Research and Design for Intelligent Control Algorithm of the LF Furnace Electrode

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Abstract. By the way of build a new model to intuitively response the temperature changes in the refining furnace, using the results of the temperature changes to control the output of the current, and achieve the purpose of accurate control and not waste resources. Combining temperature prediction with this model, complete the adjustment work together. By the simulation shows that use this control method can adjust the current output reasonably. By this way the efficiency of electrode regulating system can be improved, and fit the practical requirement in production more.

Introduction

After high-speed development of the steel refining equipment in our country, the smelting capacity has been improved greatly. At present most of the control method of LF furnace electrode regulating modes are all around to maintain a constant current or constant impedance, although this approach to a certain extent, improved the disadvantages of artificial electrode adjusting, But inevitably ignore the uncontrollable factors affecting the temperature in the furnace, so often leads to heating temperature and the technical requirements of temperature deviation, temperature deficiency can lead to incomplete reaction, increase the number of electrical heating temperature sampling, overheating will cause the waste of resources. This also can't continuous with refining process to obtain a direct relationship between the real-time temperatures of the furnace.

This paper proposes a new model establishment method, using the energy conservation principle, calculation on the heat gains of heating and the heat losses in the furnace, and establish a corresponding function relationship between current, this can use the change of temperature intuitively and adjust the electrode targeted, there by to achieve the purpose of temperature control while avoiding the discussion about the complex temperature in real-time, targeted and effective, can realize the goal of improving the production efficiency, reduce energy consumption.

The establishment of the control model

The control principle

According to secondary voltage change in LF furnace smelting process as the arc current change, the rise of temperature of the molten steel requirements, while maintaining the LF furnace under the premise of three-phase electrode current balance and stability, make steel actual temperature rising curve and the theory required to minimize the deviation between temperature rise curve.

The temperature rise model based on energy conservation

According to the above control strategy control model is established. Transformer secondary side voltage rating for the fixed value, actually short net voltage will be changed in accordance with the change of electric arc current; molten steel temperature rise curve T=T(t), temperature rise curve made by the technological requirements of different steel grade. By the sensors measures the secondary side single-phase current I, voltage U, secondary side power factor $\cos\varphi$ and the real-time temperature of the molten steel T.

Suppose the short-net resistance is R, η is the arc heating efficiency, according to the energy conservation:

$$\Delta t(\sqrt{3}IU\cos\varphi - 3I^2R)\eta = C_g(T)m_g(T_0 - T) + C_z(T)m_z(T_0 - T) \qquad (1)$$

Where I is the single-phase electrode given current, the function between U and I as follows:

$$U = (\frac{g\sqrt{z^2+x^2}+1}{g})\cdot I \qquad (2)$$

Where g is the conductance of the arc, with arc linear proportional relationship, z, x is the impedance and the inductance short-net. At the moment according to the technological requirements of temperature rise curve corresponding to the temperature of liquid steel t0 is T_0. T is the actual measuring temperature of molten steel and steel slag at the moment t. Δt is the time that steel and steel slag from temperature T reached to T_0 used, $\Delta t = t_0 - t$. m_g is the weight of the steel, m_z is the weight of the steel slag, C_g (T) and C_z (T) are the molten steel and the steel slag specific heat at constant pressure.

Suppose $\frac{g\sqrt{z^2+x^2}+1}{g} = a$, then the left of (1) can be represented as $\Delta t（\sqrt{3}\cos\varphi a I^2 - 3I^2R）\eta$, put the formula （1）into differential，Because of the liquid steel refining process is relatively stable，so If we ignore ΔI^2 the impact on the accuracy of model is very small, therefore:

$$\Delta t（\sqrt{3}\cos\varphi 2aI（I+\Delta I）dI - 6IRdI）\eta = -[C_g(T)m_g + C_z(T)m_z]dT \qquad (3)$$

After tidy:

$$\Delta t（2\sqrt{3}U\cos\varphi dI - 6IRdI）\eta = -[C_g(T)m_g + C_z(T)m_z]dT \qquad (4)$$

(3) for the difference equation:

$$\Delta I = -\frac{C_g(T)m_g + C_z(T)m_z}{\Delta t(2\sqrt{3}U - 6IR)\eta}\Delta T \qquad (5)$$

ΔI is the electrode current that combination of furnace temperature conditions to calculate the amount of the change， solve the formula (1):

$$I = \frac{\sqrt{3}U\cos\varphi}{6R} - \frac{1}{2R}\sqrt{\frac{1}{3}(U\cos\varphi)^2 - \frac{4R（C_g m_g + C_z m_z)(T_0 - T)}{3\eta\Delta t}} \qquad (6)$$

Where I is a given current value at the initial moment in LF furnace, current I change with the arc length which the proportional valve to adjust the electrode position, arc length changes on the relationship between the current changes:

$$\begin{cases} \Delta I = \beta\frac{r+R}{R^2+x^2+r\cdot R}\Delta l_h \\ I = \frac{\alpha+\beta(l+\Delta l)}{\sqrt{z^2+x^2}} \end{cases} \qquad (7)$$

The design of the intelligent control algorithm

We can see by the model above, the system described in the refining process, the relation between electric current and temperature can make use of traditional PID algorithm to control, but in the actual production process, the temperature of the sampling interval is long, the entire refining cycle short, using PID controller to meet the requirements of control accuracy, the temperature forecast and the control model, it can greatly shorten the sampling interval, also made the current output is more stable, reduce the impact on the grid, and improve the control precision.

Refining furnace simulator training

First use of the refining furnace temperature prediction system was added into refining furnace simulator training, refining furnace simulator USES is based on ELM algorithm may enter 1 output, hidden layer neurons according to empirical formula set for nine of the neural network structure, u(k) is the measured temperature, as shown in figure 1.

