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DEVICE FOR EXCITATION AND STABILIZATION OF WELDING ARC

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The circuit design of the device for formation of increased voltage was proposed, providing facilitation of ignition and stabilization of welding arc burning at direct/alternating current. The device operates according to the algorithm Lift-Arc and provides ignition of the arc at a minimum required power due to limitation of rate of voltage growth at the arc gap. For safe operation the time limit for action of higher voltage was also introduced. Due to application of the advanced elementary base it was possible to simplify the electric circuit of the device for arc stabilization at maintaining the high consumer properties. 10 Ref., 5 Figures.

Keywords: *electric arc, welding, arc ignition, stabilization of arc burning, welding inverter, open-circuit voltage*

In manual arc welding with a covered electrode, as well as in welding in inert gas (MIG), including that with a non-consumable electrode (TIG) the need is occurred, firstly, to facilitate the initiation of arc discharge, secondly, to stabilize the process of arc burning. At the power supply from the alternating current mains, the repeated excitation of arc should occur after each transition of power source voltage through zero. Moreover, in TIG welding it is desirable to limit the power, which is released at the arc gap breakdown, as at the increased discharge power the erosion of non-consumable electrode occurs, which reduces its service life. Therefore, the urgent problem is the design of device for arc stabilization, which will realize the exciting of arc at the minimum required discharge energy and provide a stable burning of the arc during welding process.

In manual arc welding using electrodes at direct current with the power supply from inverter source the problems with ignition and maintaining of the arc (arc burns unstable, electrode often «sticks») are occurred. The cause is the low open-circuit voltage $U_{o\text{-}c}$ of inverter power sources for arc welding. Thus, for the sources, designed according to the bridge circuit, $U_{o\text{-}c}$ amounts to 60–65 V; for the sources based on forward converter $U_{o\text{-}c}$ amounts to 50–60 V (pulses of the amplitude of about 100 V and pulse duty factor of 0.5).

The conventional devices for arc stabilization include step-up transformer, spark generator with a discharger and high-frequency (broadband) transformer, the secondary winding of which is connected in series or in parallel with the arc gap [1–4]. Such a circuit allows forming high-voltage pulses at the arc gap and providing ignition of the arc. Among its disadvantages the large dimensions and weight of the transformers, complicated control of pulses power, wide range of generated electromagnetic interferences, short service life of discharger and the need in its periodical replacement should be mentioned.

In the works [5–8] the devices for arc stabilization are described, in which contact-free switching elements like transistors and thyristors are applied. This provides a significant improvement in the reliability of welding equipment, fitted with such devices, and the possibility to control characteristics of igniting pulses within the wide ranges.

In the work [9] the device for arc stabilization was proposed, providing the control of power for excitation of the arc due to changes in the supply voltage of resonance circuits. In the circuit of the device the additional controllable source of the higher voltage of direct current, two resonant circuits with appropriate control circuits were introduced. This leads to complication of circuit, increase in power losses and deteriorates the consumer qualities of the device.

In the work [10] the method for increasing intensity of plasma formation was proposed due to the use of several resonance circuits, operating at a phase shift and loaded to the common high-frequency transformer. However, the use of non-firing thyristors in the devices as the key elements, does not allow increasing the operating frequency, simplifying the circuit and improving the weight and size characteristics of the arc stabilizer [9, 10].

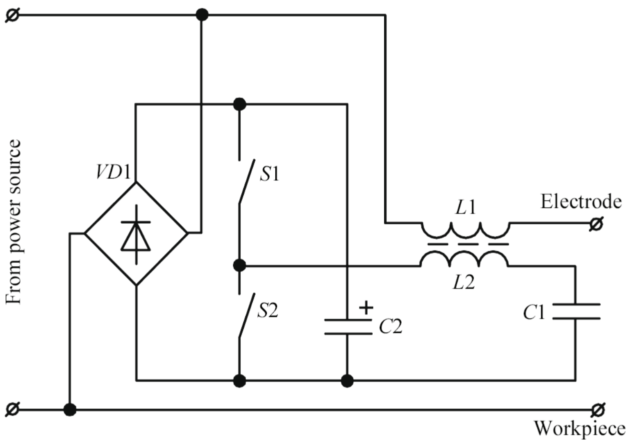

Figure 1. Block-diagram of device for arc stabilization

The authors designed the device for arc stabilization which is switched in series with the electrode and allows the formation of higher voltage at the latter. The device does not require a separate power source (it is supplied from the welding power source), allows increasing the resistance of non-consumable electrode in TIG welding due to limitation of the rate of voltage growth at it and excitation of arc with the minimum required power, increasing the duration of period of maintaining the higher voltage at the electrode in manual arc welding and facilitating the process of arc initiation.

It is based on the principle of producing the higher voltage by «pumping» the serial resonant circuit from the controllable source of alternating voltage with a variable frequency. As the latter the switching unit on the field-effect transistors was used, controlled from the single-crystal microcontroller.

