Specifics of Pulsed Arc Welding Power Supply Performance Based On A Transistor Switch

N Yu Krampit [1a], PhD in Technical Sciences, T S Kust [1b], PhD in Technical Sciences, M A Krampit [1c]

[1]Yurga Institute of Technology, TPU Affiliate, Russia, Kemerovo Region, Yurga

e-mail: [a] nkrampit@mail.ru, [b] kust@tpu.ru, [c] krampitm@tpu.ru

Abstract. Specifics of designing a pulsed arc welding power supply device are presented in the paper. Electronic components for managing large current was analyzed. Strengths and shortcomings of power supply circuits based on thyristor, bipolar transistor and MOSFET are outlined. As a base unit for pulsed arc welding was chosen MOSFET transistor, which is easy to manage. Measures to protect a transistor are given. As for the transistor control device is a microcontroller Arduino which has a low cost and adequate performance of the work. Bead transfer principle is to change the voltage on the arc in the formation of beads on the wire end. Microcontroller controls transistor when the arc voltage reaches the threshold voltage. Thus there is a separation and transfer of beads without splashing. Control strategies tested on a real device and presented. The error in the operation of the device is less than 25 us, it can be used controlling drop transfer at high frequencies (up to 1300 Hz).

1. Introduction

Switching high currents occurs when designing pulsed arc welding power supply devices, provided that processes are changed rapidly, but weight and size characteristics of these devices are modified minimally. Ascertainment of a rational method for designing pulsed arc welding power supply devices is possible on condition that solutions of problems below are found:

  - an appropriate power switch to control large-scale load is selected;
  - a control circuit of a power switch is identified;
  - a device based on the circuit above is designed and tested.

2. Results and Discussion

Thyristor [1], bipolar transistor [2] and MOSFET [3] are used as power switches in pulsed arc welding power supply devices. Each circuit has its specifics, as well as strengths and shortcomings.

   The following drawbacks affecting the power supply device are to be taken into account when designing a thyristor-based power supply device [4]:

  - low operating speed because of a long turn-off time;
  - restricted controllability: low-power control circuit is used for thyristor activation, whereas power circuit – for its blanking;
  - blanking is possible via short voltage impulses, decreasing interference immunity of thyristor-based devices.

A power supply device can be based on a bipolar transistor. There are three main connection circuits of a bipolar transistor available: common base transistors, common emitter transistors and common collector transistors. Each of them has its shortcomings [5].

Defects of the common base connection circuit are as follows:

- low current gain (below 1);
- low input resistance;
- two different voltage sources for power supply.

The common emitter connection circuit has worse temperature and frequency characteristics than the common base connection circuit, so it is its main drawback.

A common collector connection circuit can be considered imperfect because its coefficient of voltage gain is below 1.

The paper presents a voltage feedback algorithm to control drop transfer.

MOSFET is a voltage-controlled transistor in comparison to the bipolar one. It is currently the best possible low-energy circuit in the static quiescent mode [6]. These transistors are of a small size but their capacity amounts to hundreds of Watt. They are also distinguished by high operating speed and good interference immunity.

Pulsed arc welding is a reasonably complex process. Electric current pulse-up is to be at the rigorously defined moment in order to support electrode metal drop transfer to a weldpool. As the result of a couple of milliseconds error the main condition of process control "one impulse – one drop" is broken, as the consequence, electrode metal splashing increases.

As there are a lot of factors affecting the process of welding, it's rather difficult to predict it and set all welding parameters beforehand. Any current network disturbance or slip of a wire supply mechanism can lead to the increase in an inter-pulse period. This problem is rationally solved by means of arc voltage feedback because the arc is shortened; consequently, arc voltage gets diminished when balancing an electrode drop on the wire end (Figure 1). A stable welding process i.e. without electrode metal splashing is possible via regulating the threshold voltage, followed by a pulse pile-up. The control algorithm is presented in Figure 2.
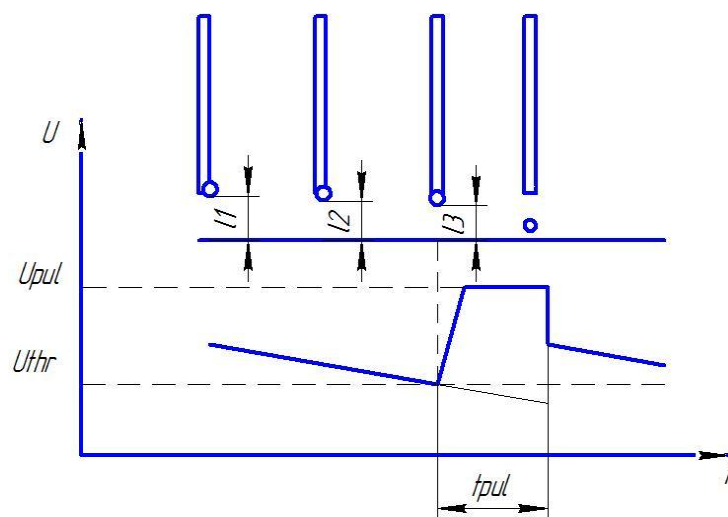

