SIMULATION OF ELECTRIC CIRCUIT AS A STAGE IN DEVELOPMENT OF POWER SOURCE WITH CONTROLLABLE SHAPE OF ALTERNATING CURRENT

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The paper shows the effectiveness of simulation of electric circuit for power sources of alternating current of a controllable shape at evaluation of output power characteristics and methods of their regulation.

Keywords: *arc welding, power sources, alternating current, simulation, current of a controllable shape*

Welding electrical equipment at present time is designed based on up-to-date element base allowing obtaining the characteristics of power supplies which provide increase of the quality of welded joints with simultaneous improvement of the economic factors. However, achievement of these goals is related with complication of hardware and functional constituents of developed equipment. It requires a development of special electric regulation systems, performance of complex mathematical calculations for selection of that or another elements of the electric circuit and construction of expensive physical models.

Such tasks can be solved with the help of modern packages for mathematic and simulation modelling [1] with a less labor content and higher efficiency. These packages were used during development of the electric circuits for power supplies of alternating current of a controllable shape. Study [2] showed that control of the shape of direct and reversed polarity current is very perspective, since it allows performing alternating current MIG/MAG welding of high strength steels and aluminum preserving high indices of the mechanical properties of deposited metal. It was also noted that elimination of chemical elements is smaller in comparison with direct current welding.

Some circuits of investigated alternating current supplies are given below. In the first circuit, a diode bridge, consisting of $VD1$–$VD4$ diodes with inductance $L1$ in its diagonal [4], is connected in series with secondary winding of transformer $T1$ instead of thyristor bridge [3] in contrast to existing developments. A regulator consisting of two thyristors of opposite-parallel connection $VS1$, $VS2$ and resistor $R1$ is connected to primary winding circuit of the transformer.

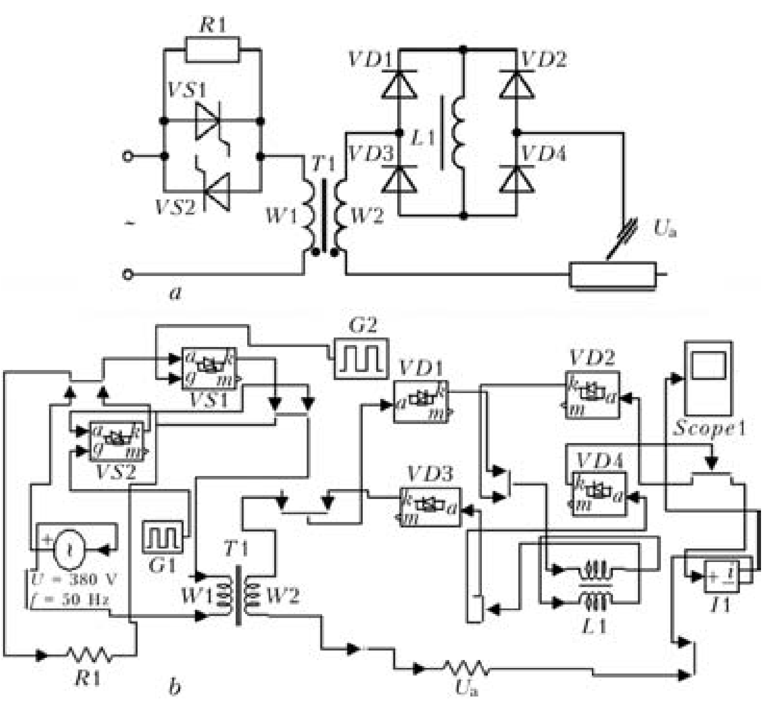

Figure 1. Electric circuit of the power source of alternating current of the controllable shape (*a*) and its simulation model with recording devices *I*1, *Scope*1 and pulse generator (*b*)

