Application of Artificial Intelligence Technology on the Submerged Arc Furnace

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ABSTRACT

To optimize the power control of submerged arc furnace for ferro-alloy and other products, an artificial intelligence technology based scheme, using artificial neural network as well as expert system and fuzzy control technology, is introduced in this paper. First, the optimal power setpoint is generated through on-line furnace electrical parameter calculation through fuzzy artificial neural network and combined with expert system, and then, together with transformer voltage tap change, an intelligent electrode regulation with fuzzy artificial neural network is introduced to track the above optimal power setpoint. The simulation results demonstrate that it is feasible to realize the optimal power control through applying artificial intelligent technology.

INTRODUCTION

The artificial intelligence technology based on fuzzy control, expert system and artificial neural network is developed rapidly in recent years. Many problems in various professions which were very difficult before for the traditional control algorithms are solved easier now by using this new technology. The success of IAF (Intelligent Arc Furnace) Controller of Neural Application Corporation of USA in the area of steelmaking is a good example.

On submerged arc furnace, which is used to produce ferro-alloy or other products, the optimization of power supply is also a technical problem that is always concerned. Comparing with steelmaking arc furnace,submerged arc furnace has more complex influence facts because a part of current flows through the resistance of raw material between electrodes besides the current flowing through arc. In addition, the determination of the optimal furnace working point and the choosing of reasonable steps to correct the deviation of neutral point of the bath are complicated multivariable control process. In the other hand, from the point of view of metallurgy, perform a stable bath, it is not expected a frequent movement of electrodes, so the final control decision could not only consider the optimization of electrical variables. Besides, when abnormal phenomena occur, such as raw material sudden falldown or electrode breakage, the expected treatment is much different from the normal operation. All above facts are very difficult for traditional control and make a good chance for the application of artificial intelligence technology on submerged arc furnaces.

In this paper, an artificial intelligence technology based scheme is introduced to realize the optimal power control of submerged arc furnace, using artificial neural network as well as expert system and fuzzy control technology. Two main parts, power setpoint dynamic optimization and intelligent electrode regulator are described. The synthetic application of above technology will improve the control quality, raise the on-line rate and truly make the automatic control system of electrodes indispensable for production.

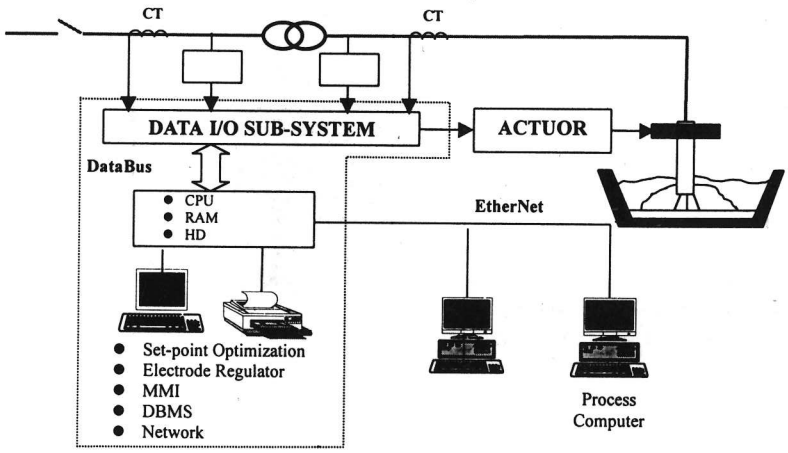


Fig. 1 The principal diagram of the artificial intelligence technology based optimal power control system.

The function and structure of optimal power control system

Fig. 1 illustrated the principal diagram of the control system.
In this optimal control system includes the following main functions:

- power setpoint dynamic optimization
- artificial neural network based electrode regulation
- synthetic control output
- database management and statistical process analysis
- man-machine interface
- report print
- network communication

Power setpoint dynamic optimization

The selection of the reasonable power setpoint is to maximize the arc power into the furnace, under the limits of certain conditions.

Artificial neural network based electrode regulation

To track the optimized power setpoint through the regulation of the electrode positions.

Synthetic control output

After synthetically considering the normal calculation output and abnormal furnace process reaction, find the output of the control signal after fuzzy treatment is performed.

Database management and statistical process analysis

The following databases are included:

- Furnace electrical parameter database
- Metallurgical process real time database
- Database for report
- Database used for power setpoint optimization
- Database for artificial neural network training

With the above database, off-line optimization calculation are periodically performed to adapt the changes of electrical network, raw materials, product grades; and the operators can conduct statistical process analysis on the metallurgical results of each heat and find the relations among various variables to optimize the operation.

Man-machine interface

As a foreground process, friendly man-machine interfaces provide a deep understanding of the metallurgical processes and equipment operation status to the operators, mainly included the following diagrams:

- control system diagnosis diagram
- equipment operation status diagram
- synthetic furnace metallurgical process diagram
- intelligent regulation diagram
- power setpoint diagram
- diagram for maintenance