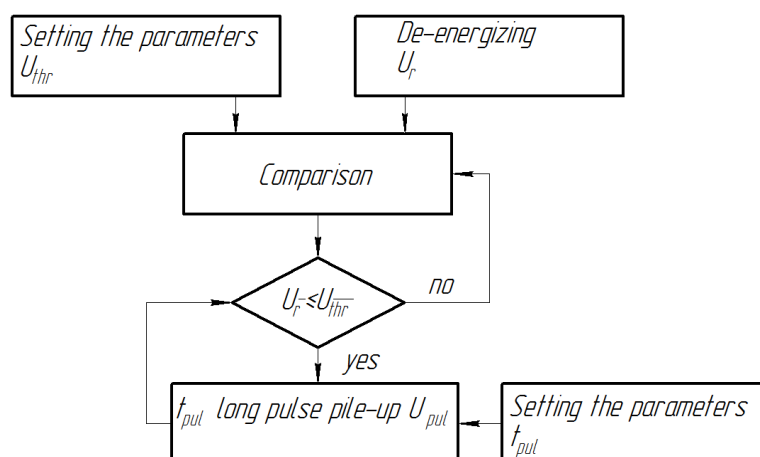**Figure 1 -** Control strategy of voltage feedback drop transfer

Figure 2 - The algorithm to control voltage feedback drop transfer

Microcontroller Arduino UNO, having 6 analog inputs and 14 digital inputs and outputs, operated at frequency 16 MHz was used to control the transistor. 5 V digital input voltage was sufficient to turn on the MOSFET. They also can be used as pulse-width modulation outputs (PWM), i.e. an irregular shape of the impulse can be set [7, 8].

The algorithm above was tested on pulsed arc power supply device. Oscillograms of the process are shown in Figure 3. They demonstrate that at the frequency less 1300 Hz time inaccuracy is irrelevant and does not exceed 25 us.
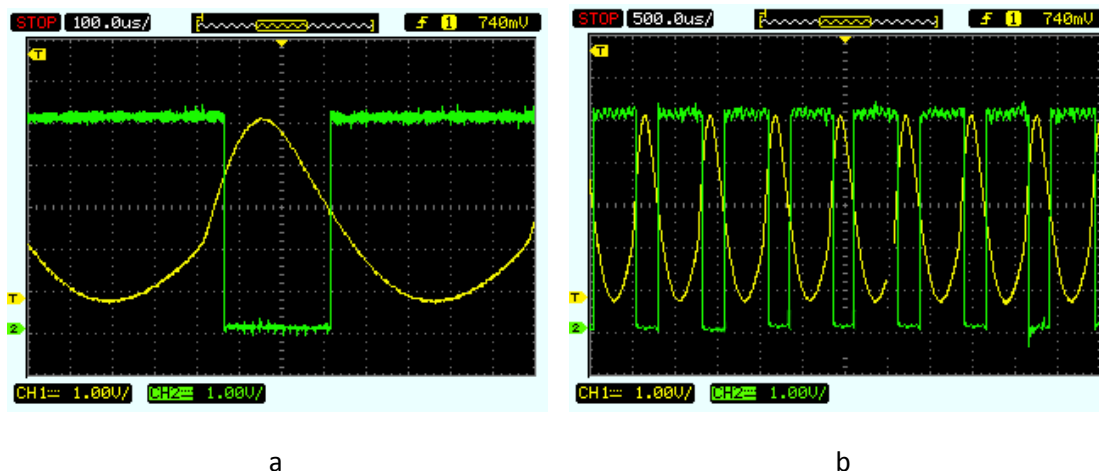

a	b

Figure 3 Pulse pile-up at Uthr
f=1300 Hz; Uthr=3 V

The authors [9] suggest a pulsed arc welding mechanism, where a wire section is heated by flowing inter-pulse current. However, overheating is possible. The wire can get crumpled up when entering a terminal clamp owing to limpness caused by heating over the defined temperature. The current flowing through the wire diminishes to the inter-pulse current. These parameters are to be adjusted when welding; and wire overheating is to be avoided.

