ALL-PURPOSE POWER SOURCE FOR ARC WELDING AND PLASMA CUTTING

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A new design of an all-purpose inverter current source is considered for mechanical processes of arc welding and surfacing of steels and aluminium alloys. The source features the capability of fast and controllable setting of many parameters of the welding process and regulation of any appearance of external static volt-ampere characteristics and dynamic properties, as well as realization of pulsed modes in a wide range.

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At present both traditional rectifiers and inverter power sources are used in welding fabrication. Sources with adjustable thyristor-type rectifiers or inadjustable rectifiers will still be in demand in the market for a long time, owing to a comparative simplicity, reliability and relatively low price. They can be used in modern efficient welding processes, for instance in the method of welding with forced short-circuiting (FSC) developed by ITS and SELMA companies (RF–Ukraine) [1]. At present inverter power sources of varying degrees of complexity are ever more intensively introduced into welding fabrication. For sound performance of welding-surfacing operations, achievement of a high efficiency and fulfilling the objectives of energy- and resources saving, the users will select exactly such power sources.

Two tendencies can be outlined in inverter power source design. The first is aimed at lowering of weight and dimensional characteristics of the equipment and improvement of its efficiency [2], and the second tendency is aimed at realization of electrode metal transfer control [3]. The latter of the defined tendencies requires availability of «intelligent» sources that have already been developed, or are being developed and manufactured by various companies now. Their feature consists in the possibility of realization of algorithms of electrode metal transfer control, such as metal transfer by surface tension forces (STT) and cold metal transfer (CMT).

It should be noted that despite the attractiveness of developments of inverter-type power sources using the intellectual potential of their software, the following tasks are still unsolved or only partially solved:

- ensuring reliable enough design solutions on source protection at operation under the real production conditions;
- realization of modular design of power components to ensure a wide range of nominal current values and various levels of output voltage;
- optimization of maintenance, additional programming or reprogramming to obtain qualitatively new processes of welding and surfacing, corresponding to the conditions of modern fabrication, advanced technologies, etc.

The purpose of this work is to familiarize welding fabrication specialists with the development made by Laboratory of Electronic Technology, Ltd. (St.-Petersburg, RF) with technical and consultational assistance of PWI experts.

The presented development is based on the principle of separation of the power and information components of the power source, ensuring the versatility and high level of equipment unification, and also allowing solution of a number of problems related to control of arc processes in welding and cutting.

Versatility is considered in several aspects: possibility of conducting a number of processes of welding and surfacing, as well as achievement of effective control of the process of welding or surfacing. For instance, in mechanized welding with short-circuiting (SC) electrode metal transfer with minimum level of its losses and sound weld formation can be ensured. Rather important in terms of power source versatility is ensuring its operation under diverse production conditions. In arc and plasma-arc processes of welding availability of a wide range of welding current (I_w = = 10–1500 A) and arc voltage (U_a = 16–260 V) values is required.

The simplest way to create all-purpose equipment for welding is development of a powerful source providing the required range of values of welding current and voltage for cutting. For the majority of users such a power source will be redundant in terms of its components and realized characteristics. Moreover, it will be expensive and, therefore, will not have the anticipated wide application.

For this reason, in the considered study the goal of equipment versatility is achieved by application of one typical power functionally complete block — module with minimum required parameters, which provides high values of efficiency, reliability, as well as the required load and dynamic characteristics.

Module control is numerical and envisages mounting power-independent storage in equipment for storing welding programs and parameters of power source setting up.

Each module is made so that the radiators of its power keys are located inside the module, and all the electronic components are outside. With such an arrangement air passes through the module, without contacting the electronics, or contaminating it. This is particularly urgent for real operation conditions (high dust level, presence of an electrically-conducting medium, etc.). A variant of mounting the source into a plastic waterproof case was developed that can be effectively used in development of a new set of equipment for underwater arc welding and cutting of metals by a consumable electrode. Selection of power characteristics of the source (current and voltage) is performed by parallel (in welding) and in series (at certain modes of welding and cutting) connection of the modules. Organization of the power source external characteristics required for the welding process and their no-failure operation are achieved using a special computer program.

