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WELDING CURRENT FORMERS USING ARTIFICIAL LONG LINES

O.Ye. Korotynskyi, M.P. Drachenko, A.M. Zhernosekov, I.V. Vertetska

E.O. Paton Electric Welding Institute of the NASU
11 Kazymyr Malevych Str., 03150, Kyiv, Ukraine

ABSTRACT

Application of artificial long lines in arc welding equipment is considered. These lines allow forming pulsed welding currents of a regulated shape. The need for such currents is determined primarily by the objectives of pulsed technologies, where the load current shape ensures the required time law of power input into the technological object. The most characteristic examples of such technologies are pulsed laser welding, laser heat hardening, laser piercing of holes, etc. The possibility of adjustment of amplitude-time parameters of load current pulses in a broad range allows determination and further on ensuring the optimal parameters of pulsed electrophysical processes in order to improve their quality and productivity. Special pulsed current generators are required to create such energy flows, which are described and proposed in the paper.

KEYWORDS: welding current formers, artificial long line, step-down multiphase converter, pilot-arc power source

INTRODUCTION

Artificial long lines (ALL) are currently used to construct pulsed formers of arc welding currents. The need for such currents is determined primarily by the objectives of welding technologies, where the load current pulse shape ensures the required time law of power input into the technological object. The most characteristic examples of such technologies are pulsed laser welding, laser heat hardening, laser piercing of holes, capacitor discharge resistance welding, etc. Possibility of adjustment of amplitude-time parameters of load current pulses in a broad range allows determination and furtheron ensuring optimal parameters of pulsed electrophysical units, in order to improve their quality and productivity. Generation of such currents requires special pulsed current generators (PCG) [1–3].

Proceeding from the abovesaid, the proposed work is devoted to creation and development of versatile pulsed current generators designed to construct welding current formers with high characteristics of energy efficiency and electromagnetic compatibility (EMC) [4].

The objective of this work is substantiation and creation of structures of powerful generators of regulated pulsed currents (GRPC) and their experimental investigation. Electrotechnological generators of regulated pulsed current are required first of all as a tool, which allows experimental investigation of the main parameters of pulsed technological process, including current shape, in order to improve both the process quality and its efficiency. In addition, pulsed technological units with amplitude-time pulse parameters regulated in a broad range are of great interest when working under the conditions of small-scale production with frequent changes of product range and kinds of structural materials. Recently, high-frequency converters operating in the pulse-width regulation mode have been used with success for generation of current pulses of a regulated shape in the pulse duration range from several milliseconds to seconds, at load current levels of several hundred amperes. Such converters use modern power transistors, capable of switching hundreds of amperes of current at frequencies of up to hundreds of kilohertz.

When developing generators of rectangular current pulses of a regulated duration, partial discharge of capacitive storage is most often used, when a fully-controlled power key connects the load to the storage for the time which is equal to pulse duration. A serious drawback of such generators is the energy stored in the device significantly exceeding the energy evolving in the load during the pulse time, as power key malfunction can result in grace accidents, which can lead to load failure. The above disadvantage is overcome, when a fundamentally new type — a homogeneous artificial long line (HALL) is used as storage and forming two-terminal network (FTTN). Here, not only the energy accumulated in the storage is lowered, but also its weight and dimensional characteristics are reduced.

The proposed approach consists in a combined use of ALL-based generators and storages using supercapacitors (SC) having high energy efficiency and electromagnetic compatibility characteristics. It allows creating promising devices for pulsed-arc welding.

METHODS OF INVESTIGATION

The following solutions are mainly used when creating pulsed current generators:

- method of partial discharge of capacitive storage [5, 6];
- ALL application as current formers [7, 8];
- multiphase step-down voltage converters (choppers) with microprocessor control [9, 10].