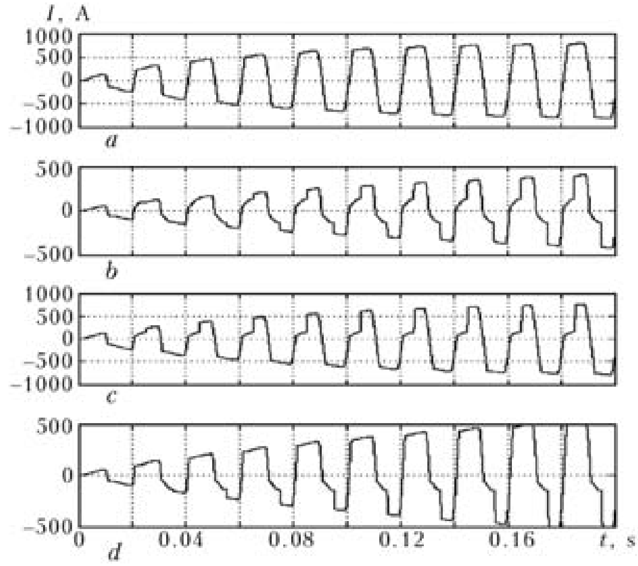

Figure 2. Oscillograms of load current of the power source (see Figure 1, *b*) obtained at different values of control pulse phases by thyristors *VS*1 and *VS*2: *a* — 0 and 0.010; *b* — 0.005 and 0.015; *c* — 0.005 and 0.010; *d* — 0 and 0.015 s

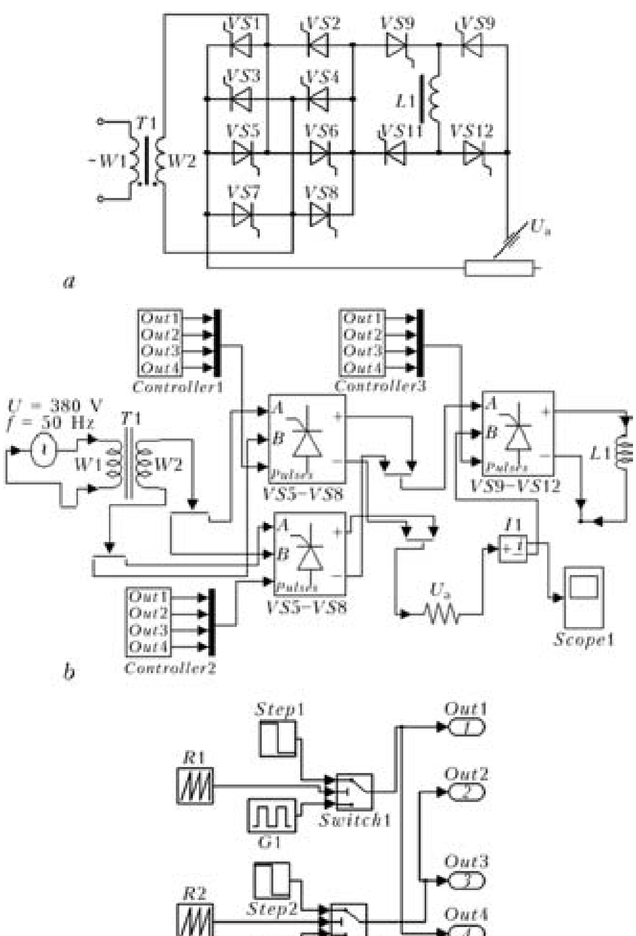

Figure 3. Electric circuit of the power source of balanced and unbalanced alternating current of low frequency (*a*) and simulation models of given power supply (*b*) and block of phase regulation *Controller* (*c*)

Here and in further circuits a load (arc) is represented by linear element, i.e. pure resistance.

Regulation of load current output is carried out on the primary circuit of a reducing transformer in which current is in several times lower than in the secondary circuit. Such an approach significantly widen power capabilities of power supply and allows applying it for arc welding as well as for electroslag technologies at current value of 10 kA and higher. At that the power supply has higher reliability and relatively small price. Pulse generators *G*1 and *G*2 for phase regulation by *VS*1 and *VS*2 thyristors, current meter *I*1 and oscillograph *Scope*1 are used in the simulation model (see Figure 1, *b*), developed in MATLAB package. Such parameters as inductance of choke-accumulator *L*1, impedance of resistor *R*1, connection time of thyristors *VS*1, *VS*2 were varied in significantly wide ranges during simulation process for obtaining welding current of necessary shape and rate of its rise at polarity change. The oscillograms, given in Figure 2, showed the possibility of providing load current integrity and relatively high alternating rate as well as obtaining of different shapes of current of direct and reversed polarity in operation from the power supply (see Figure 1, *a*).

