COATED ELECTRODE MANUAL-METAL ARC WELDING WITH HIGH FREQUENCY WELDING INVERTER POWER SOURCES

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Abstract – **The main application of electric arc is arc welding which represents a method of melt welding. The length of electric arc is little (up to 10 mm), the voltage is reduced (up to 45 V), and current can have the values in large limits (5- 5000 A). Through welding with high frequency power sources (tens kHz) the used transformer has the weight, the gauge and the electric winding and core length are extremely little.**
In the papers are shall analysed different work structures of coated electrode manual-metal arc welding inverter sources with the advantages and the disadvantages against the classic power sources. Through currents and voltage measurements are shall drawn conclusions about the improvement of the performances.

Keywords: *inverter power sources, manual-metal arc welding, electric arc.*

1. INTRODUCTION

Electric arc welding it consists of heating the metal surfaces of the parts to be joined to their plastic temperature and of applying the mechanically pressure in order to achive the union of metalic parts.
Through passage of heavy localized electric current the heating is accomplished. It use the alternating current or direct current.
The electric arc (that is discharge into a gas) is ignition between the electrode and the pieces at low voltage drops (10-40 V) at high currents (5-2000 A) [1].
From the all welding proceedings, manual-metal arc welding with consumable electrodes (sticks) is made in the world approximately 30%. A part of manual-metal arc welding is using the inverter welding power sources.

2. INVERTER POWER SOURCES

The development of the inverter power sources is incident to the evolution of the power electronics that is able to operate to high frequency.
This source type does the part from the category welding rectifiers commanded indirectly. For the welding rectifiers a main element is matching transformer to the ignition and initiation necessary values of electric arc.
Therewith it assures the galvanic separation between the supply mains and the welding circuit.
The welding transformer, through volume and weight, is the main element of the power source.
The commutation block - the inverter - is connected in the primary circuit of transformer. The inverter operate frequency is between 20-100 kHz through the use of semiconductors devices with power performances (MOSFET and IGBT transistors) [2].

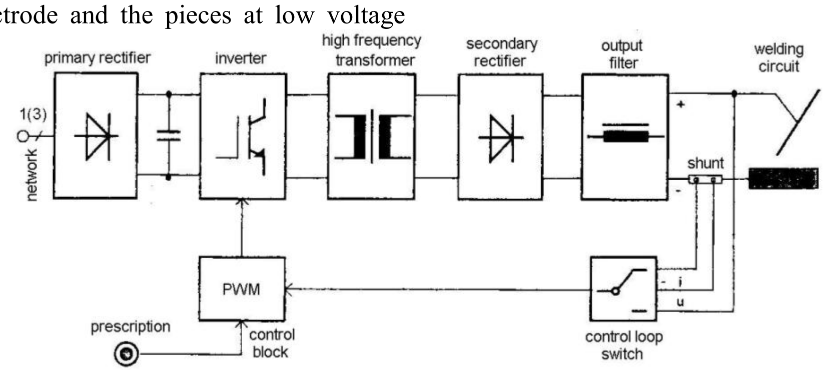

Figure1: The block diagram of the inverter welding power sources.

The secondary voltage is rectified, filtred and applied to the load.
Through utilization of the high frequencies inverter, is considerable reduced the gauge and the weight of the transformer:

$$A_{Fe} \cdot A_b = \frac{S_1}{2{,}22 \cdot k_{cu} \cdot J \cdot B_m \cdot f} \quad (1)$$

A_{Fe} – transverse cross section area of feromagnetic core [m^2];
A_b - transverse cross section of primary and secondary coils [mm^2];
S_1 – apparent power of transformer [VA];
k_{cu} – fill factor of coil [-] (0,6-0,8);
J – current density from windings (2-5 A/mm^2);
B_m – magnetic flux density (0,15-0,2 T);
f – inverter frequency [Hz].

In the relation (1) the voltage and current are consider to be sinusoidal and are neglected the pelicular affect and the proximity.

3. THE INVERTER POWER SOURCES TYPES

The electric structures for electric arc inverter welding power sources are: forward, push-pull forward, semi-bridge and bridge with power semiconductor devices MOSFET or IGBT [3,4].