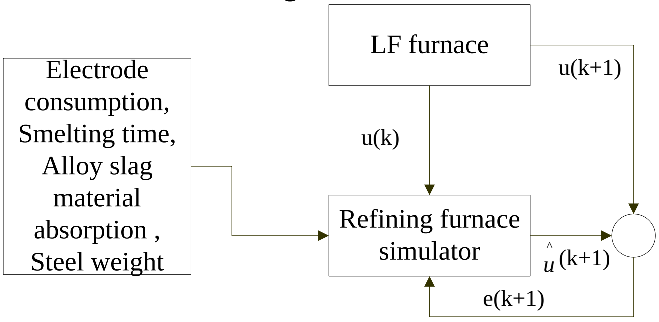

Fig.1The principle of the LF furnace simulator training

Using the theory of temperature forecast to predict the temperature of the refining furnace next sampling instant output and the change trend of temperature with time, The output u (k + 1) and the predicted output $\hat{u}$ (k + 1) the difference between the weight of refining furnace simulator update complete for refining furnace simulator training.

According to the error of less than 5 ℃ is considered to meet the requirements of actual production prediction, prediction accuracy of 90%, after training base can be used in practical production.

The electrode regulator based on temperature prediction

Combining this refining furnace simulator with the regulator, the intelligent control made up of regulator and refining furnace simulator, the principle of the intelligent control as shown in figure 2.

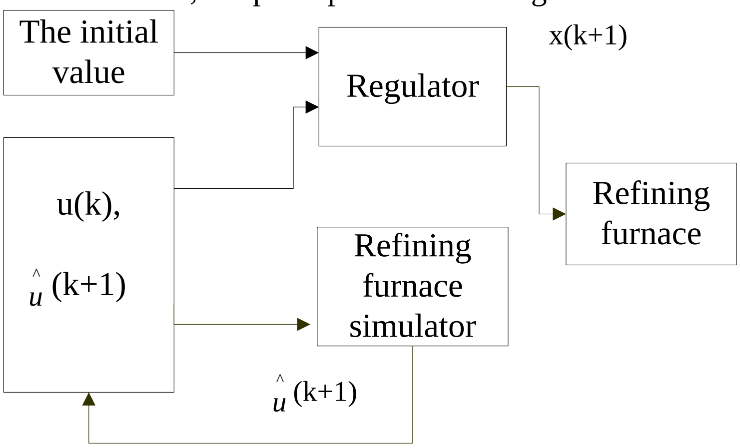

Fig.2 The principle of the intelligent control

Input for the effects of the temperature forecast results of temperature in the regulator, calculated x (k + 1) as a new current input values, produced by refining furnace simulator to predict temperature $\hat{u}$ (k + 1) as the temperature of the next input signal, the regulator and simulators to refining furnace electrode automatic adjustment process.

The simulation experiment research

In this paper, the LF furnace electrode regulating system in MATLAB environment, the simulation of 80t LF furnace refining process in the output of the current situation, the controller module i model for type (5), refining furnace current module I model for type (7), the results are shown in figure 3.

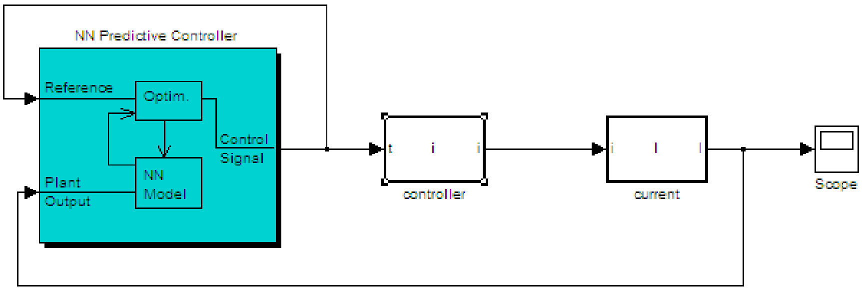

Fig.3 The simulation system

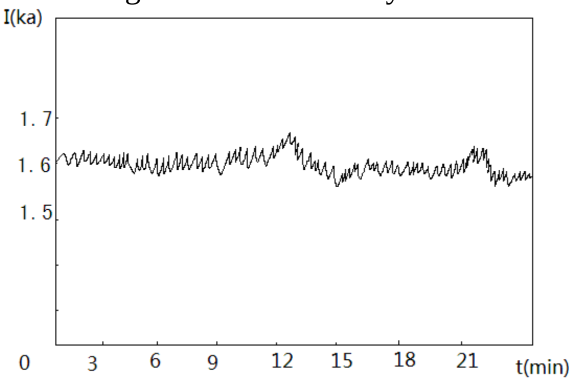

Fig.4 The system current output

By the output current can be seen that in the first place in the process of refining current of different control methods as heated at a constant level, but fluctuate around a current point, floating range is less than 2 kA, so the system current output more stable, according to the characteristics of the refining furnace work more targeted, this can effectively avoid the shortage of excess heat and heat up, adapt to the actual working environment more, use this system can not only improve the efficiency of refining, while avoiding the unnecessary waste of resources.

The conclusion

According to the working conditions of refining furnace and its characteristics, this paper designed the intelligent model, by the principle of conservation of energy, can be intuitive response from within each time interval between the heating temperature change influences on current, which can change current according to the actual situation for heating. Based on the established model characteristics, need to shorten the sampling interval, so joining the temperature forecast control method, to improve the production efficiency but also can avoid the waste of resources. And through the simulation results can be obtained, using this control method of the model, the output current of refining process is more reasonable and targeted, the adaptability of system significantly improved, better cope with the actual working environment.

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