ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 6, Issue 9 , September 2019

Optimization of Electric Modes of Modern Arc Steel-Smelting Furnaces with Static Thyristor Compensator

Jumaev Odil Abdujalilovich, Ramil Rashidovich Sayfulin, Khalilov Utkirbek Inoyatullayevich

Associate Professor, Automation Faculty, Navoi State Mining Institute, Navoi,Uzbekistan
Assistant Professor, Automation Faculty, Navoi State Mining Institute, Navoi,Uzbekistan
Graduate Student, Automation Faculty, Navoi State Mining Institute, Navoi,Uzbekistan

ABSTRACT: The article discusses the basic principles of optimizing the electrical modes of modern arc steelmaking furnaces with a static thyristor compensator (STC). The proposed STK model is made scalable in terms of the number of filter-compensating circuits (FCC) and thyristor-reactor groups used. One of the options for implementing an adaptive PI controller is presented in which, using the feedback circuit, both the dynamic characteristics of the thyristor that affect the moment of switching on the FCC and the reactivity of the statism X_s,, STC, which determines the regulation angle of the thyristor-reactor group (TRG), are taken into account.

KEY WORDS: Static thyristor compensator, voltage transformer, reactor, mathematical model, STK control system, arc steel-smelting furnace.

I.INTRODUCTION

In electric arc furnaces, the conversion of electric energy into heat takes place in an electric arc and the heat generated in this case is transferred to the metal either by radiation (indirect action, the arc burns between the electrodes), or directly due to thermal conductivity (direct heating, the arc burns between electrode and metal). They are the main units providing smelting of high-quality alloy steels and alloys.

II. SIGNIFICANCE OF THE SYSTEM

Successes in the development of energy conversion technology, the emergence of high-power direct current sources, and the achievements of the refractory industry, which ensured the high stability of the hearth in which the hearth electrode is mounted, led to the creation of a number of successful arc steel-smelting furnaces designs .

III. LITERATURE SURVEY

In the process of melting metal in an arc steel furnaces, it is necessary to adjust the power of the arcs by changing the amount of energy introduced into the furnace [1]. The active power of the arcs in arc furnaces is regulated by changing the secondary voltage of the furnace transformer, and at constant voltage by changing the current in the electrical circuit of the furnace. To maintain a given value of the phase current and, accordingly, the arc power, an automatic electrode movement system is used. The control system for the electrical mode of the arc steel furnaces, as a rule, is a two-level one.

IV. METHODOLOGY

At the second higher level, the melting stages are identified, and on it - the selection of the corresponding working curve, the steps of the transformer and reactor, which form the task for the lower level system. The input signals of a typical control system are: the number of the melting profile, determined by the initial composition of the charge, and the amount of electricity introduced into the furnace from the beginning of the melting. The movement of the electrodes is controlled by a system that includes a nonlinear proportional-integral controller operating in the mode of maintaining impedance (in the initial stages) and maintaining the active resistance of the arc (in the final stages). In fig.

1 is a block diagram describing the classical problem of optimizing the electrical modes of modern arc steel-smelting furnaces [2]. Two main stages can be distinguished here:
1) setting the melting program (profile);
2) setting the parameters of the electrode movement control system.

At the first stage, the selection of the optimal electrical characteristics of the arc steel-smelting furnaces for each melting stage is performed by setting the steps of the transformer and reactor. After that, the optimal working curve is selected that determines the position of the working point on the electrical characteristics of the arc steel-smelting furnaces $(P_c = f(I_c))$.The most important step in setting the profile setting system is to determine the boundary values of the parameter responsible for the transition from one melting stage to another. As such a parameter, as a rule, the power consumption W_Σ, measured on the secondary side of the furnace transformer is used.