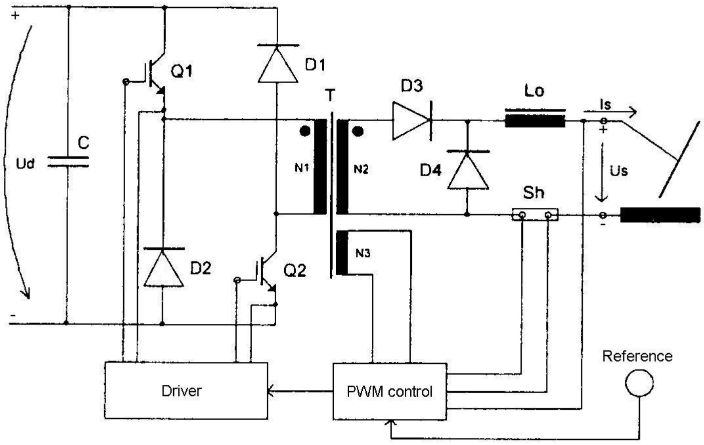

Figure 2: Block diagram for forward inverter welding power sources with two transistors.

In fig.2 is presented the forward inverter welding power sources with two transistors. It is use two power transistors Q_1 and Q_2 (IGBT type) and two diodes D_1 and D_2 for core demagnetizing. Q_1 and Q_2 are drive simultaneous. The maximum duty factor is D_{fmax}=0,5. The voltage drop on each transistor is U_d. The control output power is made with PWM regulator at constant commutation frequency through change duty factor. The welding power source are supply single-phase (220 V a.c.).

At power source with push-pull forward inverter (fig.3) is used with matching transformer with section primary winding, the neutral point be connect between the capacitors C_1 and C_2.

The transistors Q_1 and Q_2 can be commanded simultaneously or alternative. The voltage on transistors is reduced and output frequency is doubled when the transistors are commanded alternative. In this case, the structure and matching transformer are complex.

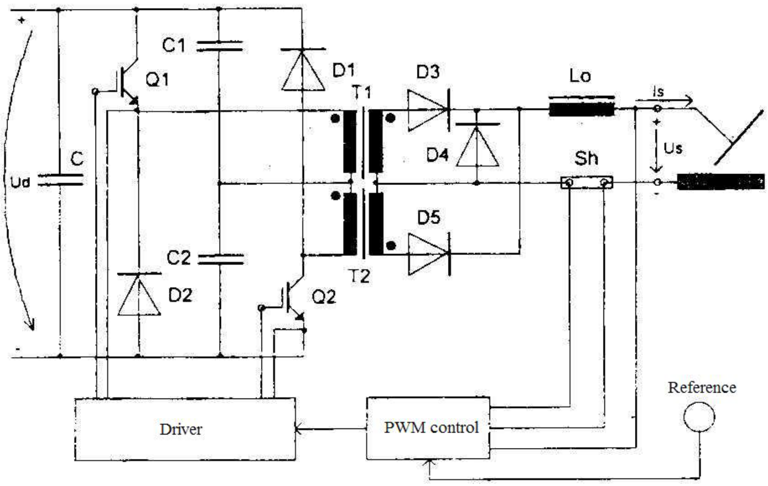

Figure 3: Block diagram for push-pull forward inverter welding power sources with two transistors.

In fig.4 is presented the configuration of the semi-bridge power source. The transistors Q_1 and Q_2 are commanded alternatively a semiperiod. The voltage drops on transistors is equal with 1/2·Ud. It can be utilized the transistors that have diodes incorporate. C_3 has the role to block the continuously current through the primary winding of transformer.

