

Formula (12) w_p is on the verge of weighting function, which is equivalent relationship [10]:

$$\|U\|_\infty < \frac{1}{w_p} \tag{13}$$

Set the sensitivity function of the system U

$$U = \left(1 + G(s)H(s)\right)^{-1} \tag{14}$$

The weighted sensitivity function can be chosen as [11]:

$$w_p = \frac{s^2 + 24.49s + 150}{1.5s^2 + 0.03s + 0.00015} \tag{15}$$

This function ensures that the phase margin reached 43.3 degrees, the amplitude margin reached 4.76db. This design uses γ = 0.1 ~ 10, the conditions of tolerance 0.001 iterate down calculations and depending on the controller design standards $\|w_p U\|_\infty < 1$.Through MATLAB programming, after 20 this iteration. The result of the iteration is γ = 1.0004, and the system is stable. By the formula (14) (15) (16) the flue gas desulfurization controller transfer function H (s) is optimized for

$$H(s) = \frac{25.32s^3 + 1224s^2 + 1330s + 1.564\times10^4}{s^4 + 12.70s^3 + 69.45s^2 + 218.7s + 0.2708} \tag{16}$$

On the basis of building the model of the system through Matlab simulation. The results of the PID control algorithm and the weighted sensitivity algorithm are used in the real time output under the action of the step response and the external disturbance. Under the different conditions, the requirements of the flue gas desulfurization system can be completed. Simulation of the classic PID control algorithm is shown in Figure 7.

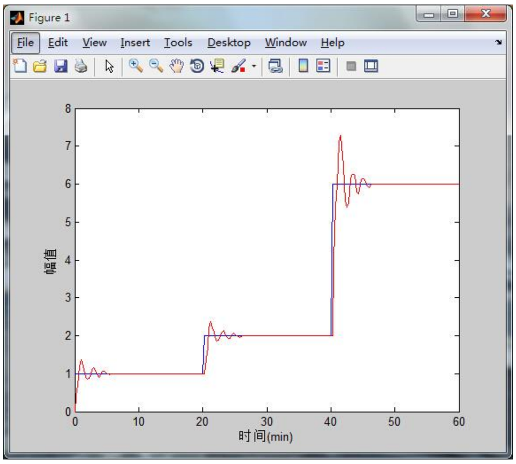

Figure 7. Simulation Diagram of the Classical PID Control Algorithm

Using weighted sensitivity control algorithm for the simulation is shown in Figure 8.

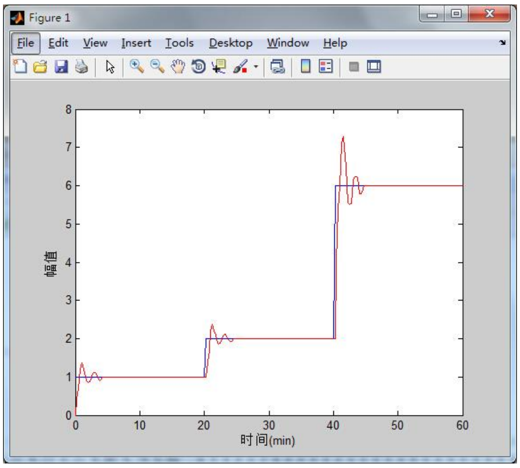

Figure 8. Using the Weighted Sensitivity Control Algorithm Simulation

From Figure 7 it can be seen that the general PID control algorithm is very obvious, the system is slow and the overshoot is large. From Figure 8 it can be seen that the use of the weighted sensitivity control algorithm results in the rise time of the system is fast, the number of oscillations is less, and the overshoot is small, so it can meet the design requirements of the flue gas desulfurization controller.

5. Conclusion

The simulation results can be seen, the use of weighted sensitivity algorithm system more stable. The amount of the limestone can be reduced by the amount of the super tone, and the reaction is more economical; the vibration control is better to ensure that the actuator does not need to work frequently, and reduce the loss of the device; control time is short to reduce the discharge of pollutants can be guaranteed. Since the sulfur content of the flue gas is not stable, the weighted sensitivity algorithm will increase overshoot system. Limestone and flue gas reaction also need time to achieve the flue gas control in advance, so as to achieve the effect of accelerating the system stability and reducing gas emissions.

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