The interpretation of electrical measurements of submerged arc-resistance furnace

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Abstract **The article describes measurement of currents and voltages in submerged arc-resistance electric furnace which were done to identify arc parameters. Waveforms of registered currents and voltages have been shown. Characteristics of arc developed in original C# software has been presented.**

Keywords **submerged arc-resistance furnace, electric arc parameters, nonlinear systems, measurements.**

I. INTRODUCTION

Ferrosilicon is one of the basic raw material in the steel industry. It is an alloy of iron and silicon. The production of the ferrosilicon in submerged arc-resistance electric furnaces has steadily expanded during the past decades. It is associated with a high technological demand for ferrosilicon which is used as a source of silicon to deoxidize steel and other ferrous alloys. Ferrosilicon is also used for manufacture transformer and electric motors cores. The power consumption during the production of ferrosilicon is very high, so the reduction of power looses is very desirable in this process. It can be done by appropriate control of the entire process, but it requires a great knowledge about raw materials, process and its thermal and electrical parameters.

The article deals to the identification of some electrical parameters which are important for the control of thermal process. An exemplary schematic diagram of a submerged arc- resistance electric furnace with measured currents and voltages has been shown in fig. 1.

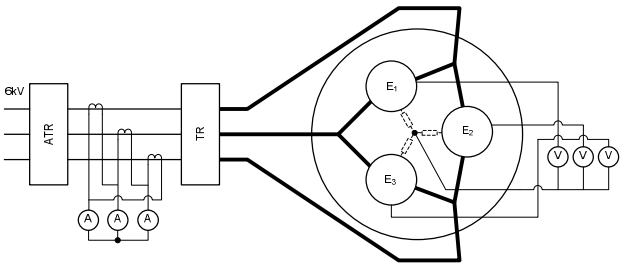


Fig. 1 A schematic diagram of a submerged arc furnace with simplified measured systems.

The uncontrolled nature of the steel melting process is a source of the unpredictable and random currents and voltages harmonics generated by arc furnace [1], [2] and [5]. As a result of these permanent fluctuations of currrents, voltages and powers, the electric energy is introduced into the furnace in an inhomogeneous manner. This conclusion makes difficult the control process of the arc furnace. The control system based on maintaining constant current or constant impedance are very often used. There are three sources of control for the furnace:

- by stepping up or down the electrode voltage,
- by the control of the raw material,
- by the moving of electrodes.

Unfortunately, neither maintaining a constant current or a constant impedance do not provide an optimal supply conditions and a production.

The dynamic and extensive measurements on the furnace, have been developed. The results of these measurements has been presented in these article.

II. DESCRIPTION AND ANALYSIS MEASUREMENTS

The submerged arc-resistance furnace in the company Re Alloys (Łaziska Górne, Poland) has been used to produce ferrosilicon FeSi75. It is powered from factory power system 6kV by means of 12MVA autotransformer. The transformer of the furnace gives voltage range from 70 to 140V. This system of transformers are connected to electrodes by the high current path. The current in electrode is about 35kA and the total power consumption is equals of 8,5MVA with $tg\phi \approx 0{,}48$. The simplified diagram of the system has been shown in fig. 2.

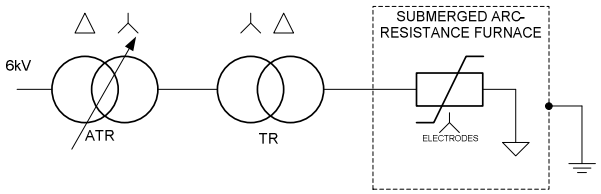


Fig. 2 Simplified diagram of considered arc furnace.

A suitable equipments have been used for measurements. Phase voltages of electric arc furnace have been measured directly on the columns of electrodes in the measurement system. The voltage of an electrode is collected from its coat derived over the cap of the furnace (Fig. 1) and it is referenced to the anti-electrode which is placed in the bottom of the tank furnace. There is a conventional zero point. The currents flowing by electrodes has been determined from measurements currents by means of current transformers (Fig. 1) connected in the primary side of the furnace transformer. Collected a large number of measurements allow to observe the state of the transition of the furnace from asymmetry to symmetry. Recorded waveforms of voltages and currents of the arc allow to plot a characteristics of the arc in a dynamical way. This characteristics has been determined based on the well-known model Franzisa [3]:

$$\frac{di(t)}{dt} = \left[e_k(t) - R_{ek} i(t) - \frac{i_k(t)}{g_k(t)} \right] \frac{1}{L_k}, \qquad (1)$$

