Causes of the appearance of current waves in high voltage electric arc furnaces, and methods of their reduction

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Abstract. This article presents a method of generation and reduction of current waves in high-voltage electric arc furnaces in industrial and mining enterprises, in contrast to existing methods. The developed method is currently relevant for the solution of problems related to the generation of current waves during the operation of high-voltage electrics are furnaces with a power of 3 MWt used in the melting and pouring of metals of different densities at the Navoi mechanical engineering plant. The main goal of implementing the developed method is to reduce the electric energy consumption of high-voltage electrics arc furnaces and to increase the efficiency of electric energy consumption of the furnace.

1 Introduction

Currently, high-voltage electrics arc furnaces are widely used in the melting and casting of metals in the leading countries of the world. Also, more than 60% of the electricity consumption in large power-consuming industries and mining enterprises falls on high-voltage electric arc furnaces. we can see this indicator in the example of the Navoi mechanical engineering plant (Figure 1).

As it can be seen in Figure 1, more than 60% of the electricity consumption of the Navoi Machine-Building Plant is consumed by high-voltage electric arc furnaces. Therefore, reducing the electric energy consumption of high-voltage electric arc furnaces and increasing their efficiency is one of the significant problems of today [1]. High-voltage electric arc furnaces reduce the resistance of metal deposits when melting metals of different densities. As a result of this, the increase in current waves leads to the operation of protective devices, an increase in the melting time, a change in other parameters in the power chain, an increase in the constant current of the circuit, a decrease in the electrical energy efficiency of the device [2].

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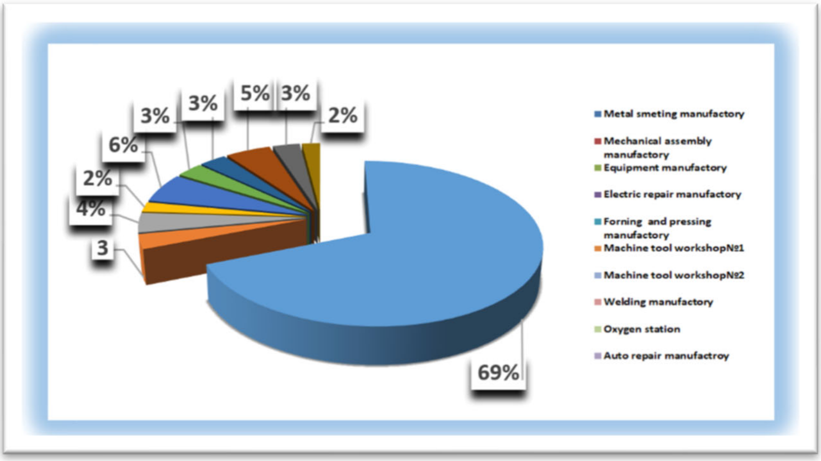

Fig 1. Indicators of electricity distribution of the Navoi machine-building plant.

The following factors cause the appearance of current waves:

- when electric arcs are generated in the electrodes, current waves appear due to a sudden change in the value of variable parameters in the electric circuit.
- current waves appear because of the use of measuring devices with less sensitive parameters in the circuit of the control block.

To prevent such problems occurring in the working processes of high-voltage electric arc furnaces, it is desirable to develop methods of reducing the current waves that appear in them [3].

2 Materials and methods

Nowadays, in high-voltage electric arc furnaces, as a result of the increase in current waves and the influence of signals, the device's electrical energy efficiency decreases.

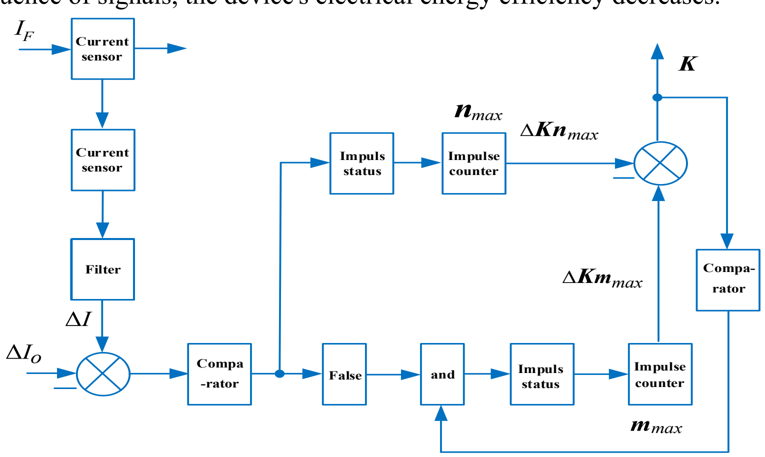

Fig. 2. Structural diagram of the contour coefficient control system.