Figure 1 shows two variants of ALL application for welding equipment. The first variant (*a*) is a series con-

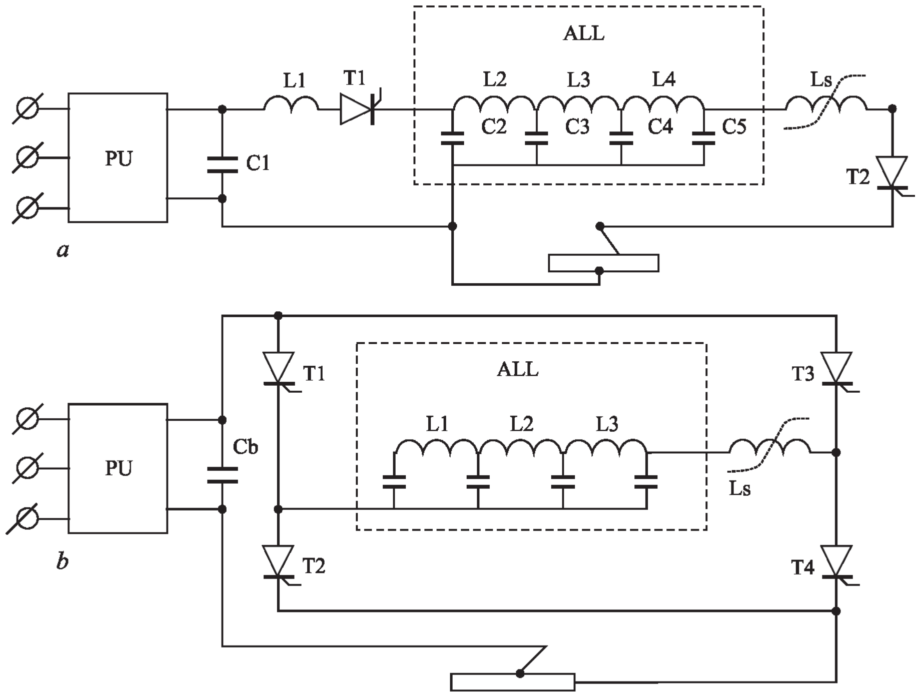

Figure 1. Variants of ALL application (for *a*, *b* description see the text)

nection of three-phase rectifier, charge switch, ALL and switch of its discharge on the load. The second variant (*b*) includes charging rectifier, capacitive storage and bridge inverter, with ALL connected into its diagonal.

Let us analyze ALL operation as part of pulsed welding current sources.

Based on the considered welding systems, a variant of the circuit of inverter-type pulsed current former was proposed. It incorporates ALL shown in Figure 2. A chain of three LC elements is used as current pulse former. The main calculations are used according to works [11, 12]:

$$I_p = (U + U_c - U_a)/2\rho;\ \rho = (L_c/C_c)^{1/2},$$

where I_p is the current pulse amplitude; U is the power source voltage; U is the charge voltage of the forming line; U_a is the voltage across the arc gap; ρ is the wave impedance.

Pulse duration is defined by the following expression:

$$t = 2.2n(L_cC_c)^{1/2},$$

where n is the number of forming line cells; L_c is the inductance of the forming line cell choke; C_c is the capacity of the forming line cell capacitor.

Thus, the duration of the pulse front is determined by the following relationship:

$$t_f \approx 0.61 - (L_c - C_c)^{1/2} = 0.27t/n,$$

and pulse cutoff duration is given by the following expression:

$$t_{end} \approx (0.075n + 2.3)\ (L_cC_c)^{1/2}.$$

An operating mockup of pulsed welding current source was developed and tested according to the diagram in Figure 2 (Figure 3).

Current pulses were generated using the known "skew bridge" circuit, with ALL connected into its diagonal in series with pulse transformer Tr2. Short-circuited ALL output is connected to Tr1 transformer, which is used in the circuit of the former of arc standby current. Here, the standby current is formed in the pauses between working current pulses.