Figure 1 shows the block diagram and Figure 2 shows the principal electric circuit of the designed device for arc stabilization.

During switching on of the power source, the capacitor *C*2 (see Figure 1) is charged through the diode bridge *VD*1 up to open-circuit voltage of the source.

In the case of manual arc welding the arc excitation is carried out after short-circuiting (SC) of the electrode at the workpiece (function Lift-Arc). The control program monitors the voltage at the output of the source. During SC the voltage becomes close to zero. At this time, the supply of the circuit is provided by the charged capacitor *C*2.

During removal of electrode from the workpiece the SC disappears, at the output of power source the voltage appears. At this time the switching unit, formed by the keys *S*1, *S*2, starts operation. It operates at the pulse duty factor of 50 % and at a variable frequency. The operation starts from the maximum frequency, which significantly exceeds the resonance frequency of the circuit *L*2*C*1. By decreasing the output frequency of the switching unit the current of the circuit *L*2*C*1 and the voltage at the throttle *L*1 grow. Further, two scenarios are possible:

- at some voltage the arc initiation occurs at *L*1. The voltage at the output of the power source is reduced to the value of voltage at the arc gap, the control system blocks the operation of the keys *S*1, *S*2. In such a way a «soft» ignition of the arc is provided;
- reaching the required (maximum) current of «pumping» the circuit *L*2*C*1, the reduction in frequency is stopped, the system switches to the steady state. To provide the safe use of the device, the high voltage at the output is only supported during the preset holding time, after which the operation of the keys *S*1, *S*2 is blocked.

The operation at the frequencies higher than the frequency of serial resonance of the circuit *L*2*C*1 provides «soft» switching on of the power keys due to inductive nature of input impedance of the circuit, which in capacity of keys allows applying the field-effect transistors, characterized by a relatively longer time of reverse recovery of the inverse diode.

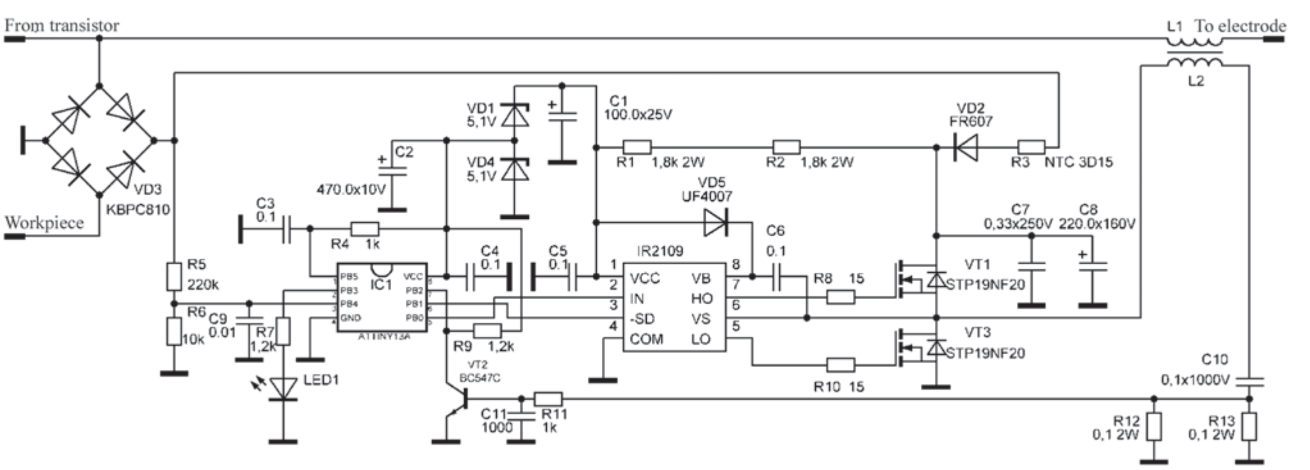

Figure 2. Principal electric diagram of device for arc stabilization

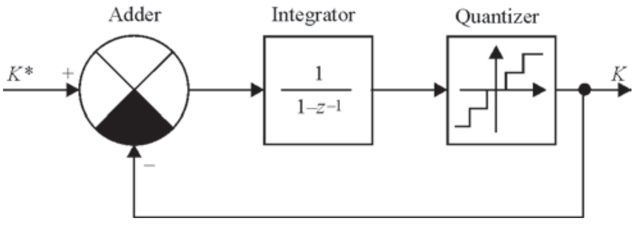

Figure 3. Structural scheme of algorithm for realization of fractional division factor

In case of TIG welding the operation of the system is similar, only the parameters of the circuit *L*2*C*1 are different (it is necessary to provide a higher voltage as compared to the manual arc welding). The arc initiation occurs after each transition of the power source voltage through zero.

The elements *VD*1, *C*2 also protect the output of power source from entry of high-voltage from the throttle *L*1.