Therefore, as a solution to the problems related to the power consumption modes of high-voltage electric arc furnaces, it is desirable to automatically control their operating modes and reduce current surges. As we know, overshooting and undershooting of current surges occurring in high-voltage electric arc furnaces depends on its contour coefficient [4]. Therefore, we created the structural scheme of the control system of the contour coefficient (K) of high-voltage electric arc furnaces based on the Proteus program (Figure 2).

From Figure 2, we can see that the structural scheme of the high-voltage electric arc furnace control system includes a two-contour controlled cycles:

- Current stabilization circuit. The current stabilization circuit consists of the general control system, shock-free ignition of block arcs and operating modes in the output block.
- Contour under pressure of current fluctuations. The circuit under pressure of current fluctuations consists of a block of smoothing current waves under pressure and filtering various signals [5].

The two-contour control cycless described above switch high-voltage electric arc furnaces to shock-free ignition modes, and the current consumed by the furnace is measured using a xolla sensor. The signal received from the xolla sensor is transmitted to the vibration sensor. The signal received from the vibration sensor is filtered and compared with the maximum permissible level values of the current waves ΔI_o. If this signal exceeds ΔI_o, then the comparator starts, and the pulse shaper starts, the value with the adder counter decreases step by step by the coefficient *Ko* until the moment $\Delta I_o > \Delta I$ or the steps reach the number n_{max} [6]. If, as a result of these actions, the level of oscillations decreases until the condition $\Delta I_o > \Delta I$ is fulfilled, then the comparison changes its state and the activating signal moves to the second element of *"I",* according to the condition of the permissible signal $K<Ko$. The "I" element activates the circuit and starts increasing the value of the "pulse shaper - counter" *(K)* [7]. An algorithm for controlling the contour coefficient in high-voltage electric arc furnaces is presented (Figure 3).

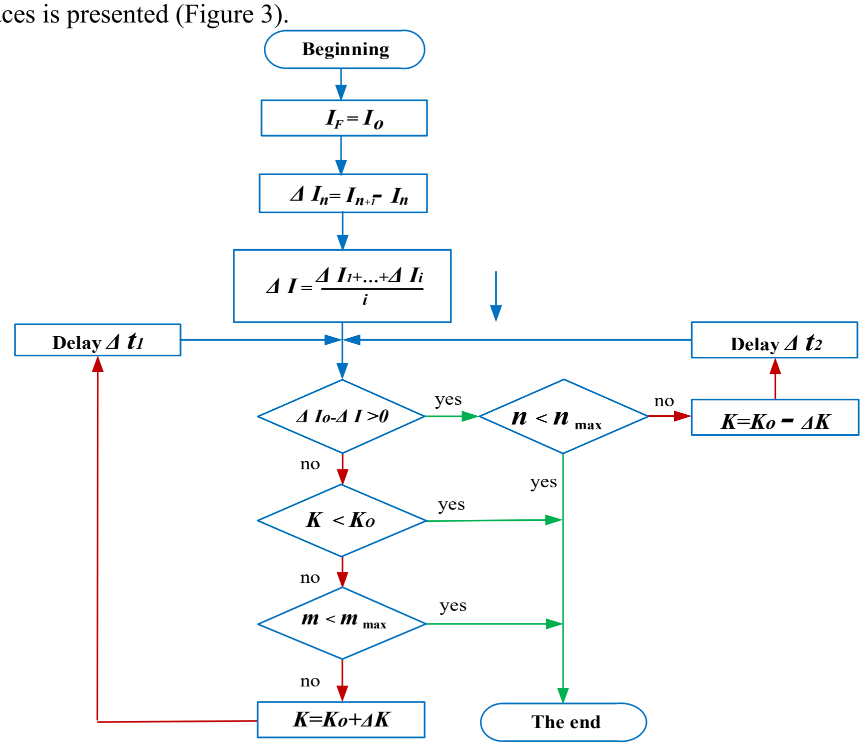

Fig. 3. Contour coefficient control algorithm.

The working principle of the structural scheme of the contour coefficient control system under pressure is explained through this developed algorithm [8]. In the structural scheme (Figure 2) we included current fluctuations in the contour under pressure (Ko) (Figure 4).