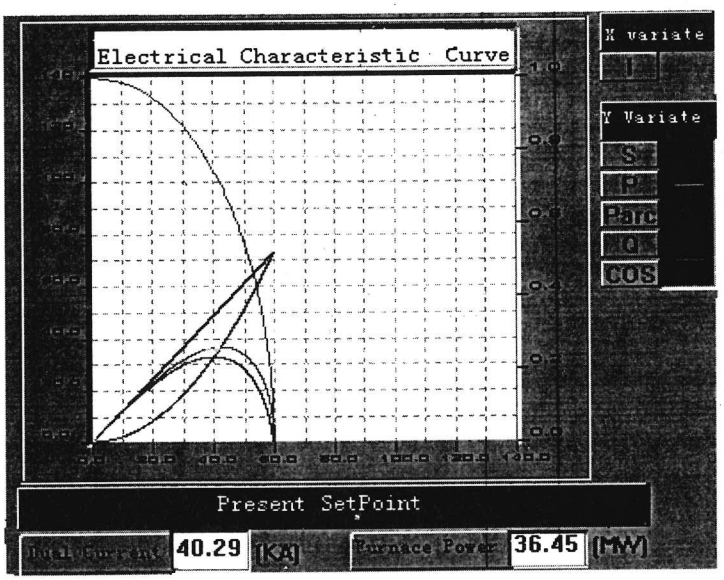
Report print

The following reports are generated:

- Heat report, including process variables and event log
- Trend curves
- Statistical reports, such as shift report, daily report, monthly report, yearly report

Network communication

To exchange information related with optimal power control, this system communicate with material charging computer and process computer through network.



I — dual current;
S —apparent power;
P —furnace power;
Parc —arc power;
Q —reactive power;
COS — power factor;

Fig. 2 electrical characteristic curve and the present setpoint

Power setpoint dynamic optimization

The function of this part is selecting reasonable power setpoint through on-line furnace electronic parameter calculation and using artificial neural network integrated with expert system reasoning. That is selecting reasonable decision variables to maximize the arc power into the furnace under the following limits:

- Maximum power smaller than the rated power of the transformer
- Working current smaller than the rated current of the transformer
- Reasonable transformer voltage tap
- Balanced three phase arc power
- High power factor

Fig.2 gives electrical characteristic curve and the present setpoint.

In this system, the following algorithms are included to realize the power setpoint optimizations:

- Prediction the trends of electrical parameters with mathematical model Database for artificial neural network training
- Maximum permitted arc power calculation with electrical characteristic curves
- Combined working voltage and current set based on expert system

First, on-line electronic parameter prediction model is used to predict the variation of the furnace electrical parameters based on the present change of transformer current and voltage. Then draw the electrical characteristic curves and calculate the maximum arc power value and the working current and voltage selection ranges to realize this maximum arc power, and using the power input expert system to determine the optimal power setpoint.

Based on the ferro-alloy metallurgical knowledge and the experience of metallurgical experts, a power input system is established, which transform various non-structed and heuristical information into a reasoning process to obtain the solution. The expert system is consisted of knowledge base and reason engine, and the knowledge base taking the form of generation rules, such as IF-THEN sentences,and the reason engine is based on deductive reason mechanism, such as forward reason, backward reason or duplex reason.

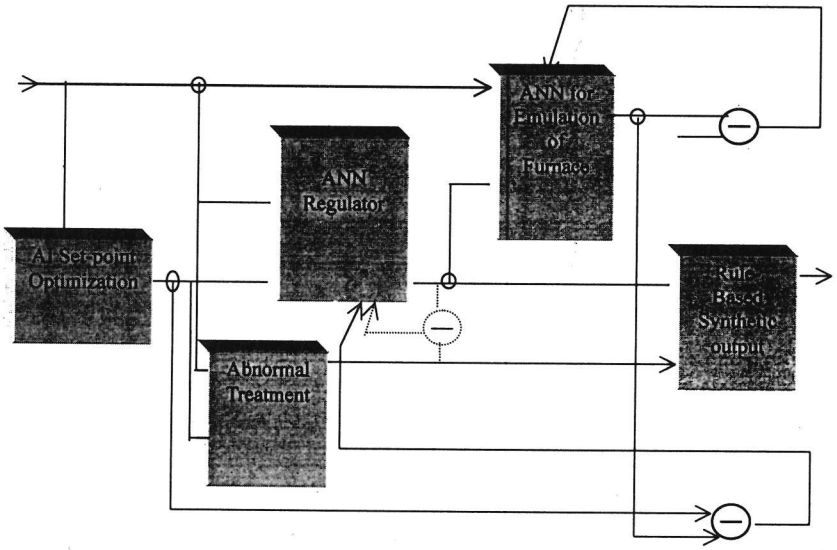


Fig. 3 The principal diagram of artificial intelligent electrode regulator

INTELLIGENT ELECTRODE REGULATOR

The function of this part is together with the change of transformer voltage tap, the movement of electrodes are controlled through an intelligent electrode regular with fuzzy artificial neural network to track the above optimal power setpoint.

Fig. 3 gives the principal diagram of artificial intelligent electrode regulator.

The artificial intelligent electrode regulator includes artificial neural network furnace emulation model and artificial neural network regulator. The former is used to predict the change trends of furnace variables, such as current, voltage, active power and passive power, while the later is used to calculate the output of the regulator through comparing the set-point and the predicted values.

Three layer forward network model are used to setup the artificial neural network, General Delta algorithm of BP is used to train the artificial neural network, to meet the speed requirement of real time on-line calculation.

In this artificial neural network electrode regulator, electrode-slip record also used to train the artificial neural network, to obtain a more reasonable movement of electrodes, moreover, conductivity of raw material is monitored, integrated with material addition control, to meet the requirement of both heat balance and material balance.

In some abnormal conditions, such as over-current or short-circuit protection, rapid reactions are needed. To avoid the artificial neural network too complicated and obtains rapid reactions, an expert system escort algorithm is considered in this intelligent regulator. These abnormal conditions are directly determined by the expert system. Through analyzing the furnace process, synthetically considering the normal calculation output and abnormal furnace process reaction, the expert system output the control signal after fuzzy treatment.

Conclusion

The research group has finished the developing work on laboratory and simulation result shows the technology is feasible. It is expected that the good result will be obtained in industrial application.

Reference

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