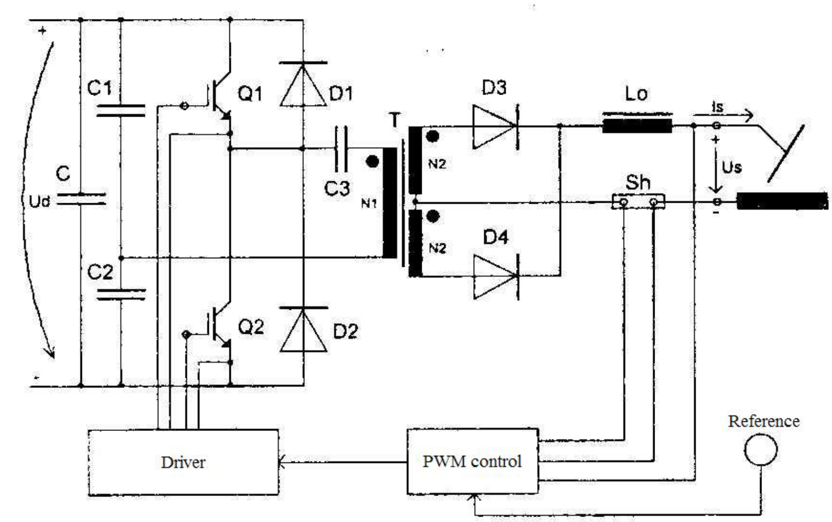

Figure 4: Block diagram for semi-bridge inverter welding power sources with two transistors.

The bridge power source has the configuration from fig.5 that permits bigger powers comparative with other configurations.
It is utilized four transistors (Q_1-Q_4) that are commanded alternatively, two on the diagonal (Q_1 and Q_3; Q_2 and Q_4). The disadvantages of this scheme is the number of semiconductors devices and the statement complexity.

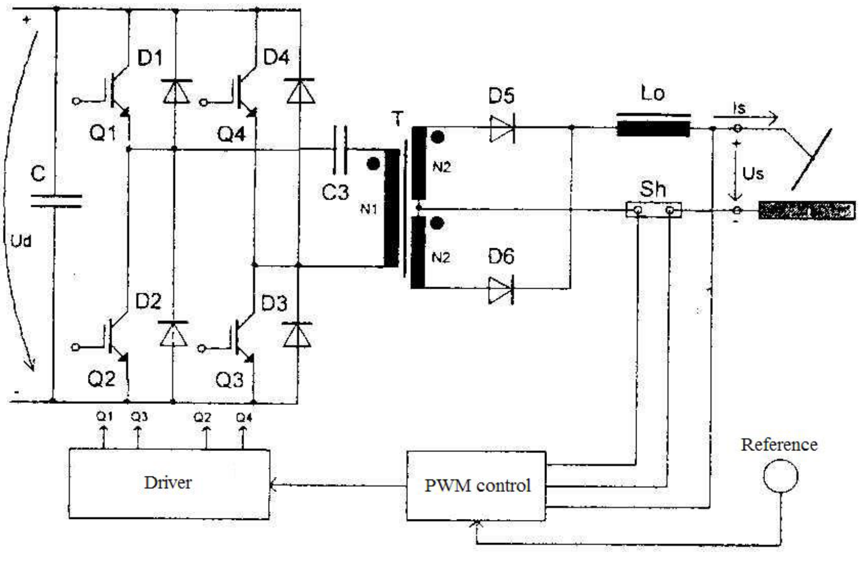

Figure 5: Block diagram for bridge inverter welding power sources with four transistors.

4. EXPERIMENTAL RESULTS

At experiments was used a forward inverter welding power sources, with two transistors Xenta Compact K 5-90 A (T.I.P., Germany). The welding is made at d.c. and constant current. Some parameters are presented bellow: U_1=230 V (50/60 Hz), U_0=63 V (no-load voltage) and $f_{inverter}$=20 kHz. At I_2=5A, U_2=20.2 V and I_2=90A, U_2=23.8 V. At I_2=30A, cosφ=0.77 and I_2=95A, cosφ=0.85 (index 2 represent welding circuit) [5].

D_c [%]	40	60	100

I$_2$ [A]	80	55	45
U$_2$ [V]	23.2	22.2	21.8

Table 1: Duty cycles, welding currents and voltage drops.

I$_1$[A]	6	7.3	11
S$_1$ [kVA]	1.3	1.7	2.6

Table 2: Primary currents and apparent powers.