Developed control system provides at power source output the dynamic and volt-ampere characteristics (VAC) required for each welding process. Control system determines many conditions of current and voltage that may be realized in operation. A clear and convenient interface for entering and correction of power source characteristics is important here.

We will demonstrate the operation of power source control system in the case of graphic design of external VAC. VAC are usually presented in the form of curves which at crossing the axes determine SC current and open-circuit voltage. There exists a multitude of them and user base can be compiled, if required by the customer.

VAC of welding current power source determine in many respects the possibility of realization of the welding process, its quality [4], and even the ability to ensure a certain type of electrode metal transfer, as, for instance, the above-mentioned process with FSC. The universally accepted form of VAC presentation is the graph. Therefore, entering and correction of VAC were realized in the graphic form by a special editor on PC, connected to power source through USB interface.

A specially developed graphic editor allows drawing the required VAC on the computer screen, and then sending it for execution to the system. View of editor program screen and VAC curves are shown in Figure 1. VAC entering in most of the cases is required

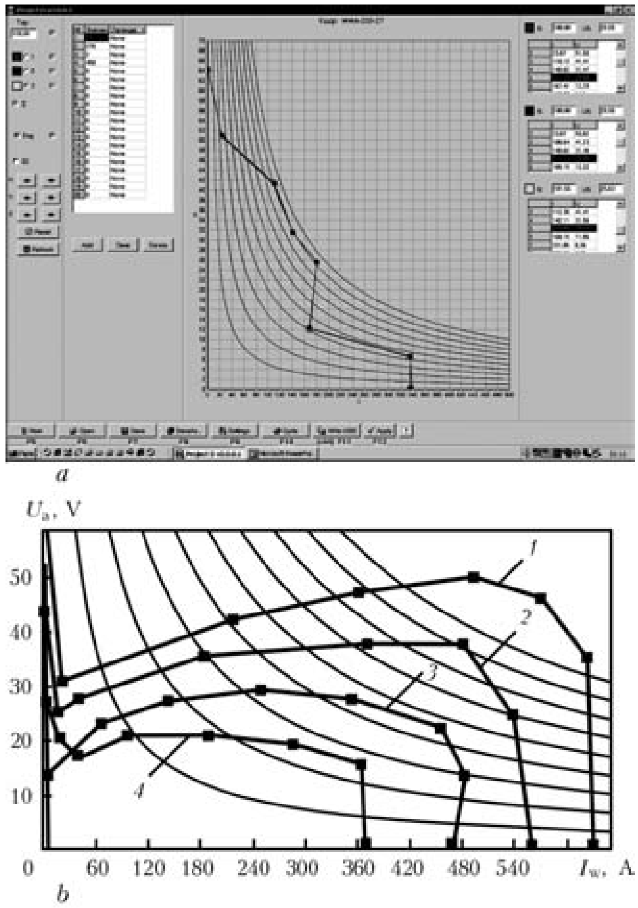

Figure 1. View of editor program screen for entering VAC into power source (*a*) and VAC curves generated in mechanized welding in different modes (*b*): *1* — $I_w > 250$; *2* — 150–250; *3* — 100–150; *4* — 50–150 A

for total setting up of the system under the conditions of production and initial programming, as well as for research and technological practice that we believe to be the most important. Source memory allows storing hundreds of VAC, and the welder just has to select the most suitable of them for specific welding conditions, welding consumables and modes.

It is known [5] that consumable electrode arc welding is a complex dynamic process that includes both fast (for instance, drop formation and transfer), and long-term (for instance, weld formation) processes. Sound performance of welding requires equally good control of these processes at any stage of their running. Different duration of welding processes also requires different methods of their control.