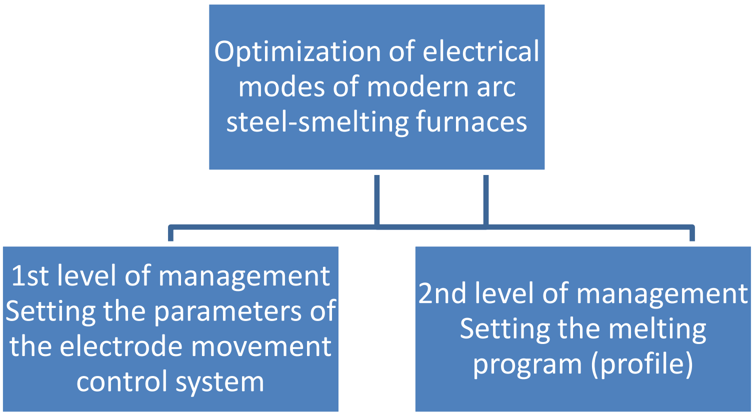

Fig. 1. The task of optimizing the electrical modes of modern arc steel furnaces

At the second stage, the parameters of the electrode movement control system are adjusted. This process can be divided into three stages. At the first stage, they calculate and set the optimal values of the variables by which the operating point is maintained on the electrical characteristic. They can be: impedance or conductivity of the arc steel-smelting furnaces phase on the secondary side of the transformer, arc resistance, voltage, power or arc current. At the second stage, optimal dynamic indicators of the quality of regulation of the system are achieved by setting the correct values of the coefficients of nonlinear proportional-integral regulators.

At the last stage, the operation of auxiliary systems is optimized. It should be noted that not all of these optimization problems can be solved by simple workshop specialists, since the existing control systems supplied by foreign manufacturers have a closed structure of functional blocks, which makes it difficult to correct and optimize the electrical modes of the arc steel-smelting furnaces taking into account local conditions and technological features.
As mentioned earlier, most existing control systems use the energy consumption W_Σ as the main parameter for the transition from one stage of smelting to another. Thus, the urgent task is to develop an improved control system for the electrical mode of the arc steel furnaces, in which the transition from one stage of melting to another would be carried out using a parameter that most accurately reflects the current technological stage.

Much attention is paid to energy saving and the quality of electricity, which is especially important for energy-intensive consumers such as electric arc furnaces. One of the important problems in the operation of electric arc furnaces is the asymmetry in the distribution of the arc power in phases, which leads to accelerated wear of the lining and a decrease in the average furnace power. Depending on the cause of the asymmetry, it is divided into [3]:

- structural, caused by the asymmetry of the shape of the short network or the unequal parameters of the wires. The mutual inductance and reduced active resistances are different for each phase;
- operational, caused by the instability of arcing and frequent collapses, and displacements of the charge, especially during the melting period, as a result of which the currents of individual phases change from zero (arc break) to the operational short circuit current.

The asymmetry of the load of the arc steel furnace causes the appearance of voltage asymmetry on the substation tires of power systems, which worsens the quality of electricity and leads to a decrease in the efficiency of the efficiency of both electric furnaces and consumers that are powered by substation buses shared with it.

In the design and operation of electric arc furnaces, it becomes necessary to calculate the asymmetry of currents and voltages both for selecting power supply schemes and for developing measures for balancing the operation of furnaces.

To achieve this goal, the following tasks were solved:
- analysis of various types of short networks and revealing the nature of their asymmetry; possible ways to eliminate structural and operational asymmetries;
- development of a mathematical model for calculating the asymmetry of currents, voltages and power transfer in phases in the current supply system of three-phase arc electric furnaces.

Accounting for asymmetry allows you to comprehensively evaluate the processes when changing the mode and select the best energy mode, to obtain more reliable results.

The inclusion in the electrical circuit of the furnace reactance of a short network significantly affects the electrical characteristics of the furnace and leads to the loading of its sources of high reactive power.

Calculations and analysis of asymmetric operating modes of the furnace are necessary to solve many practical problems: analysis of the operation of automatic power controllers, choosing the best control parameter and creating the most advanced type of controller; selection of an appropriate short network design and development of measures to maintain equal capacities of all phases of the furnace; setting relay protection and automatic furnace regulators, checking their sensitivity for various types of asymmetric short circuits; analysis of furnace performance.

In the well-known classical methods of calculating three-phase asymmetric circuits, the resistance of each phase is assumed to be constant, independent of the current. The application of these methods for calculating asymmetric circuits with arcs in which not the resistance of the arcs, but the voltage across the arcs is constant, is impossible.

The design circuit of the circuit is shown in Fig. 2.

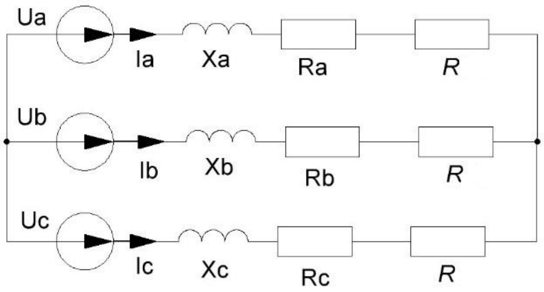

Fig. 2. The design scheme of the asymmetric circuit of an arc steel furnace:

