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FORWARD INVERTER SOURCE WITH INCREASED POWER FACTOR

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A paper proposes a circuit design of single-phase forward inverter source with increased power factor. A peculiarity of the source is absence of additional power inductive components, reduced capacity of storage capacitor in direct current circuit and simplified limit circuit of its charging current. The source has increased open circuit voltage, which does not depend on mains voltage and allows providing easier arc ignition in manual arc welding. Current consumed from mains is 30–45 % lower than in «classical» inverter sources without power factor corrector due to increased power factor. 11 Ref., 1 Figure.

Keywords: *power factor, welding, welding inverter, source, arc ignition, arc burning stabilizing, open circuit voltage*

Inverter sources have gained wide distribution for solution of the problems of automatic and manual arc welding, plasma cutting, plasma and electric arc spraying as well as concurrent processes. At that inverter sources for manual and semi-automatic welding acquired the widest distribution. They provide due to their mass and dimension parameters, ease of work, high mobility of welder and possibility of formation of special type output VAC and their regulation in welding for ensuring optimum conditions of electrode metal transfer and decrease of spattering.

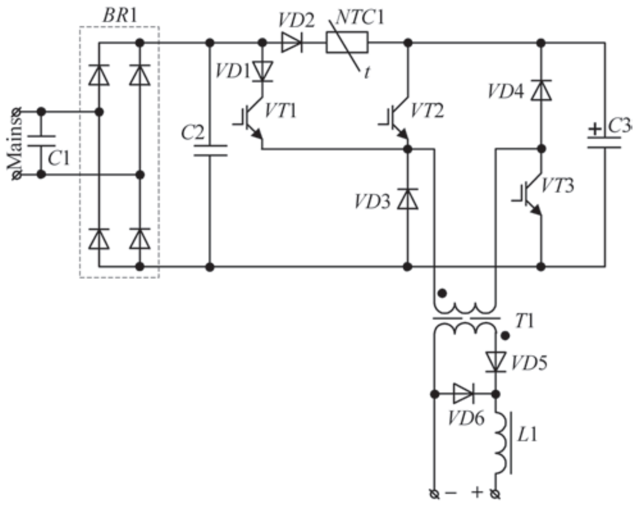
Sources for welding and related processes, widely applying electric arc, are nonlinear loads, i.e. generators of mains current higher harmonics. Work of such equipment in electric mains can result in the problems of electromagnetic compatibility with other technical means.

It should be noted that development of inverter welding sources is aimed at obtaining of high specific power, high efficiency, flexible formation of output VAC etc., but electromagnetic compatibility of source with mains is of extremely low attention. The electromagnetic compatibility implies a harmonic factor and consumption current unbalance factor (for three-phase sources), power factor (calculated in accordance with IEEE1459-2010 standard), level of high-frequency noises and etc. It is not quite correct to refer welding sources to energy-saving equipment [1–7] due to high harmonic factor in consumption current and on data of [8] electric welding equipment makes 65 % of potential sources of electromagnetic noises.

High-frequency energy conversion [9] is used for efficiency increase and improvement of mass and dimension parameters of welding sources. It results in decrease of weight and dimensions of source (up to 70 % according to [10]), reduction of energy losses in source, increase of performance and rise of range of output parameters regulation. Regardless obvious advantages of the inverter sources on weight and dimension characteristics and efficiency, developers do not pay enough attention to problems of increase of their power factor. Thus, testing of single-phase inverter source SELMA ARC-160 at consumption power 1.1 and 3 kW showed that its power factor varies from 0.652 (1.1 kW) to 0.702 (3 kW) and cosφ on the first harmonic makes from 0.992 (1.1 kW) to 0.998 (3kW).

Low power factor in inverter sourses is explained by high content of the harmonics in consumption current (harmonic factor is more than 100 %). This results in rise of energy losses in mains (these losses to a first approximation depend on square of true power factor) and distortion of mains voltage form. Appearance of voltage surges in mains is also possible due to resonances on higher harmonic frequencies at welding source operation, moreover voltage amplitude can reach 800 V [11].

