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AC ARC STABILIZER FOR WELDING TRANSFORMERS

V.V. BURLAKA, S.V. GULAKOV and **S.K. PODNEBENNA**
SHEI «Priazovskii State Technical University»
7 Universitetska Str., 87500, Mariupol, Donetsk Reg., Ukraine. E-mail: office@pstu.edu

Circuit design of AC arc stabilizer for welding transformers is proposed. A special feature of the stabilizer is application of resonance voltage rise in the transformer secondary winding to ensure repeated ignitions of the arc after each zero current transition. This allows reducing energy losses in the arc stabilizer and ensuring effective formation of high-voltage pulse packets for guaranteed breakdown of the arc gap. Application of the proposed arc stabilizer allows performance of DC welding with electrodes at power supply from welding transformers without rectifiers. The stabilizer is designed for operation with transformers not fitted with electronic regulators: mainly with transformers with a magnetic shunt of TDM, STSh type. 12 Ref., 6 Figures.

Keywords: *electric arc, welding, arc ignition, arcing stabilization, welding transformer, arc ignition voltage*

In manual arc welding the process quality and productivity are affected by the ability of the power source to provide easy ignition and stable burning of the arc. In AC welding arc reignition should occur after each zero transition of welding current. Devices for arcing stabilization or arc stabilizers are used for this purpose.

Arc ignition is associated with the need to generate high voltage. This can be achieved through application of additional windings of the welding transformer [1]; special circuits with additional inductive components which are connected in parallel [2] or in series with welding transformer secondary winding [3–8].

The first approach requires changing the transformer design and is not suitable for modification of the available park of welding transformers.

Realization of the second approach leads to greater overall dimensions and weight of arc stabilizer in connection with availability of additional inductive components, particularly those that are included into the welding circuit in series with the transformer secondary winding.

An original approach to creation of arc stabilizers is application for arc reignition of the energy which can be accumulated in the stray field of welding transformer. Considering that welding transformers usually have a falling output characteristic and greater scatter, such an approach seems promising.

References [9, 10] describe AC arc stabilizer, which is connected to the terminals of welding transformer secondary winding and contains an electronic switch, connected to this winding, and switch control circuit.

The circuit enables igniting the arc after zero transition of the mains voltage, and reigniting the arc in the case of its breaking; contains no power inductive components, and has simple connection. The disadvantages of this circuit are the impossibility to form output voltage pulses of higher frequency, as at a failed attempt of arc gap breakdown, the energy stored in the welding transformer magnetic field is scattered in the form of heat on overvoltage protection elements of the electronic switch. That is why increase of output pulse frequency will lead to overheating of switch protection elements. Moreover, the high rate of output voltage change leads to generation of radio frequency noise. This impairs the consumer properties of arc stabilizer.

The authors improved AC arc stabilizer [11] that allowed reducing energy losses in it, increasing the duration of the period of maintaining higher voltage at the electrode at manual arc welding and facilitating the process of arc initiation, thus improving the consumer characteristics and widening the device application field. Moreover, a variant of the device was created [12], which has increased output voltage without the need to apply power components with increased working voltage.

The idea consists in connecting a capacitor to secondary winding of welding transformer. The capacitor forms an oscillatory circuit together with transformer leakage inductance. Connected in parallel to this capacitor are electronic keys with the control circuit that ensures «pumping» of the circuit with energy. This leads to voltage increase on the capacitor and welding source output.

Simplified circuit of power components of the device for AC arc stabilization that implements the described principle is given in Figure 1.

Formation of higher voltage of arc initiation is realized at the expense of pumping the resonant loop formed by T1 and C_R elements.

VD1, S1 elements operate in positive halfwave of secondary voltage of welding transformer T1 (SI is switched, S2 is switched off), VD2, S2 elements operate in negative halfwave (S2 is switched, S1 is switched off).

We will consider the process in the positive halfwave.