U_a, U_b,U_c- phase open-circuit EMF of the low voltage windings of the transformer;
$Z_a = R_a + jx_a; Z_b = R_b + jx_b; Z_c = R_c + jx_c$- intrinsic resistance of the current lead;
$R \quad (R_{da}, R_{db}, R_{dc})$ – resistance of arcs of each phase of the furnace.
for this circuit, one can write the following equations according to the second Kirchhoff law:

$$I_a = \frac{U_a - U_{oo}}{Z_a} = (U_a - U_{oo})Y_a$$
$$I_b = \frac{U_b - U_{oo}}{Z_b} = (U_b - U_{oo})Y_b \quad (1)$$
$$I_c = \frac{U_c - U_{oo}}{Z_c} = (U_c - U_{oo})Y_c,$$

where $I_a; I_b; I_c$- currents in the phases of the circuit; $Y_a; Y_b; Y_c$- conductivity in the phase branches; U_{oo}- voltage neutral offset.

In addition, for a three-wire three-phase circuit, the following relation holds:

$$I_a + I_b + I_c = 0. \quad (2)$$

The schemes of the “star-delta”, “delta-star” and “delta-triangle” type in the calculations are given by converting the active or passive triangle into an equivalent “star-star” scheme (Fig. 2).

Consider the case when it is necessary to ensure the same mode of operation of the furnace in current in phases. From the system of equations (1) and (2) we express the currents in phases through the input voltage and circuit resistance. We introduce the following parameters:

$$Z = Z_a Z_b + Z_a Z_c + Z_c Z_b, \quad (3)$$
$$R_d = R_{da} R_{db} + R_{da} R_{dc} + R_{dc} R_{db}, \quad (4)$$
$$ZR = Z_a R_{db} + Z_a R_{dc} + Z_b R_{da} + Z_c R_{da} + Z_b R_{dc} + Z_c R_{db}, \quad (5)$$

Solving equations (1) - (5) together, we obtain the following system:

$$I_a = \frac{Z_b U_a + R_{db} U_a + Z_c U_a - Z_c U_b + R_{dc} U_a - R_{dc} U_b - Z_b U_c - R_{db} U_c}{(Z + R_d + ZR)},$$
$$I_b = \frac{-Z_c U_a - R_{dc} U_a + Z_c U_b + Z_a U_b + R_{dc} U_b + R_{da} U_b - Z_a U_c - R_{da} U_c}{(Z + R_d + ZR)}, \quad (6)$$
$$I_c = \frac{-Z_b U_a - R_{db} U_a - Z_a U_b + Z_a U_c - R_{da} U_b + R_{da} U_c + Z_b U_c + R_{db} U_c}{(Z + R_d + ZR)}.$$

This system of equations allows you to calculate the circuit (Fig. 2) relative to the currents in the phases of the circuit.

V. EXPERIMENTAL RESULTS

According to these formulas, we calculate the arc resistance in each phase. Next, check the calculated resistance value with the previous value. If the difference is less than the permissible error, we exit the resistance test cycle. We write the result into a prepared array of results. Next, we calculate the arc resistance for the next value of the circuit current. Calculation of symmetric modes of operation by power, voltage and arc resistance occurs according to a similar algorithm.

Used in the metallurgical industry, arc steel-smelting furnaces (SMF) are characterized as receivers with a rapidly changing load. In the process of their work, the generation of higher harmonics currents, a significant voltage asymmetry, and reactive power surges are observed. These phenomena lead to voltage fluctuations in the supply networks, which negatively affects the work of other consumers of electricity, as well as the operation of the arc furnace itself. The use of static thyristor compensators (STC) allows you to increase the throughput of power lines, limit temporary overvoltages, reduce losses, improve the sinusoidality of the voltage curve in various network operation modes. Filter-compensated circuits (FCCs) configured in a specific way allow you to compensate for higherorder harmonics. The generation of reactive power in the FCC is discrete, therefore, to obtain a smooth regulation of the reactive power, the thyristor-reactor group (TRG) is used together with the FCC.

In addition, the use of TRG can increase the stability of the system and dampen power fluctuations. The parameters of the system in the STC are regulated in phases, thereby balancing the system.
In fig. 3. A functional diagram is given in accordance with which the STC is controlled.