The second circuit (Figure 3, *a*) is a basis of power part of the source of balanced and unbalanced alternating current of low frequency [5]. Preliminary investigations of submerged-arc welding showed that reduction of frequency of welding current up to 12–16 Hz has positive effect on structure of deposited weld metal. Such welding is carried out from the power supply with a discrete regulation of current frequency and independent regulation of duration of its half cycles based on the thyristor regulator. It is built only on two bridge circuits which are switched to the secondary winding of power transformer [6]. This indicate a relationship between the welding current frequency, weld pool free oscillation frequency and technological indices of welding quality. However, presence of welding current ripple with 100 Hz frequency at two or more half cycles, forming that current, is characteristic for the electric circuit of such power supply. The third thyristor bridge *VS*9–*VS*12, having choke-accumulator *L*1 in its diagonal, is connected to output of double-bridge regulator *VS*1–*VS*4 and *VS*5–*VS*8 for reduction of current ripples. The regulation of frequency of welding current is performed similar to the scheme of work [6], namely, through development of positive and negative polarity pulses of determined duration and their modulation.

It should be noted that the duration of pulses of direct and reversed polarity current can be regulated independently in a wide range that significantly increases efficiency of modulation mode.

Simulation model of given power source, shown in Figure 3, *b*, contains three controllers *Controller* 1–3, designed for phase regulation of duration of direct

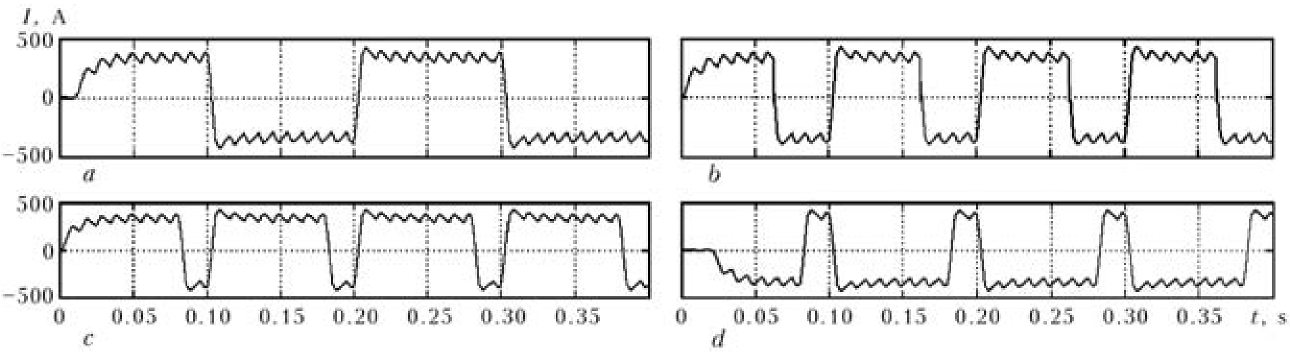

Figure 4. Oscillograms of balanced (*a*) and unbalanced (*b*) alternating current of low frequency obtained at different values of pulse duration of load current of reversed and direct polarity: *a* — 0.1 and 0.1; *b* — 0.08 and 0.02; *c* — 0.06 and 0.04; *d* — 0.02 and 0.08 s