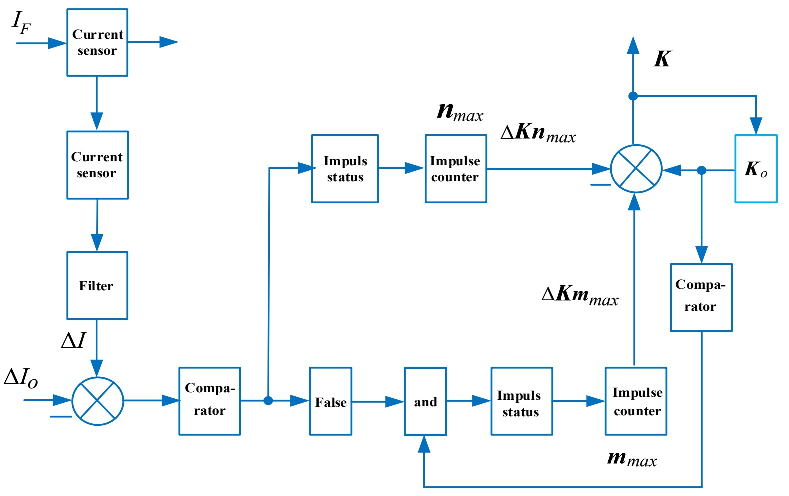

Fig. 4. Structural scheme of the pressure control system of the contour coefficient.

From Figure 4, we can see that by introducing the contour coefficient (K_o) into the structural scheme of the control system under pressure in high-voltage electric arc furnaces, it is possible to partially compensate for the changes in the contour parameters that occur during the melting of various metals, to prevent the appearance of current waves, frequency increases [9].

It is noted that when high-voltage electric arc furnaces work, regular waves appear than frequency f_1=2-10 Hz, which negatively affects the electrical energy performances of the furnace and increases power consumption.

The installed full power (P_Σ) for high-voltage electric arc furnaces is calculated based on the following formula:

$$P_\Sigma = P_{arc} + \Delta P_{pd} + \Delta P_{pc} \quad (1)$$

where (P_{CAP}) is the cumulative arc power; (ΔP_{pd}) -power drop in resistance; (ΔP_{pc}) power in current conductors [10].

When waves occur in the current, losses occur in the smoothing resistance, which depends on the resistance material, the effective value of the alternating current component, and the frequency of the oscillation.

$$P_{pd} \approx (K_1 f + K_2 f^2) I^2 \quad (2)$$

where K_1 and K_2 are coefficients, determination of material and construction resistance; I – current values of current waves [11].

3 Results and discussion

Current waves in high voltage electric arc furnaces cause increased power dissipation and reduced furnace power. It can be seen from formulas 1 and 2 that with an increase in frequency and current waves, the electrical energy efficiency of the device decreases [12].

As a result of the control of the circuit coefficient, we managed to reduce current surges and improve electricity consumption.

It is observed that the increase of current waves, the change of the contour coefficient occurs as a result of the influence of signals. The results of the modeling of the two-circuit current system in high-voltage electric arc furnaces are presented in the signal form of the circuit coefficient (K) in Figure 5, the nominal value, in Figure 6, the halved value, and in Figure 7, the doubled value.

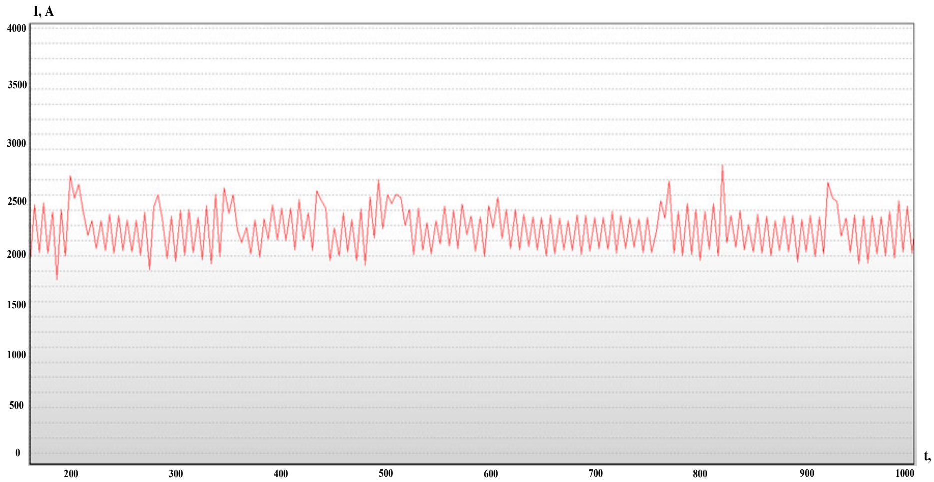

Fig. 5. Current diagram of high-voltage electric arc furnaces in a two-contour system $K = K_n$.