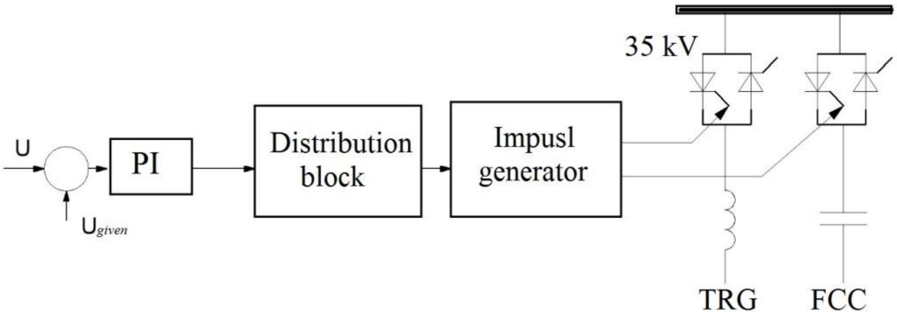

Fig. 3. Functional control circuit STC

The level of reactive power compensation is determined by the voltage amplitude, which is compared with the reference value and with the help of the PI controller, a correction signal is generated that arrives at the TRG and the FCC.

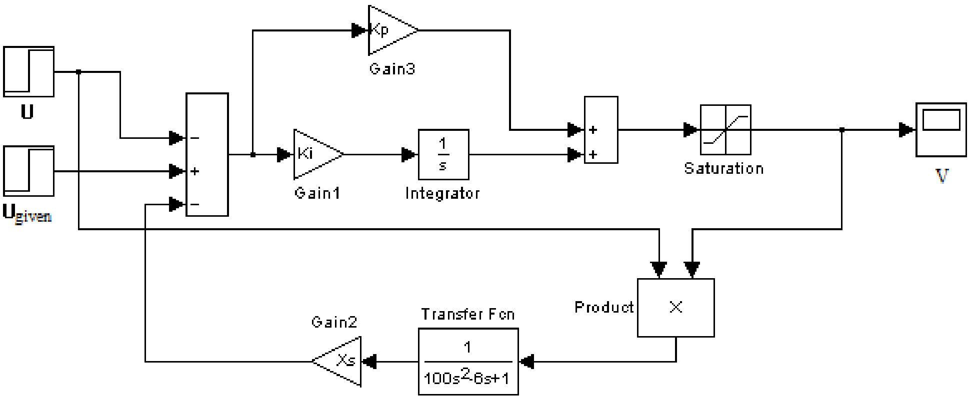

Fig. 4. The block diagram of the PI voltage regulator

As a result, the required level of voltage stabilization is achieved. The distribution unit performs the function of dividing the control signal to turn on the corresponding FCC and selecting the required angle of regulation of the TWG. The determination of the parameters of the PI controller by the classical method is difficult due to the fact that their variation strongly depends on the operating modes of the arc furnace.

The determination of the parameters of the PI controller by the classical method is difficult due to the fact that their variation strongly depends on the operating modes of the arc furnace.
It was shown in [4] that even for the simplified STC model, which takes into account more than 100 possible combinations of switching the reactor and furnace transformer, the system of equations of electric and nonlinear circuits turns out to be very complex and difficult to implement in practice.

One of the options for implementing an adaptive PI controller is shown in Fig. 4. In this controller, using the feedback circuit, both the dynamic characteristics of the thyristor affecting the moment of switching on the FCC and the reactance of the statism X_s, STC, which determines the angle of regulation of the TRG, are taken into account.

VI.CONCLUSION AND FUTURE WORK

Using the proposed model of a power supply system for the arc steel-smelting furnaces in the presence of an STC makes it possible to evaluate the impact on the quality indicators of the electric network of the parameters and operating modes of the arc steel-smelting furnaces, as well as to take into account its own characteristics of the network that affect the control algorithms of the STC.

The weakening of the effect of the non-stationary parameters of the chipboard on the quality indicators of the supply network can be achieved by constructing the STC control system based on modern microprocessor technology.

REFERENCES

[1] Kochkin, V.I. The use of static reactive power compensators in electric networks of power systems and enterprises / V.I. Kochkin, O.P. Nechaev. - Moscow: Publishing House NTs ENAS, 2002 .-- 248 p.
[2] Hingorani, Narain G. Understanding FACTS: concepts and technology of flexible AC transmission systems / Narain G. Hingorani, Laszlo Gyugyi. - New York: IEEE PRESS, WILEY INTERSCIENCE, 2000 .-- 428 p.
[3] Mathematical description of complicated power supply systems / V. Soloviov, A. Kupov, K. Khandoshko, A. Kupova // Proc. 11th Int. conference "Electrical machines, drives and power systems ELMA 2005. - Sofia, 2005. - 487-490 pp.
[4] Materials of the VI International scientific and technical conference: Modern equipment and technologies of the mining and metallurgical industry and ways of their development. Kim V.I., Zhumaev O.A., Ruziev T.D. Automated control system for an arc steel furnace. Navoi, 2013 489-490 pp.