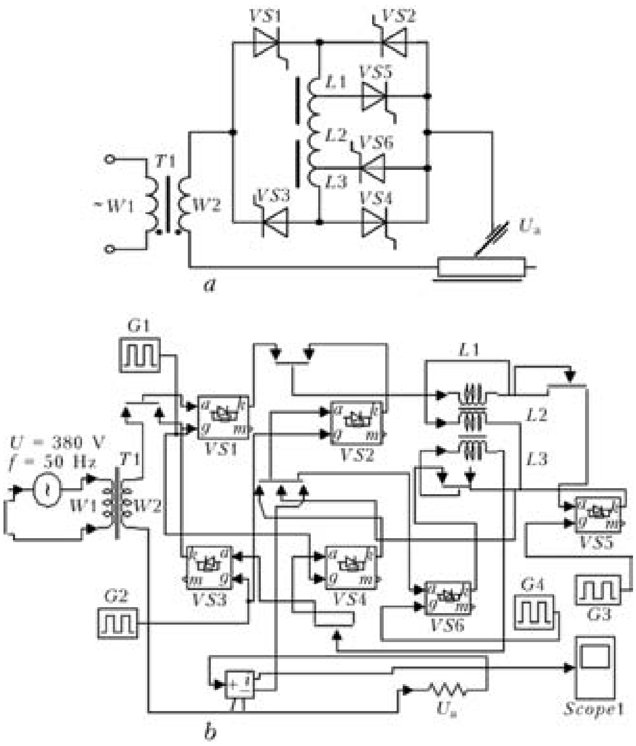

Figure 5. Electric circuit of the power source of alternating current of the controlled shape (*a*) and its simulation model with recording devices developed in MATLAB package medium (*b*)

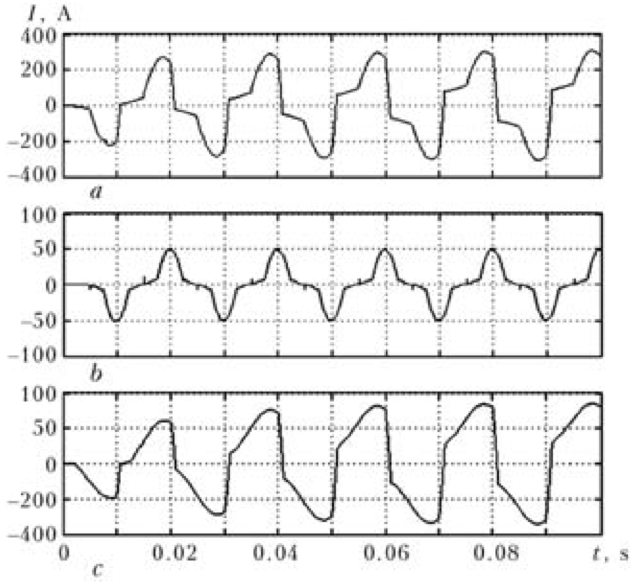

Figure 6. Oscillograms of load current of the controlled shape (see Figure 5, *b*) at different values of turn-on time of thyristors *VS*1–*VS*4, *VS*5 and *VS*6: *a* — 0–0.01, 0.05 and 0.0015, *b* — 0.005–0.015, 0.0075 and 0.0175; *c* — 0.0025–0.0125, 0.005 and 0.015 s

and reversed polarity current, as well as device for current measurement *I*1 and oscillograph *Scope*1 besides three thyristor rectifying bridges *VS*1–*VS*4, *VS*5–*VS*8, *VS*9–*VS*12 as in the basic electric circuit. The outputs *Out*1–*Out*4 of each controller (see Figure 3, *c*) are connected to controlling electrodes gates of thyristors *Pulses* of corresponding rectifying bridges. The regulation of duration of pulses of direct and reversed polarity current is carried out using given model, consisting of a generator of different shape signals *Step*, *R*, *G* and controlled switch of signals *Switch*. The oscillograms of load current, representing work of power supply in balanced and unbalanced modes, are shown in Figure 4.

The next example considers one of the variants of the power supply of alternating current of the controllable shape. The electric circuit of the power supply [7] and its model are shown in Figure 5. In this scheme two thyristors *VS*5 and *VS*6, linked to each other, are additionally connected to the output of the bridge by alternating current and part of choke winding together with transformer *T*1, thyristor bridge *VS*1–*VS*4 and choke *L*1 on its diagonal. This solution allowed controlling the values and shape of principal current, including rectangular one, as well as shape of the pulse which is superimposed on the principle current (Figure 6) using pulse generator *G*1–*G*4. Such a combined power supply increases performance of the whole system at transition processes that has significant importance in submerged-arc welding where a lag of power supply is the reason for osculation of mode parameters of welding process.