In the practical realization of the device for arc stabilization for manual arc welding (see Figure 2) the keys *S*1 and *S*2 are produced on MOSFET transistors STP19NF20, the diode bridge *VD*1 of the type KBPC810, capacitors *C*1 of 0.1 μF×1000 V, *C*2 of 220 μF×160 V. The throttle is wound on the core ETD59/ 31/22 with a non-magnetic gap of 0.4 mm for linearization of weber-ampere characteristics. *L*1 has 14 turns, *L*2 has 12 turns.

The maximum current of circuit pumping is determined by the resistance of resistors *R*12, *R*13 and firing voltage of the transistor *VT*2, which approximately amounts to 0.6 V. For the rated values, shown in the circuit, the amplitude of the current in the circuit can reach 12 A.

The formation of the controlling pulses for transistors of the keys *S*1, *S*2 is carried out using the specialized driver IR2109 from the single-crystal microcontroller ATTINY13A. The switching frequency can vary from 18.8 to 72.0 kHz. The resonance frequency of the circuit *L*2*C*1 amounts to more than 42 kHz.

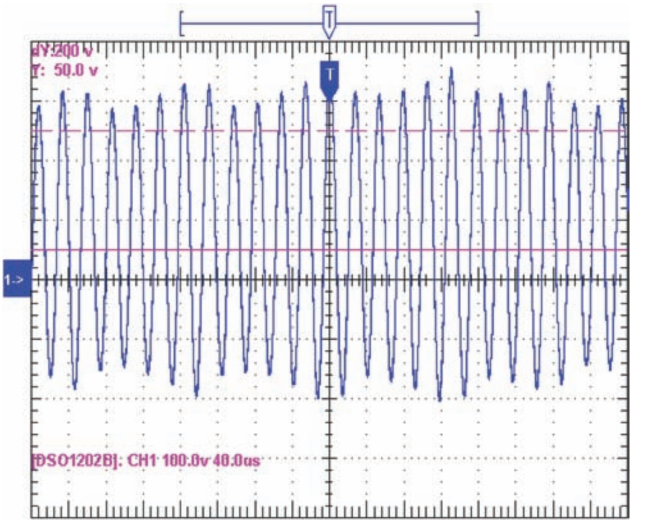

Figure 4. Oscillogram of output voltage (100 V/div; 40 μs/div)

To reduce the discreteness of change of the output frequency in the control program the division of clock frequency (4.8 MHz) of the controller was realized by the fractional coefficient. For this purpose the software sigma-delta modulator was used, the circuit of which is shown in Figure 3, where K^* is the required division factor (can be fractional); K is the actual division factor (integral).

The work of the algorithm results in the fact that the value of the coefficient K changes within some period so, that the average value of K strives to the preset K^*.

Figure 4 shows the oscillogram of the output voltage of the device in the absence of the arc. The periodic oscillations of the amplitude are explained by the work of algorithm of formation of fractional division factor.

The amplitude of the voltage at the electrode during operation of the device exceeds 300 V, which provides an easy ignition of the arc in manual arc welding. The time holding for the initiation of arc is established as about 1 s, in accordance with the requirements of DSTU 2456–94.

The appearance of the device is shown in Figure 5.

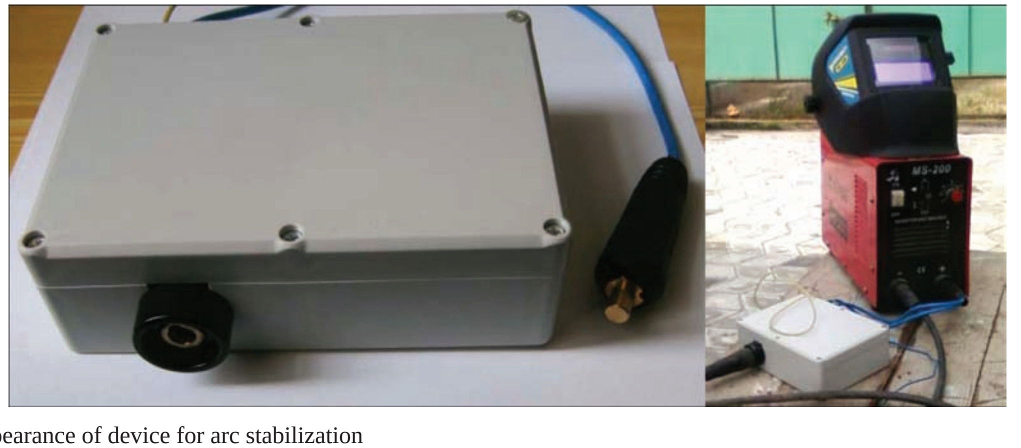

Figure 5. Appearance of device for arc stabilization

The application of the proposed device for arc stabilization allows improving the stability of quality of welded joints, the resistance of non-consumable electrode (in TIG welding) and facilitating the process of arc initiation in manual arc welding, especially while using welding electrodes of direct current.

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