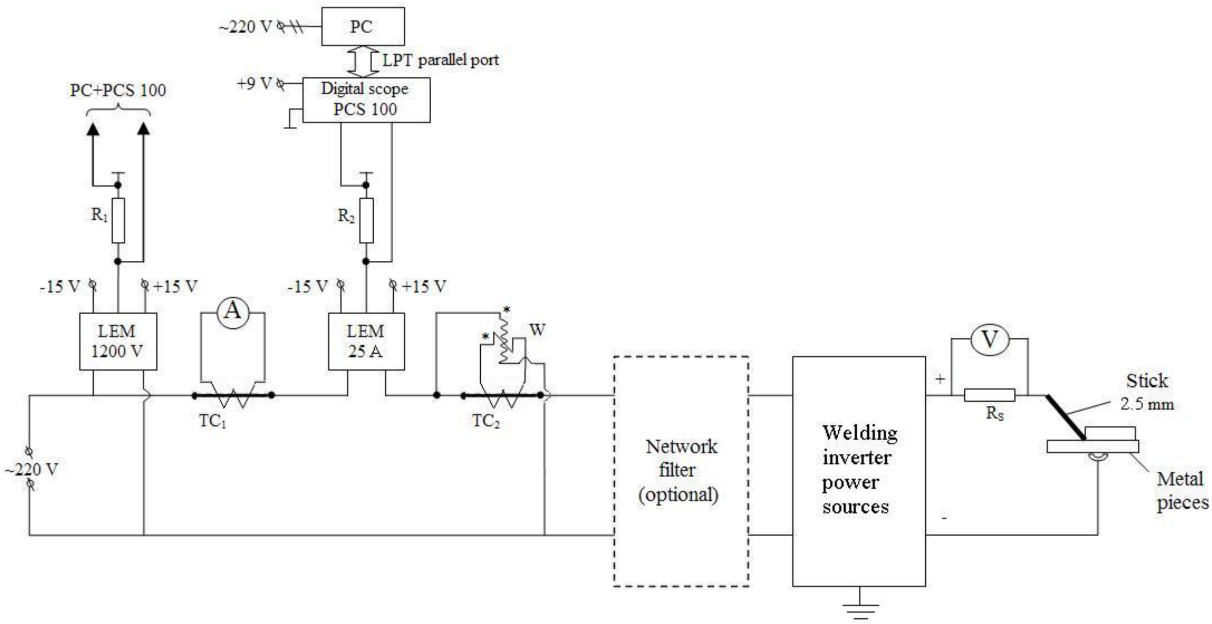

Figure 6: The experimental circuit used to measurements.

In fig.6:

- TC$_1$ 25A/5A current transformer, Metra type;
- LEM 25A Hall current transducer;
- R$_2$=119 Ω;
- PCS 100 digital scope, one channel, Velleman type;
- W wattmetre with light spot, EL 21 type;
- TC$_2$ 100A/5A current transformer, Metra type;
- welding inverter power sources Xenta Compact K, T.I.P. type;
- coated electrode 2.5 mm;
- A ammeter Protek 506 (TRMS);
- Multistab 235 voltage stable source for Hall transducer (±15V);
- Multistab 235 voltage stable source for wattmetre lamp (+6V);
- AN 156 voltage stable source for digital scope PCS 100;
- LEM 1200 V Hall voltage transducer;
- R$_2$=300 Ω;
- R$_s$ shunt resistance 100mV/100 A;
- V voltmeter Protek 506 (TRMS).

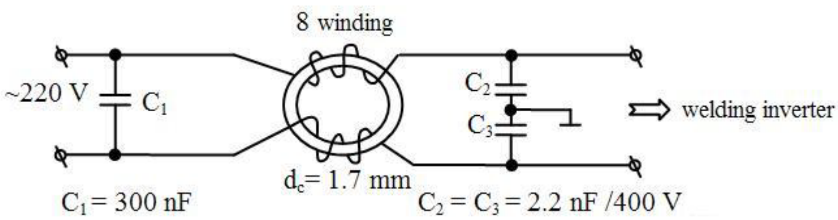

Figure 7: Networking filter include in welding inverter power sources.

