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Modeling, identification and controlling of the systems with electric arc. Applications regarding the electric arc furnace

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In this paper is taken into consideration the actuality domain of controlling metallurgical process using conventional and unconventional (fuzzy logic) methods with particularization of the problem of modeling and controlling the process of steel production in the direct-action three-phase electric arc furnace.

This paper with a basic text of 221 pages is structured in 5 chapters, it is based on a bibliographic list of 125 topical titles, edifying for the research in the thesis.

Chapter 1 presents the motivation and objectives of the thesis, the advantages and disadvantages of the three-phase electric arc furnaces, the problems that may arise during the operation of these plants, and the content of the thesis.

Chapter 2 presents the information needed to understand the melting steel process, the arc furnace installation and process identification and control.

There are presented the mathematical models approached in the literature that simulate the behavior of the electric arc, respectively the control strategies / structures synthesized in the scientific literature for controlling the process of making steel using the electric arc furnaces.

Also, a classification of electric arc furnaces is presented being mentioned the main parameters characterizing these installations from the energy point of view, but also the phenomenon that determines the occurrence of the electric arc.

For a more accurate knowledge of direct-action electric arc furnace of EBT type, the construction elements, operating regimes, electrical equipment and their operating characteristics are presented and for a more accurate knowledge of the steel production process are presented operations and technological phases in the furnace and process controlling issues.

Also, current systems of automatic control of the furnace installation as well as control systems based on intelligent techniques synthesized in the literature are presented.

Chapter 3 begins with the analysis of the data acquired from the real installation, illustrating an electrical circuit diagram of the electric arc furnace as a three-phase symmetric consumer, which is used to implement the mathematical models.

A mathematical model existed in the scientific literature based on the representation of the voltage-current characteristic that is used to simulate arc behavior (MM-0) was presented, then was developed an extended mathematical arc model (MM-LIN) that extends the area of the arc operation and it is presented a comparison of these two models.

Were proposed four other mathematical models based on the representation of the voltage-current characteristic (MM-EXP1, MM-EXP2, MM-HL, MM-DE) used to simulate the electric arc behavior and to synthesize the considered control structures, respectively a model simulating the operation of the entire three-phase electric arc furnace installation.

To develop mathematical models simulating arc behavior, the arc voltage-current characteristic was divided into several operating areas, each area having a certain variation (linear, exponential).

In order to implement different simulation scenarios, Matlab graphical user interfaces have been developed that allow the adjustment of the values of the model parameters in a certain set domain.

For these five arc models, comparative analyzes were carried out regarding the influence of the arc model parameters, as well as the voltage from the secondary side of the furnace transformer on the voltage, current and power of the arc.

The proposed models were simulated with real values of the technological installation and thus their validation is possible by comparing the data obtained by simulation with those obtained from the actual furnace, for each validation being illustrated the voltage-current characteristic of the arc, respectively of the furnace, but also the voltage waveform from the measuring point in the transformer secondary side, respectively the waveform of the arc current.

Were also developed models based on multi-layer perceptron (MLP) artificial neural networks or radial bases function networks (RBF RNAs) that have the ability to learn the behavior of the system. Another type of neural network developed was the adaptive neuro-fuzzy inference system (ANFIS) that allows prediction of both arc voltage and current according to the data acquired from the real technological installation, taking into account a certain sampling step.

Depending on the comparative analysis of the mathematical models based on the voltage-current characteristic of the arc, the exponential model based on the voltage-current characteristic (MM-EXP1) was chosen for the implementation of the control systems.

In Chapter 4 were synthesized the control systems used to obtain the maximum power or the required power of the electric arc by changing the speed and the direction of the movement of the electrodes from the three-phase electric arc furnace.

Within the developed control systems, the reference parameter was the arc current or the arc power.

Several types of control systems considered to be representative of the considered process were synthesized and analyzed: system with a fuzzy controller with one input and one output; system with a fuzzy controller with two inputs and one output; systems based on classical controller such as: proportional (P), proportional-integrator (PI), proportional-derivative (PID), proportional-integrator-derivative (PID); systems based on adaptive control strategies in which a fuzzy controller is used to tune the parameters of classical controllers.

For the implementation of the fuzzy-based logic controllers, triangular, trapezoidal or mixed (trapezoidal for the corners and triangular in the rest) membership functions are considered, 7 fuzzy sets being used for each of the linguistic variable.

If the case that the reference parameter is the arc current, the responses obtained for each of the proposed control systems have been presented for: the step variation of the reference parameter; variation of reference in the form of a sequence of steps; the introduction of a step-disturbance in the process in case of a constant reference; the introduction of a sequence of steps disturbances in the process in the case of a constant reference.

The proposed control systems have been analyzed and compared with each other in order to highlight which of them offer better performance over response time, overshot and stability of the system.

When the reference parameter is arc power, the responses obtained for each of the proposed control systems were illustrated for: introduction of a sequence of step disturbances in the case of a variable reference; changing the transformer tap changer and a step variation of the reference, respectively, introducing a sequence of step disturbances in the process.

The conclusion that can be obtained from the developments considered in Chapter 4 is that fuzzy logic-based and adaptive controllers are safe, efficient and good solutions for the problems that may arise in the steel melting process through the electric arc furnace.

Chapter 5 concludes the scientific approach undertaken by the research in the thesis, focusing on the conclusions and contributions made. Future research trends are also presented.

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