High harmonic factor of consumption current of considered inverter welding source is explained by design of its power part, namely scheme of alternating to direct voltage converter. In SELMA ARC-160 source such a converter is a single-phase diode bridge with smoothing high-capacity capacitor (around 2000 μF) at the output. Besides, it is known fact, that electrolytic capacitors, especially operating under heavy conditions (increased current and temperature), have limited service life and require periodic replacement due to



Scheme of power part of developed welding source

capacity loss and growth of internal resistance. This fact somewhat reduces reliability of inverter welding sources, power circuits of which have capacitor storages of large energy intensity.

Most of currently manufactured inverter welding sources do not have adjustment of power factor and do not satisfy standard requirements on electromagnetic compatibility of technical means (DSTU IEC 61000-3-2:2004, DSTU EN 61000-3-12:2014) in the whole possible range of working modes.

Authors developed an inverter welding source with increased power factor. The source is made based on forward converter, in which magnetization and demagnetization circuits of transformer are split and one power key is added. A circuit of power part of the source is given in the Figure.

*VT*2, *VD*3, *VT*3, *VD*4, *C*3, *T*1, *VD*5, *VD*6 and *L*1 elements form classical forward converter. Capacitor *C*3 has relatively small capacity, which allowed limitating its charging current when switching on the source using single thermistor NTC1. Mains voltage is rectified with input rectifier, formed by diode bridge *BR*1. Blocking capacitors *C*1 and *C*2 loose entry of high-frequency noises in the mains.

The peculiarity of developed source is *VD*1, *VT*1 and *VD*2 elements introduced in the circuit. Presence of *VT*1 key allows supplying rectified, but not smoothed mains voltage on power transformer primary winding. Diode *VD*2, at that, prevents discharge of storage capacitor *C*3 on T1 winding. Diode *VD*1 protects transistor *VT*1 from backward voltage at open *VT*2. Such design of power part allows limited control of shape of current consumed from the mains.

The source operates in the following way. The basic power keys are *VT*1 and *VT*3, they are synchronously regulated. Forward running of the source is started at their simultaneous opening.

If rectified mains voltage at bridge BR1 output is enough for load current keeping, then a control system sets forward running pulse duration in such a way as to provide average (for key switching period) mains consumption current proportional to rectified mains voltage. This guarantees significant increase of source power factor.

If voltage on BR1 bridge output is not enough for load current keeping, then key *VT*2 is opened and voltage from storage capacitor *C*3 is supplied on primary winding *T*1 (on *C*3–*VT*2–*T*1–*VT*3–*C*3 circuit). Since this voltage virtually equals the amplitude of mains voltage, it is enough for load charging, i.e. welding arc. Thus, at small absolute value of mains voltage the source comes in a mode of pilot arc maintaining due to energy stored in *C*3.

Backward running of the source is started from the moment of closure of all power keys (*VT*1–*VT*3). Energy, accumulated in a magnetic field of T1 transformer, is discharged into storage capacitor C3. Current, at that, passes on *T*1–*VD*4–*C*3–*VD*3–*T*1 circuit. Diode *VD*5 is closed in the secondary circuit, load current (current of choke *L*1) is locked via *VD*6.

Voltage of capacitor *C*3 can be stabilized at a level not lower that mains voltage amplitude due to discharge of *T*1 field energy into it. This allows stabilizing source open-circuit voltage and makes it independent on mains voltage.

Besides, since demagnetization (backward running) of the transformer takes place at increased voltage (on capacitor *C*3) and forward running occurs at lower voltage (rectified mains voltage), there is a possibility of converter work with relative pulse duration more than 0,5, i.e. duration of forward running can exceed half of the switching period.

Developed source uses the principle of forward conversion, therefore load power is changed with double mains frequency. However, it does not have critical importance for welding purpose due to thermal inertia of weld pool. Deionization of arc gap at mains voltage zero crossing is prevented due to transfer in a mode of «pilot» arc with small capacity (see above).

Experimental source, designed on given circuit, has power factor not less than 0.9. Thanks to this root-mean-square current consumed from mains is 30–45 % lower than in «classical» inverter sources without power factor corrector.

Application of proposed inverter welding source allows reducing losses of electric energy in a distributing network due to decrease of acting current and rise of quality of mains voltage as a result of reduction of harmonic factor.

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