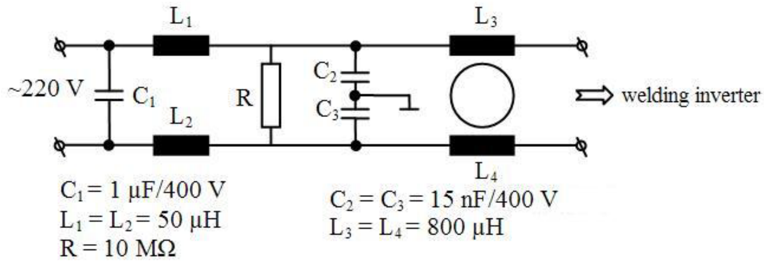

Figure 8: Optional networking filter (9A/220V)

In fig.9-16 the attenuation is 4.2 A/div. and the base time is 10 ms/div. The peak factor may be compute with:

$$k_p = \frac{I_{peak-peak}}{2 \cdot I_{TRMS}} \quad (2)$$

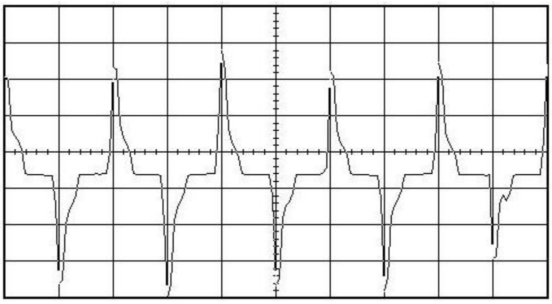
Figure 9: Primary current (dc+): I_{TRMS}= 2.95 A; $I_{peak\text{-}peak}$= 26.05; P = 1780 W; k_p=4.415

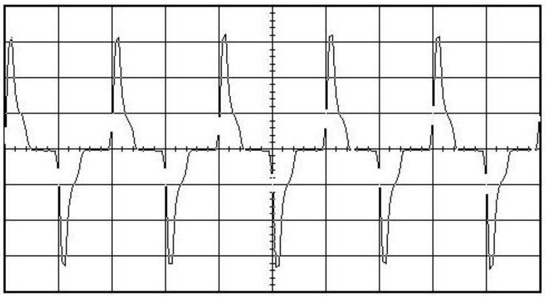
Figure 10: Primary current (dc-): I_{TRMS}= 3.35 A; $I_{peak\text{-}peak}$= 27.31; P = 1820 W; k_p=4.075

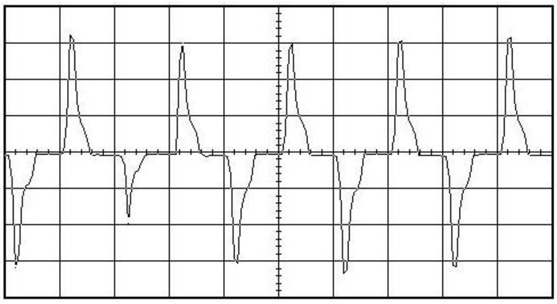
Figure 11: Primary current (dc+): I_{TRMS}= 2.9 A; $I_{peak\text{-}peak}$= 26.47; k_p=4.56

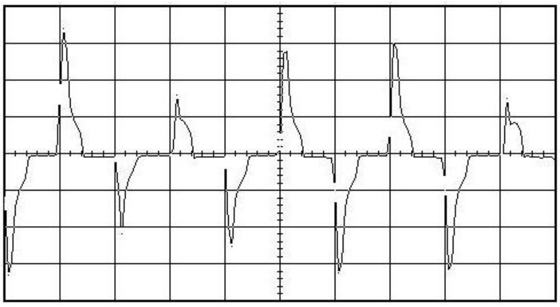
Figure 12: Primary current (dc-): I_{TRMS}= 2.75 A; $I_{peak\text{-}peak}$= 26.05; k_p=4.735

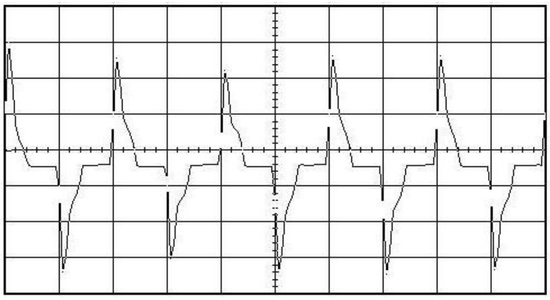
Figure 13: Primary current (dc+): I_{TRMS}= 2.7 A; $I_{peak\text{-}peak}$= 23.94; P=1720 W; k_p=4.43