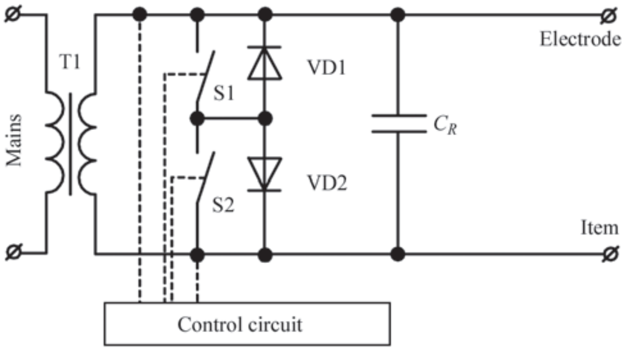

Figure 1. Schematic of power components of the device for AC arc stabilization

Key S1 opens immediately after zero transition of T1 secondary voltage. Figure 2 gives voltage oscillogram at capacitor C_R in this mode. Energy storing in T1 leakage inductance begins. As soon as current of key S1 has reached the set «pumping» current (this current determines the amplitude of output voltage and discharge energy), control system closes S1 (moment of time t_1). Resonance charging of capacitor C_R starts. After a quarter of the period of resonance frequency of the circuit formed by leakage inductance T1 and capacitor C_R, the latter is charged up to maximum voltage, and the current drops to zero. C_R discharge to T1 begins. After a half-period of resonance frequency the voltage at C_R goes through zero and becomes negative, and current reaches its minimum value. Control system opens S1 at appearance of negative voltage at C_R (moment of time t_2). This, however, does not influence the process, as diode VD2 is closed by reverse voltage.

After three-fourths of resonance frequency period voltage at C_R reaches a minimum, and current approaches zero. C_R charging from T1 secondary winding begins. When voltage on C_R goes through zero and becomes positive, winding current will flow though diode VD2 and pre-open key S1 (moment of time t_3). Additional «pumping» of the inductance up to set current will occur, which will be followed by S1 closing (moment of time t_4), and the process will be repeated. S1 switching is «soft», as it is opened at negative voltage at C_R (when VD2 diode is closed), and its closing occurs at voltage close to zero at C_R, that is the rate of voltage rise at S1 is limited by C_R action. At negative halfwave of T1 secondary voltage all the processes proceed in a similar fashion.

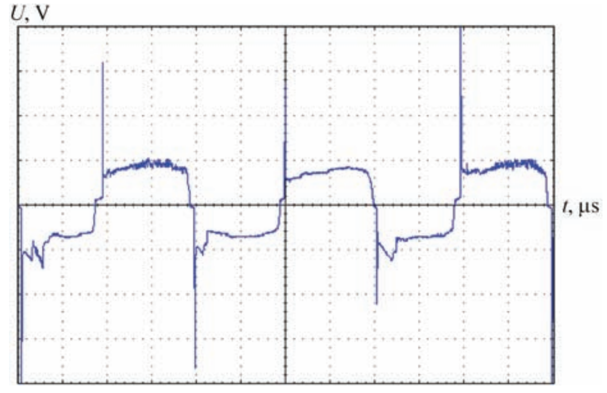

Figure 3. Oscillogram of voltage at transformer secondary winding during welding (5 μs/div; 50 V/div)

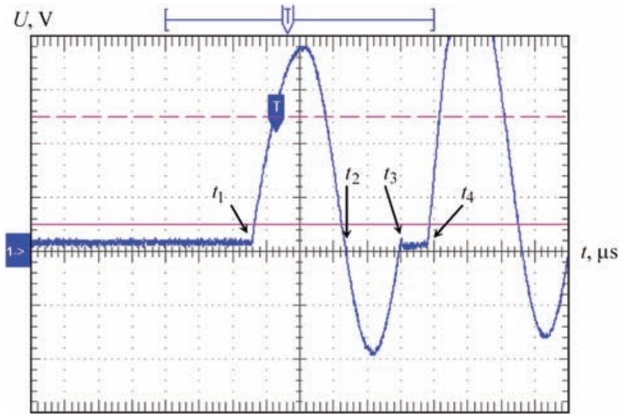

Figure 2. Oscillogram of voltage at capacitor C_R (voltage at transformer secondary winding) (8 μs/div; 50 V/div)

Two scenarios are possible during circuit operation: arc initiation occurs at certain voltage at C_R. Here, voltage at the output of arc power source decreases to the value of arc voltage across the arc gap, control system blocks operation of keys S1, S2 till the next zero transition of voltage of T1 secondary winding. This provides «soft» ignition and stabilization of the arc; if voltage at C_R becomes too high, the control circuit lowers the current of «pumping» resonant loop T1-C_R and the system goes into the steady-state mode.

During arcing, capacitor C_R does not have any significant influence on the process, because of its low capacity. Arc initiation occurs after each zero transition of secondary voltage of welding transformer.

The authors have made arc stabilization devices using the proposed engineering solution. Stabilizers were installed in TDM-401 and STSh-250 transformers, and their industrial testing was performed during repair operations at metallurgical enterprises of the city of Mariupol. Welding transformers fitted with arc stabilizers were used for DC welding with UONI type electrodes.