Figure 5 shows the current diagram of the circuit coefficient in two-contour system, where the change of current waves in the value of the circuit coefficient ($K = K_n$), i.e., increase or decrease, did not change significantly, did not affect the current form.

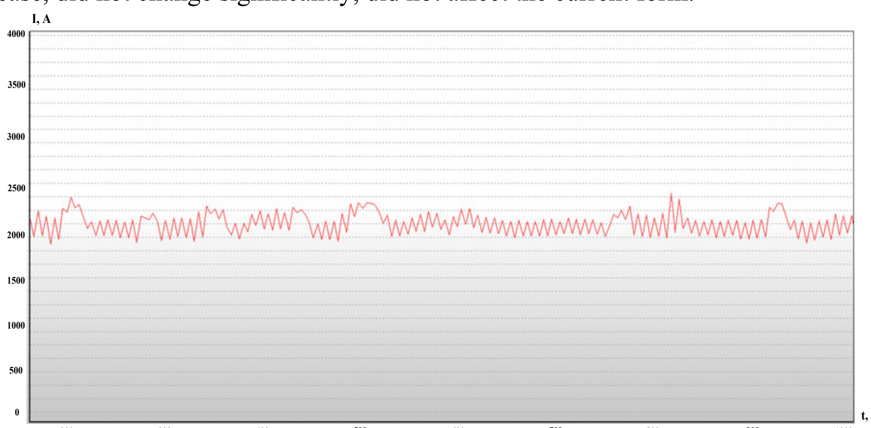

Fig. 6. Current diagram of high-voltage electric arc furnaces in a two-contour system $K = 0{,}5K_n$.

Figure 6 shows the current diagram of the circuit coefficient in a two-contour system, where it is shown that the change of the current waves at the value of the circuit coefficient ($K = 0{,}5K_n$), that is, the reduction, did not affect the current form.

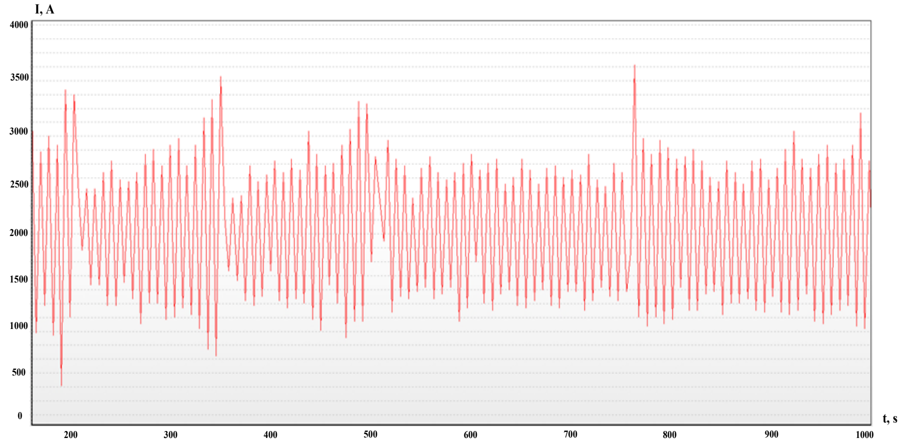

Fig. 7. Current diagram of high-voltage electric arc furnaces in a two-contour system $K = 2K_n$.

Figure 7 shows the current diagram of the circuit coefficient in a two-contour system, where the change of the current waves at the value of the circuit coefficient ($K = 2K_n$), that is, increase, leads to an increase in the electrical energy consumption of the device.

Figure 8 shows the results of the modeling of the single-circuit current system in high-voltage electric arc furnaces with the circuit coefficient (K_o) as a signal under pressure.