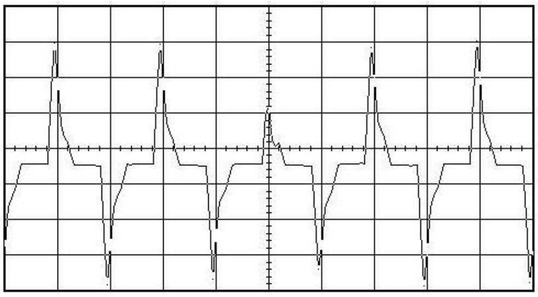
Figure 14: Primary current (dc-): I_{TRMS}= 3.45 A; $I_{peak\text{-}peak}$= 26.05; P=1800 W; k_p=3.775

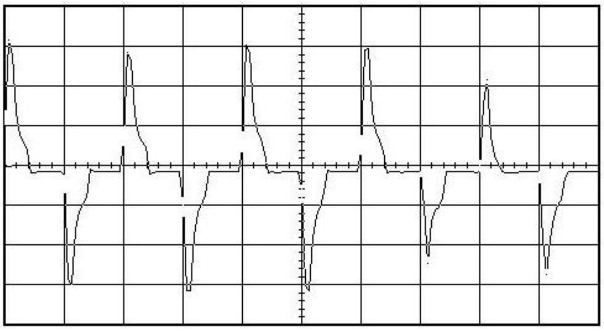

Figure 15: Primary current (dc+): I_{TRMS}= 3.5 A; $I_{peak-peak}$= 26.05; P=1820 W; k_p=3.72

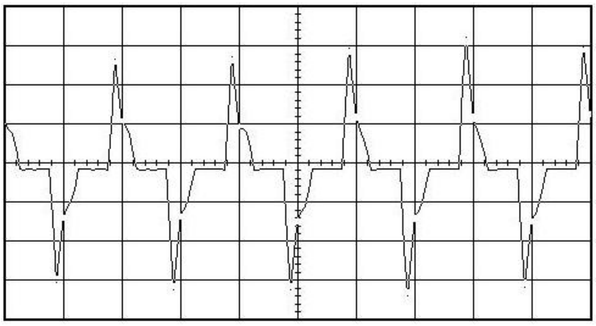

Figure 16: Primary current (dc-): I_{TRMS}= 3 A; $I_{peak-peak}$= 25.21; P=1800 W; k_p=4.2

To the realization of measurements was use the same secondary current (90A, maximum current) and the same distance between electrode and the metallic pieces.
The direct current electric arc has the direct polarity (dc-, straight-polarity arc) when the stick is connected to the source negative pole and the metalic pieces to the source positive pole. In the other case, the electric arc has the reverse polarity (dc+).
Fig.9, 10 represent current primary measurements with networking filter (fig.7) incorporated in the power sources at 90 A welding current.
Fig.11, 12 represent current primary measurements with two series networking filters (fig.7,8) at 90 A welding current.
Fig.13, 14 represent current primary measurements with networking filter (fig.7) and without earth at 90 A welding current.
Fig.15, 16 represent current primary measurements without networking filter (fig.7) and earth at 90 A welding current.

5. CONCLUSIONS

At the negative polarity, current and active power is bigger than positive polarity (fig.9,10). To these used-up measurements the networking filter (fig.7) incorporated in the power source.
When is used two series networking filters (fig.7,8) the effective absorbed currents (TRMS) from network (fig.11,12) are smaller than in the previous case, and the peak factors grow up, indicating a different form from sinusoid.
If earth missing, the absorbed currents have approximate the same form, negative polarity current is bigger than the positive polarity current (fig.13, 14). To these used-up measurements the networking filter (fig.7) incorporated in the power source.
In the situation which the earth and the networking filter (fig.7) are absent the positive polarity current is elder than one from negative polarity, and the forms of wave of currents are the same with others situations (fig.15, 16).
Generally, the negative polarity current is elder than one from positive polarity causing energy saveing. Must make the mechanical resistance of the welding for these two situation.
The networking filter incorporated in welding power sources (fig.7) do not improves form of current wave.

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