Stabilizer control system is based on single-crystal microcontroller and supports the following functions: identification of arc burning by the results of analysis

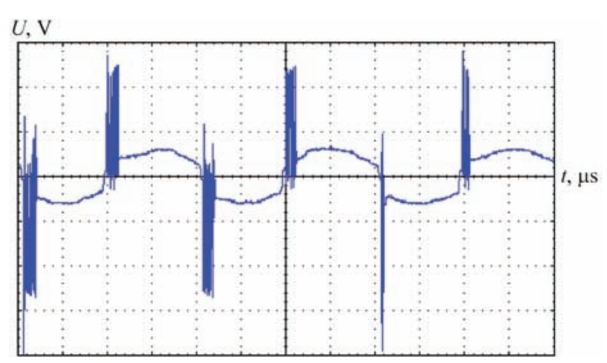

Figure 4. Oscillogram of voltage at transformer secondary winding during welding, one can see packets of arc ignition pulses (5 μs/div, 50 V/div)

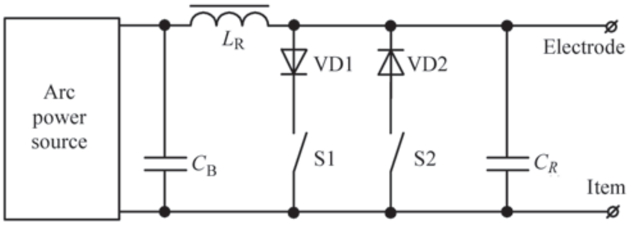

Figure 5. Circuit of power components of arc stabilization device with resonant choke

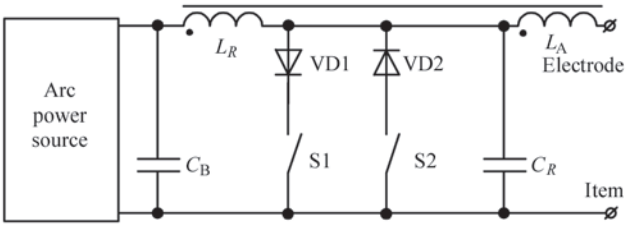

Figure 6. Power part of arc stabilization device with higher voltage

of transformer secondary voltage; stabilization of arc ignition voltage; automatic adjustment for transformer parameters; limiting the time of action of increased voltage at a failed attempt at arc initiation; thermal protection of power elements of the circuit.

Figures 3, 4 show oscillograms of secondary voltage of TDM-401 welding transformer with a connected arc stabilizer at manual arc welding with UONI-13/55 electrodes. One can see that situations arise (Figure 4), when arc reignition proceeds not immediately, but after several increased voltage pulses. Amplitude of arc reignition pulses reaches 200 V, and at initial arc ignition (after electrode closure on the item) it can be up to 300 V. Stabilizers showed stable operation in the entire range of regulation of welding current of transformers with a magnetic shunt.

The proposed arc stabilizer is suitable for operation with welding transformers, not fitted with electronic devices of welding current regulation, as appearance of high voltage of the frequency of tens of kilohertz in the transformer secondary winding can lead to violation of the mode of electronic regulator operation.

The authors developed a version of arc stabilizer with a two-wire connection to the transformer, that is power to the control system is supplied from secondary voltage. Overall dimensions of such an arc stabilizer are just 110×90×48 mm.

If the Q-factor of welding transformer leaves much to be desired, or it is undesirable to apply higher frequency high voltage to its secondary winding, it is rational to fit the arc stabilizer with a separate resonant choke with known characteristics, and install high-frequency blocking capacitor in parallel to transformer secondary winding. This, certainly, impairs the technical-economic and mass-dimensional parameters of the stabilizer, as it acquires a power inductive component. Figure 5 gives the schematic of power part of such a variant of arc stabilization device.

The device is connected between the arc power source and welding electrode, includes resonant choke L_R of blocking capacitor C_b and resonance capacitor C_R, electronic keys S1, S2 and two diodes VD1, VD2. The keys can be connected also as shown in Figure 1, circuit functionality remaining the same.

For TIG welding keys S1, S2, diodes VD1, VD2 and capacitor C_R should be designed for higher voltage, as increased voltage of arc ignition should be provided for TIG process, compared to manual arc welding. Moreover, for TIG welding the choke can be made with additional winding (L_A, Figure 6), which is connected in series with the main one.

Such «autotransformer» connection of the choke allows obtaining higher output voltage without the need to replace the force components by higher voltage ones. With correct design of the choke parameters, voltage with amplitude of several kV can be obtained at the electrode that can be used for contactless arc ignition in TIG welding.

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