Importance of the source dynamic characteristic consists in ensuring the speed and nature of power source response to introduction of a disturbance into the load (change of load). Classic solution consists in application of throttles which regulated the speed of current rise and drop in the welding circuit by changing the load inductance. Throttle application is inconvenient, as adjustment of their inductance should be step-like, requiring turning the system off for switching. In the majority of new developments of welding current power sources of the known companies (for instance, realisation of QSet function — realisation of optimal SC frequency for the given combination of gas/wire in the most recent development by Swedish concern ESAB), the required speeds of current rise and drop are achieved using electronic devices, so-called electronic throttles.

In most of the cases, duration of current rise (drop) in welding is equal to approximately several milliseconds. In the development considered by us, such tasks are solved also by application of programmable electronic means. Here the energy capabilities of the module allow reaching maximum values of welding current by an order of magnitude faster. Therefore, the control system even for the fastest response to introduction of disturbances should «decelerate» the module, lowering the fast rate of current rise. This can be done, for instance, by the control system issuing every 0.1 ms the commands for current increase by 10 % of the sought value. Thus, the rate of current rise is changed, and the required dynamic characteristics of the power source are generated in the ranges required for welding and cutting.

In the power source, in which dynamic and VAC output characteristics are adjusted in a rather simple way, any of the known algorithms of electrode metal transfer control can be realised, that, as follows from analysis of welding equipment of the known manufacturers, is a priority task, solution of which ensures a sound and efficient running of the welding processes. Note that several new control algorithms were generated at validation of the system of graphic design of welding process characteristics, including on-line regulation of the fronts of pulse rise and decrease, as well as simultaneous control of the power source and drive of electrode wire pulsed feed [6]. The latter solution, in our opinion, is one of the directions of further improvement of welding current power source and equipment sets for mechanized and automatic welding as a whole.

Figure 2. Variant of design of welding current source LET 350 with metallic sheath and touch-type display

At present practically all the levels of control of welding processes and methods of their implementation have been developed. All the known control algorithms of the pulsed-arc process with a wide range of parameters of variable characteristics (level, pulse repetition rate, frequency and pulse shape) have been verified in the power source [7].

Control system of the power source contains built-in sensors of current and voltage that are used both to solve the internal tasks related to control of arc process parameters and to transfer information to external devices.

All the capabilities of the power source control system are provided by digital processing of the current state so that it can be called complete numerical control of the welding process (NCWP). Here it is appropriate to apply such a concept as graphic design of power source characteristics for any possible arc welding process with those parameters that the technologists believe to be necessary and the most effective.

For convenience the power source control panel incorporates a graphic display that is used to implement various intuitively understood algorithms of control and monitoring by a special program.

Two important features of the new development can be also noted. Upgrading of the currently available and mastering new welding technologies are essentially simplified, as it is possible to select VAC and dynamic characteristics of the power source in the laboratory at a sufficiently high level. These characteristics can be sent through the Internet or by mail for entering into any power source. As shown by experience, their incorporation into the currently available production systems does not involve any difficulties. Another advantage of the new development that, however, is not so far realized by the local users in welding, is the possibility of remote objective monitoring of welded joint performance. This is achieved by two methods: either the power source records into its memory all the process parameters, and then archives the report about work performed, or sends them to a special server, performing monitoring and recording of work performed.

Note that by agreement with the customer the power source can have gas cut-off valve and adjustable d.c. electric drives for electrode wire feed mechanism with the necessary elements of their programmed switching on by the welding cycle.