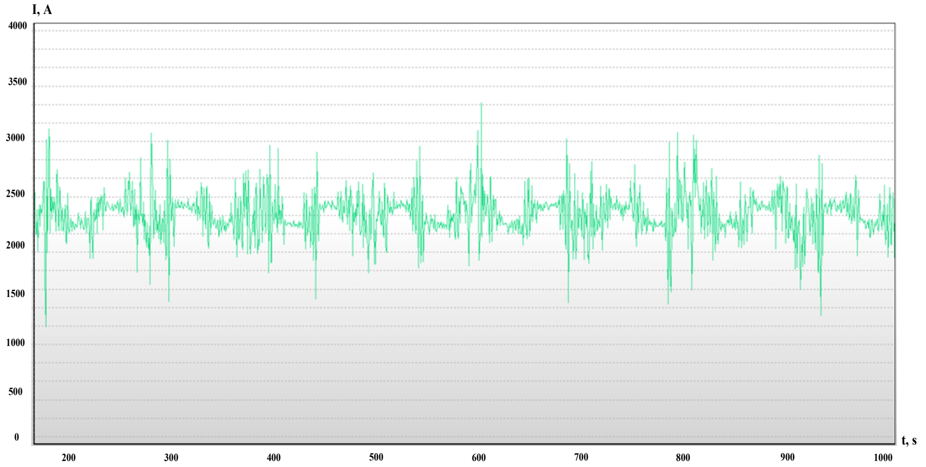

Fig. 8. Current arc diagram of pre-rectified system in high voltage electric arc furnaces.

As a result of modeling the contour current system in high-voltage electric arc furnaces, by using the contour coefficient (Ko) oscillation scheme under pressure, we managed to prevent the appearance of current waves, frequency overshoot.

High voltage electric arc furnaces reduce resistance on metal surfaces during melting of metals of different densities [13]. As a result, the efficiency of the device decreases, and the demand for electricity increases. Figure 9 shows the distribution of electric current during melting of metals in high-voltage electric arc furnaces.

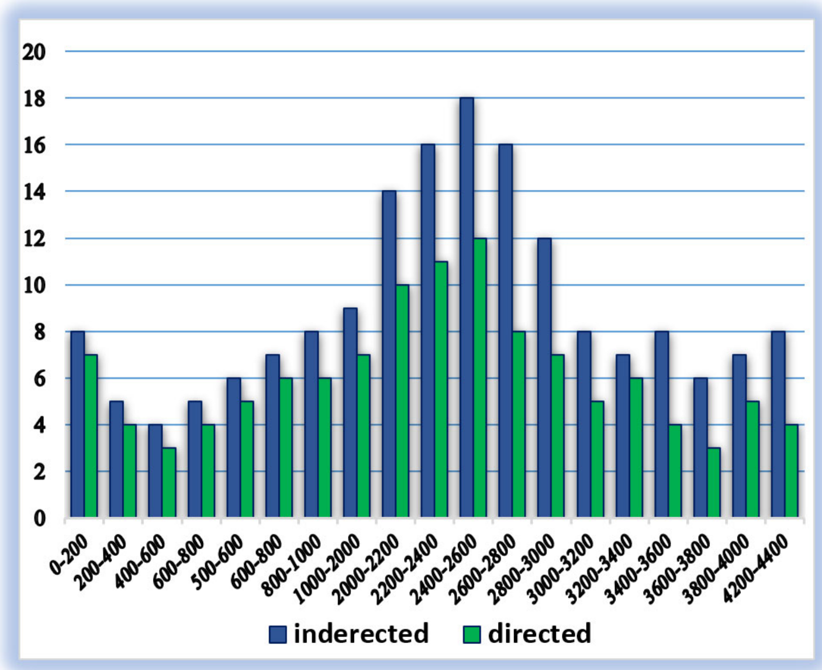

Fig. 9. Diagram of electric current distribution during melting of metals in high-voltage electric arc furnaces.

In Figure 9 the values of electric current during melting of metals in high-voltage electric arc furnaces are shown on the abscissa axis, and on the ordinate axis, the uncorrected value of electric current is shown in percent in blue and the corrected value in green [14]. The difference between the blue and green bars indicates the percentage correction of the current.

As a result of the occurrence of current waves in high-voltage electric arc furnaces and the use of their reduction method, we had the opportunity to correct the value of electric current during melting of metals.

4 Conclusion

The electric energy consumption of the high-voltage electric arc furnaces constructed in this way was analyzed, based on the results of the analysis, the development and implementation of new measures to reduce the electric energy consumption without changing the mass of molten metal were justified.

Based on this, in this article, the reasons for the occurrence of current waves occurring in the process of metal melting of high-voltage electric arc furnaces were studied, methods for their prevention were developed, and experimental studies were conducted and results were obtained. The obtained results are positive, therefore, if this developed method is put into practice, it will be ensured that the harmonic changes in the line of current waves in the working processes of high-voltage electric arc furnaces, i.e., during metal melting, will not affect other consumers, as a result of which the service life of other consumers will be extended. In addition, when melting metal, it is possible to reduce the melting time without changing the mass of the metal, increase the electric energy efficiency of the furnaces, and save electricity and resources.

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