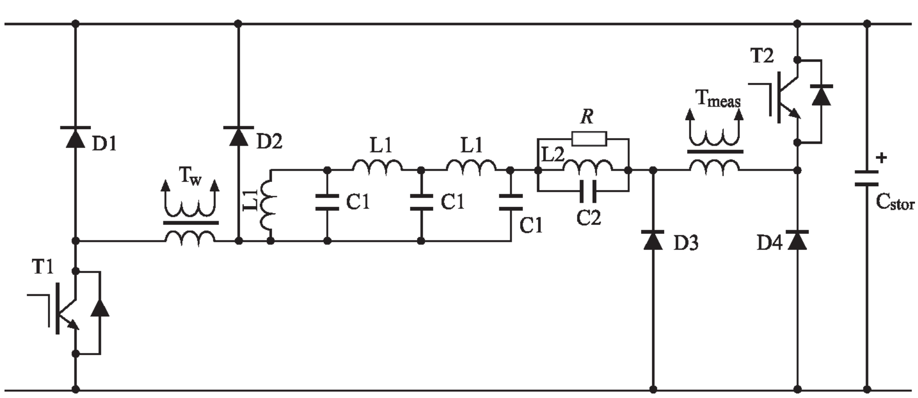

Figure 2. Explanatory diagram of ALL element calculation

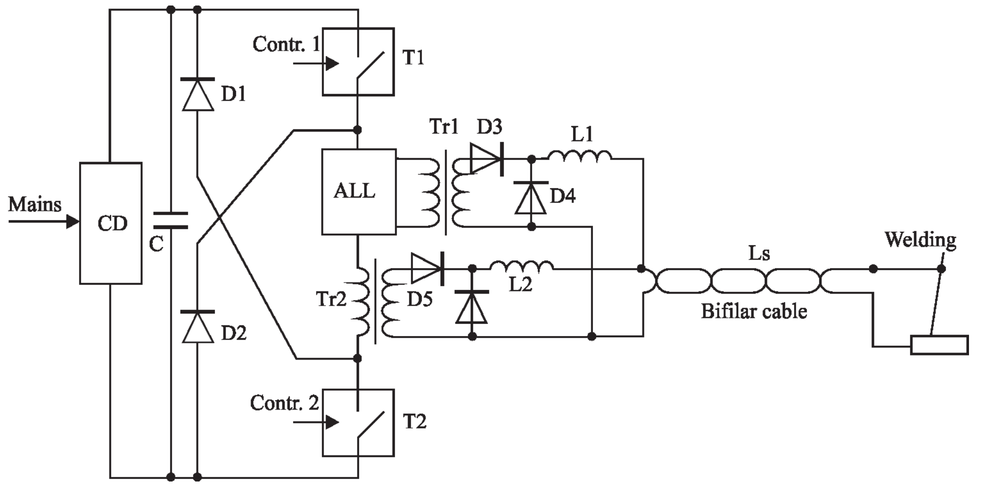

Figure 3. Block diagram of a mock-up of a welding current source based on ALL

As part of the work, a current sensor module was developed on the basis of a bifilar shunt circuit with a high level of in-phase interference suppression.

EXPERIMENTAL STUDIES OF DEVELOPED MOCKUP

The proposed device, the diagram of which is shown in Figure 3, provides a stable arc burning in the dynamic mode, which, in its turn, allows improving the quality of the welded joint and the energy characteristics of the device operation. This source was tested in the mode of welding with pulse modulation of current at the frequencies from 50 to 3500 Hz. Pulse amplitudes were varied from 50 to 100 A. The lower limit of stable welding currents was observed at currents higher than 20 A.

Figure 3 shows the oscillograms of operation of a forward converter incorporating an ALL.

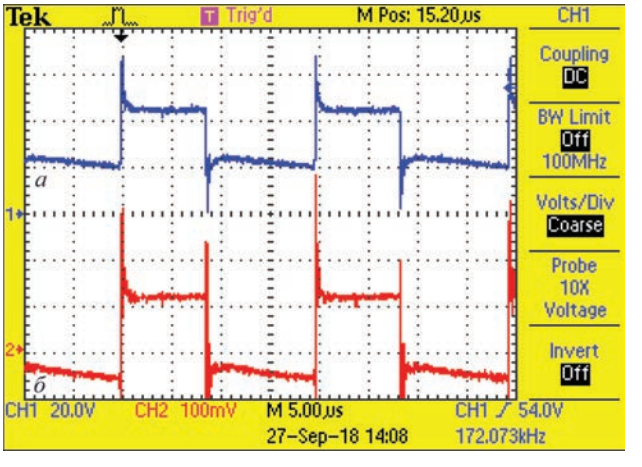

Figure 4. Oscillograms of voltage "*a*" and current "*b*" at the welding device output