During evaluation of the capabilities of the new development, specialists of «Laboratory of Electronic Technology» and PWI for several work days performed a series of studies on LET 350 power source (Figure 2) with standard feed mechanism of PDGO-510 type with its torch fastened in the welding carriage slot, with variation of VAC, dynamic characteristics of the power source, as well as with application of pulsed impacts, etc. All the power source parameters

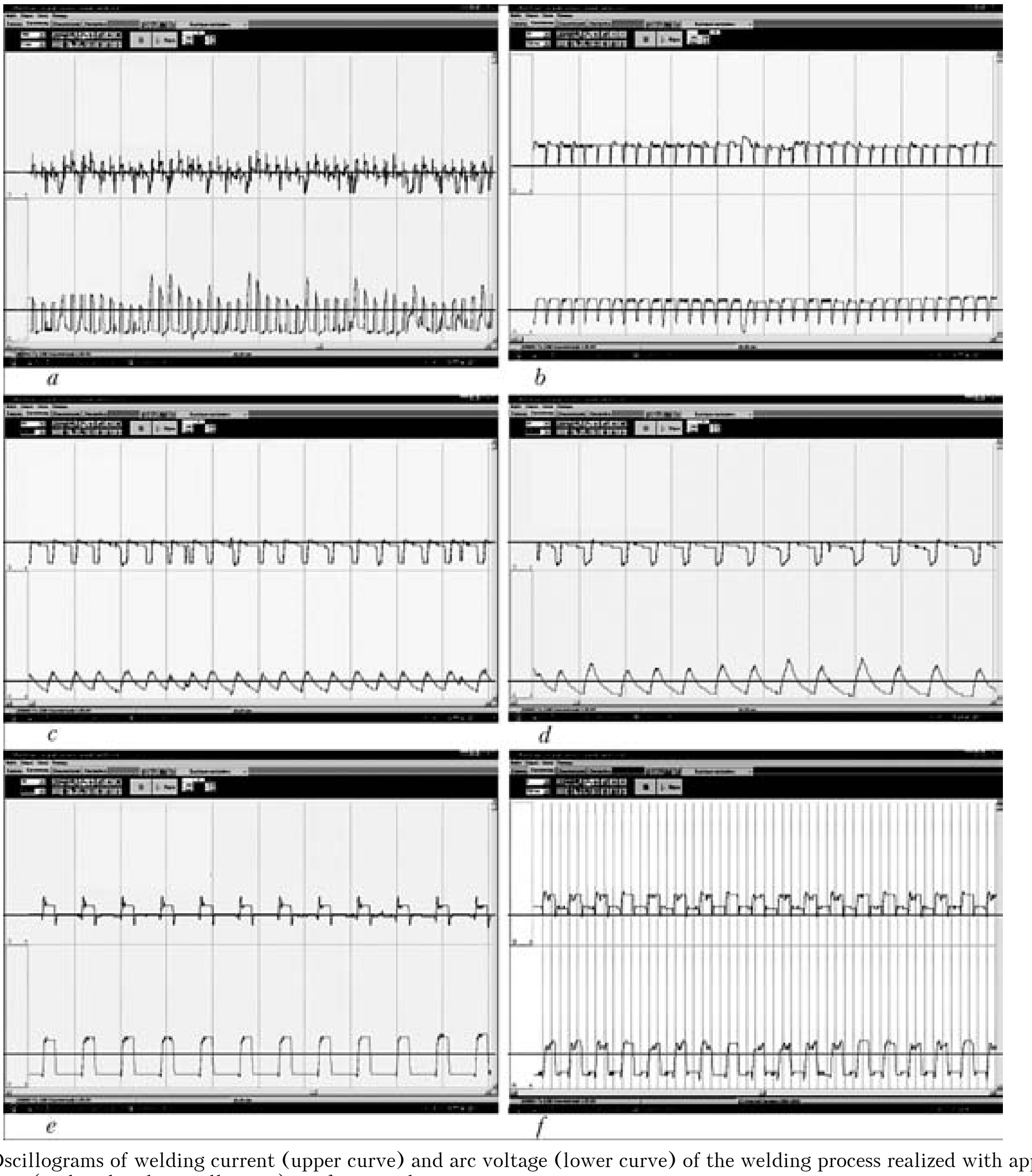

Figure 3. Oscillograms of welding current (upper curve) and arc voltage (lower curve) of the welding process realized with application of LET source (scale taken by oscillogram): *a*–*f* — see the text

were set in on-line mode and were evaluated by quality of deposited metal beads, oscillograms of current and voltage. Electrode wire Sv-08G2S of 1.2 mm diameter was used. Carbon dioxide gas was the shielding medium. The main modes were selected by recommendations of [4].