Therefore, the simulation during development of welding power supplies allows evaluating the capabilities of different circuits, various ways of regulation of power parameters and perspective of practical application, except for physical modelling.

1. Diakonov, V.P. (2005) *MATLAB 6/5 SP1/7/0 Simulink 5/6. Principles of application*. Library of Professional Series. Moscow: SOLOMON-Press.
2. Maxl, G., Posch, G. (2008) MAG-Wechselstromschweissen von hochfesten Feinkornbaustaehlen. *Schweiss- und Prueftechnik*, **3**, 35–38.

3. Zaks, M.I., Kagansky, B.A., Pechenin, A.A. (1988) *Transformers for electric arc welding*. Leningrad: Energoatomizdat.
4. Andreev, V.V., Efremenko, O.M., Zaruba, I.I. *AC power source of controllable shape for arc and slag technologies*. Pat. 47333 Ukraine. Int. Cl. B 23 K 9/10, 9/00. Publ. 25.01.2010.
5. Andreev, V.V., Moskovich, G.N., Zhernosekov, A.M. et al. (2008) Specifics of low-frequency AC arc welding. *Svarshchik*, **6**, 19–21.
6. Lebedev, V.K., Andreev, V.V., Moskovich, G.N. *Arc welding power source*. USSR author's cert. 1542721. Int. Cl. B 23 K 9/00, 9/10. Publ. 15.02.90.
7. Paton, B.E., Lebedev, V.K., Zaruba, I.I. et al. *Arc welding power source*. USSR author's cert. 1294523. Int. Cl. B 23 K 9/00. Publ. 07.03.87.

DEVELOPMENT OF METHODS OF ADAPTIVE CONTROL AND IMPORT REPLACING EQUIPMENT OF THE ORBITAL COMPLEXES FOR AUTOMATIC TIG WELDING OF POSITION JOINTS OF 89–219 MM DIAMETER PIPELINES DURING CONSTRUCTION AND REPAIR OF REACTORS OF NUCLEAR POWER PLANTS OF UKRAINE

(Innovation project of the NAS of Ukraine, realized in the E.O. Paton Electric Welding Institute)

Obtaining of the reliable data on arc current and voltage signals is very important during automatization of the processes of orbital arc welding (OAW). It is a well-known fact that OAW automatic machines operate under conditions of high level of electromagnetic fields which result in significant «noise» of signals in measurement and control channels. Different methods of increase of their stability are to be used for improving the quality of monitoring system. In the scope of this work it was proposed to use a method of wavelet transform for processing of initial sensor signals. In this case, reconstruction of measuring signals allows significantly improving a signal-to-noise ratio and thereby increasing quality of the OAW process control. The wavelet transform of time sequence of current and voltage signals lies in their decomposition according to base of determined functions with the help of scaling and transfer.

The wavelet transform provides a two-dimensional representation of signal in contrast to the Fourier transform. At that its frequency and time are the independent variables, i.e. there is a possibility to analyze the properties of the process in time as well as frequency areas. The task of optimum selection of the wavelet is not solved at present time. Therefore, the researchers are to solve it by means of selection of different variants of the mother wavelets. Haar, Morlet and Daubechies wavelets were used in solving the task of selection. The Daubechies wavelets of the 5th order provide the best metrological indecies as it was shown by solving the model problems using MATLAB package.

Welded tubular elements are widely used in manufacture of the reactors of nuclear power plants. One of the main factors, determining their reliability and serviceability, are the residual stresses (RS), originating in pipes during welding. It is considered that stresses on the base of their determination are to be constant and area of controllable surface of the object is flat during determination of the RS in welded elements using experimental methods. It was experimentally determined that a surface curvature in which the RS are investigated influences on an error during their determination. Therefore, a numerical experiment using finite-element method was made for evaluation of influence of the surface curvature on the error of determination of the RS. The results of numerical experiment and their analysis showed that the errors of RS calculation technique do not exceed 8 % in a pipe of 89 mm diameter.