APPLICATION OF STEP-DOWN CONVERTERS AS PULSED WELDING CURRENT FORMERS

Variants of ALL application in step-down voltage converters (SDVC), which can be used in multistation welding complexes, were also studied as part of the performed work. An example of ALL application in step-down voltage converters is shown in Figure 5. Adjustment of the duration and repetition frequency of current pulses is performed by electronic switch on transistor key T2.

The long line is charged from capacitive storage Csc, which is connected to charging device (CD). Monitoring and adjustment of CD charge parameters are performed in keeping with feedback signals, received from current CScd and voltage VScd sensors.

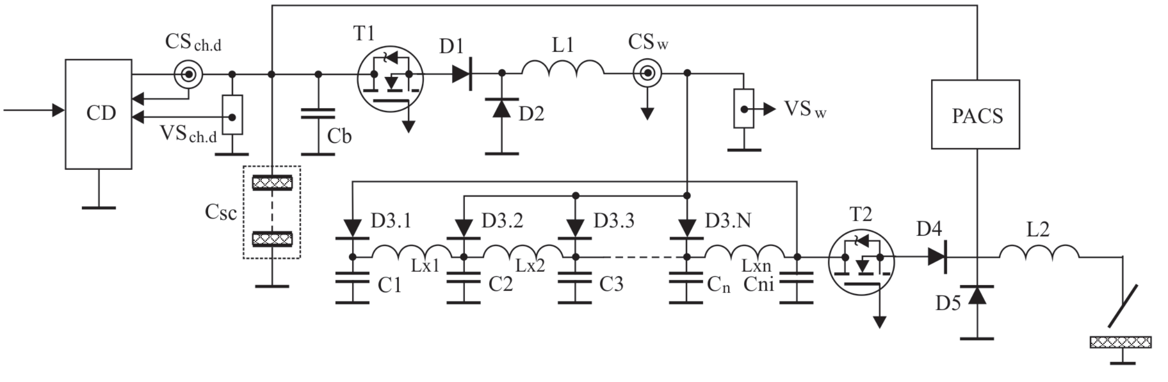

Figure 5. Step-down voltage converter — pulsed current former: CD — charging device of super capacitor battery C_{sc}, $CS_{ch.d}$ and $VS_{ch.d}$ — current and voltage sensors; SCB — super capacitor battery; TI and T2 — solid state transistor switches; D1, D2 — normalizing diodes; D2, D5 — recovery diodes; Cb — battery capacitance; CSlc and VSlc — sensors of ALL charge current and voltage; D3.1–D3.N, Lx1–Lxn, C1–Cn — ALL elements