Let us consider several variants of welding processes as an example. Welding was performed at welding current of 90–140 A and arc voltage of 18–24 V. Figure 3, *a* shows welding process oscillogram with a relatively small value of inductance in the welding circuit (lees than 0.1 mH) at uniform rigid VAC and absence of the pulsed mode of power source operation. Arc voltage value was on the lower limit of the recommended range. It is seen that the welding process was running with SC, electrode metal transfer process being quite chaotic. At increase of the inductance, the welding process in terms of transfer is ordered and stabilized. Here the arcing and SC periods can be precisely recorded, as is readily seen in Figure 3, *b*. Then, with increase of welding circuit inductance SC frequency decreases and cycle pulse repletion rate changes that can be traced by oscillograms in Figure 3, *b*–*d*. This enables regulation of heat inputs into the weld pool due to programmed variation of inductance. Oscillograms in Figure 3, *e*, *f* also demonstrate the possibility of controlling electrode metal transfer through application of various VAC of the power source and of a pulsed component of voltage with parameters close to those of natural transfer. In this case, welding was performed at a combined VAC of the type presented in Figure 4, while changing parameters *A*, *B* and *C*. The Figure also shows changes of transfer cycle pulse repetition rate.

Thus, it is obvious that changing two parameters of welding current power source (time constant of

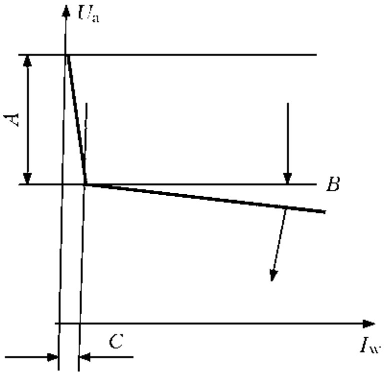

Figure 4. Combined VAC of welding current source: A — open-circuit voltage of welding current source; B — rigidity of external VAC; C — zone of higher voltage action

welding circuit at the expense of dynamic characteristics and VAC shape) by certain algorithms enables essentially influencing electrode metal transfer, stabilizing it and monitoring its energy characteristics, and, therefore, also influencing the coefficient of electrode melting and base metal penetration.

By now a program has been put together for investigation of the capabilities provided by the design of LET power source and programming system. At the first stage of investigations it is intended to determine the influence of inductance, VAC, pulsed algorithms on the welding process and welded joint formation, and in the second stage — that of various feedback structures and application of force impacts on electrode metal transfer.

CONCLUSIONS

1. NCWP provides quality setting up of equipment for specific operation, fast reproduction of settings and their repeatability. The main advantage of development of Laboratory of Electronic Technology, Ltd. [8] is provision of welded joint quality based on the principles of numerical synthesis of the welding process.

2. Realisation of the concept of a versatile system for welding and cutting with NCWP simplifies and makes less expensive the well-established systems of design, production and operation of welding equipment, thus providing a high welding quality.

3. Versatility of power sources is cost-effective for large-scale productions, operating hundreds of welding systems of various purposes and power due to simplification of their operation and possibility of manoeuvring from one site to another, and one welding process to another. Operation of equipment of one type consisting of several typical modules, is much simpler and more inexpensive that that of different equipment from various manufacturers [9].

4. The future of welding and cutting consists exactly in NCWP application. Welding productions that start applying the above principles earlier will gain a natural advantage over their competitors in terms of the cost and quality of their products.

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