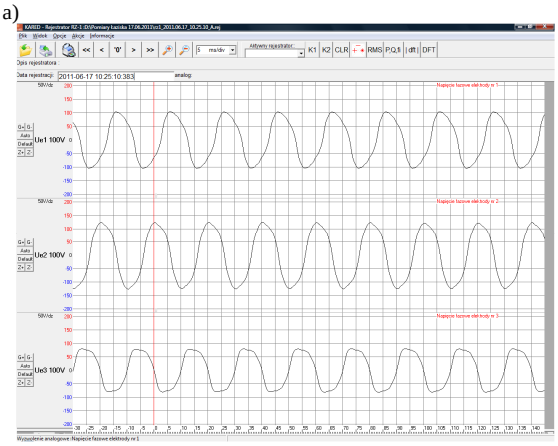
$$\frac{dg_k(t)}{dt} = \frac{g_k(t)}{\Theta_k} \left[\frac{i_k^2(t)}{g_k^2(t) U_{\tau k}^2} - 1 \right], \qquad (2)$$

where: k=1, 2, 3;

$\sum_{k=1}^{3} i_k(t) = 0$; $i_k(t)$ – measured current of k phase; $e_k(t)$ – measured k - electrode voltage; R_{ek} – substitute resistance of k - electrode; $g_k(t)$ – electric arc conductance; $U_{\tau k}$ – electric arc voltage; Θ_k – time constant of electric arc.

An exemplary results of registered waveforms have been summarized below.

a)



b)

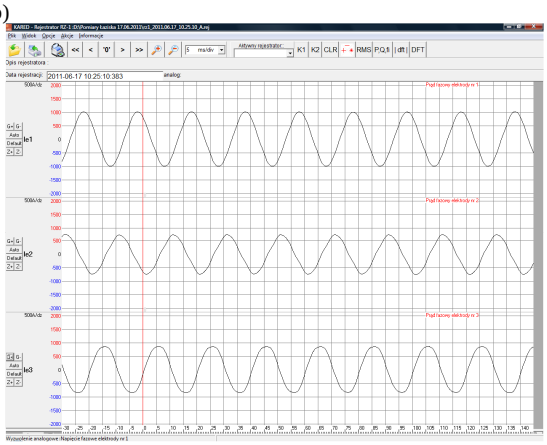


Fig. 3 Asymmetric state of the furnace operation (a) the waveforms of voltages of electrodes (b) the currents flowing by electrodes

Fig. 4 The histeresis curves of the arc furnace for each phase.

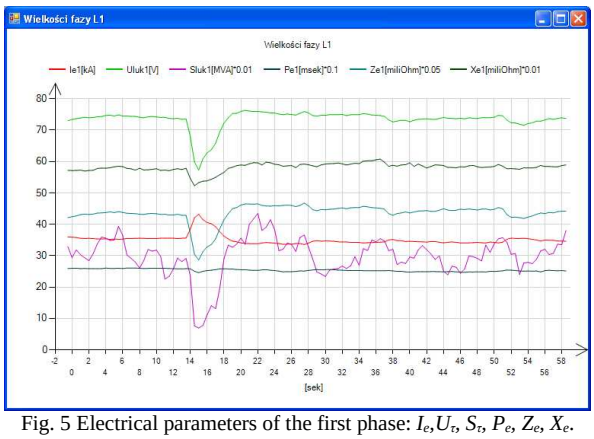


Fig. 5 Electrical parameters of the first phase: I_e,U_τ, S_τ, P_e, Z_e, X_e.

The dynamical state of the electric arc burning under each electrodes is shown in Fig .4 in form of hysteresis curves. Based on the recorded waveforms, an identification of other parameters of the arc and the current path have been done using specifically for this purpose software written in C #.

Recorded waveforms are consistent with the waveforms recorded in the plant measurement system of the furnace. Confirmed operating states (asymmetric and symmetric) are discernible in the waveforms of voltages and currents.

III. CONCLUSION

Identification of the parameters of the arc has been done for each period of the waveforms of the arc current and voltage. The shape and the slope are parameters which determine the power of arc. This parameter should be significant in the process of smelting of the ferrosilicon. Derivatives of the currents of electrodes needed to identify the parameters of the arc have been determined after an application of elementary methods of signal processing. However, it seems that application of Rogowski coils would be better and it would better identify the parameters of the arc furnace.

IV. REFERENCES

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