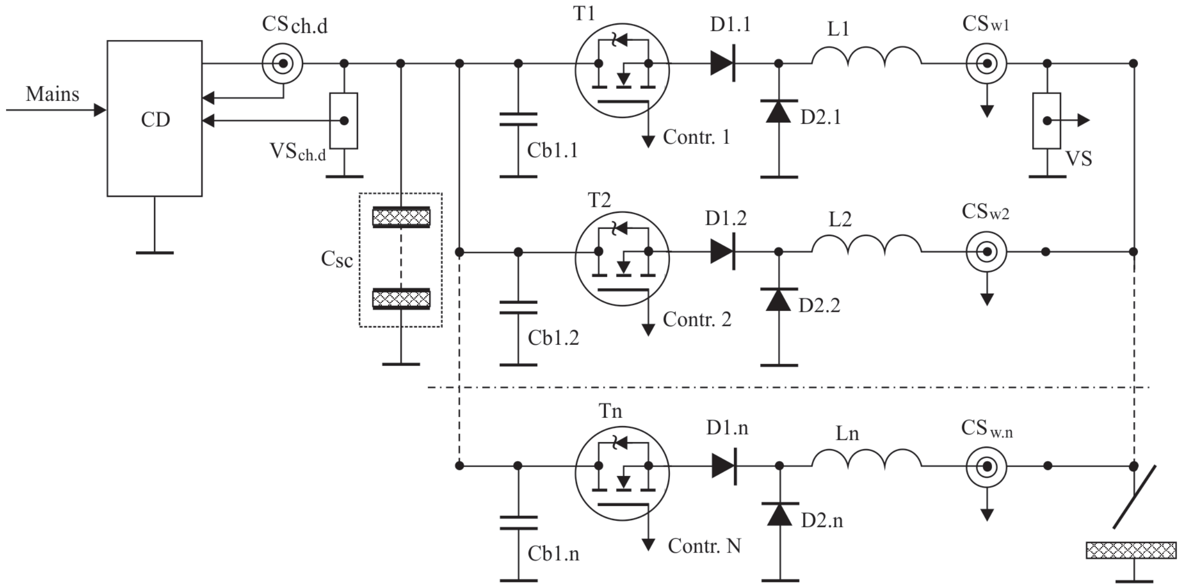

Figure 6. Multiphase SDVC — source of welding current pulses: CD — charging device; $CS_{ch.d}$ and VS_{ch} — sensors of current and voltage of charging device control; SCB — capacitive storage based on super capacitor battery; Cb1.1–Cb1.n — buffer capacitors; T1–Tn — solid state transistor current switches; D1.1– D1.n — normalizing diodes; D2.1 – D2.n — recovery diodes; T1–Tn, D1.X– D1.n, D2.x–D2.n, L1–Ln — elements of step-down converters — welding current pulse formers; $CS_{w.1}$–$CS_{w.n}$, VS_w — sensors of control current and voltage of control system of welding current pulse former

Step-down converter, consisting of TI, D1, D2, L1, performs ALL charging in the constant power mode.

Power monitoring and control are conducted by signals, which are formed by current CScd and voltage VScd sensors.

Pilot arc current source (PACS) operates continuously, and its current is summed up on the load (welding arc) with the main welding current pulses.

A variant with formation of welding current pulses without ALL application, but using a multiphase step-down voltage converter was also considered (Figure 6). Here regulation of the duration, frequency and shape of welding current pulses is performed by synchronous control of transistor switches T1–Tn.

The converter is powered from capacitive storage Csc, which is charged from charging device CD. Monitoring and regulation of SC charge parameters is performed by feedback signals, coming from current CScd and voltage DVcd sensors. In this circuit the mode of operation with interrupted currents in chokes L1–Ln is used to improve the dynamic parameters of current pulses. One of the converter channels is used to generate the arc standby current, and it operates in the mode of continuous current of choke Lo.

Comparative analysis of operation of these devices shows that preference should be given to multiphase converter circuit, as it allows regulation of the time parameters of the amplitude and shape of welding current pulse in a broad range.

CONCLUSIONS

1. Features of operation and application of welding current formers based on artificial long lines to create resource- and energy-efficient power sources for arc welding were considered.

2. Good prospects for their application are shown when powering capacitive energy storages in the mode of dynamic burning of the arc.

3. New circuits of combined power sources based on artificial long lines were proposed, and their experimental study in the range of welding current frequencies of 50–3500 Hz was conducted. Features of artificial long line functioning as part of step-down converters are considered.

4. As shown by experimental studies, these devices are characterized by high values of energy efficiency and electromagnetic compatibility.

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ORCID

O.Ye. Korotynskyi: 0000-0002-6461-8980,
M.P. Drachenko: 0000-0002-4485-2403,
A.M. Zhernosekov: 0000-0002-6404-2221,
I.V. Vertetska: 0000-0003-4971-7929

CONFLICT OF INTEREST

The Authors declare no conflict of interest

CORRESPONDING AUTHOR

O.Ye. Korotynskyi
E.O. Paton Electric Welding Institute of the NASU
11 Kazymyr Malevych Str., 03150, Kyiv, Ukraine.
E-mail: epis@ukr.net

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