A thermocouple is to be placed into a terminal clamp in order to de-energize the arc and remove electric current intensity from it. The data are converted in the microcontroller, signaling to the servodrive. The servodrive moves the second terminal clamp, changing the length of a wire section. Its resistance is changed; therefore, inter-pulse current strength and wire heating temperature vary.

One of the most frequent failure reasons of MOSFET-based electronic devices is exceeding the allowed value of drain-to-source voltage. [10]. For instance, voltage spike occurs when switching the inductive load; and its amplitude exceeds the maximal allowed voltage of a MOSFET. As the result, avalanche breakdown of a semi-conductor and transistor damage are possible. A fuse diode VD1 is placed between drain and source in the circuit for MOSFET protection (Fig. 4). Transient MOSFET processes are frequently possible due to the electrostatic discharge. Suppressor VD2 placed between drain and source makes it possible to protect the transistor from input transient processes. A protective diode is mounted with the reverse voltage value, exceeding the MOSFET input value (see Fig. 4).
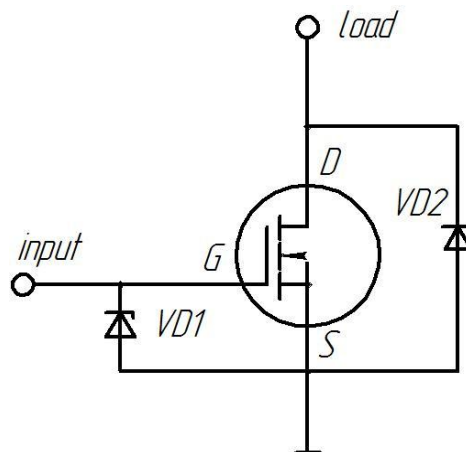

Figure 4 - A diagram of transistor protection

A modulator comprising a microcontroller and a MOSFET was designed and tested as the device base for electrode extension heating by inter-pulse current [11]. Computations of the process and carried out research reveal high energy efficiency. Quality of weld joints at diminished energy input meets the standards (Fig. 5).

Figure 5 - Electric current and voltage oscillogram of pulsed arc welding based on heating electrode extension by inter-pulse current

3. Conclusions

1. Optimal construction of devices for pulsed arc welding based on MOSFET. Microcontroller with voltage feedback serves control the transistor.

2. A voltage feedback microcontroller facilitates a controlled transfer when pulsed arc welding at frequencies below 1300 Hz.

3. This device allows to create power supplies for pulsed arc welding on the basis of any welding rectifiers at low cost price

Reference

[1]   Hao W L, Luo F and Ieee 2009 Development of Constant Voltage Control System for Hot-melt Pipe Welding Iccsse 2009: *Proceedings of 2009 4th International Conference on Computer Science & Education* 491-4

[2]   Dudrik J and Trip N D 2010 Soft-Switching PS-PWM DC-DC Converter for Full-Load Range Applications *Ieee Transactions on Industrial Electronics* **57** 2807-14

[3]   Zhang Z J, Li H M, Peng Y L and Ieee 2006 Application of MOSFET solid. state high frequency power supply in pipe welding. In: *IEEE Region 10 Conference (TENCON 2006),* (Hong Kong, PEOPLES R CHINA: Ieee) pp 9-11

[4]   Shammas N Y A, Eio S and Chamumd D 2009 Electronic Circuits for Switching-Time Reduction of Bipolar Semiconductor Devices *Proceedings of the 13th Wseas International Conference on Recent Advances in Circuits* 28-42

[5]   Kuo Y and Lei Y 2004 Fabrication and characterization of hydrogenated amorphous silicon bipolar thin film transistor (B-TFT). In: *Symposium on Amorphous and Nanocrystalline Silicon Science and Technology held at the 2004 MRS Spring Meeting,* (San Francisco, CA: Materials Research Society) pp 709-14

[6]   Stepins D 2016 An Improved Control Technique of Switching-Frequency-Modulated Power Factor Correctors for Low THD and High Power Factor *Ieee Transactions on Power Electronics* **31** 5201-14

[7]   Panigrahi P K and Sahoo S 2015 Path Planning and Control of Autonomous Robotic Agent Using Mamdani Based Fuzzy Logic Controller and ARDUINO UNO Micro Controller *Proceedings of the 3rd International Conference on Frontiers of Intelligent Computing: Theory and Applications (Ficta) 2014, Vol 1* **327** 175-83

[8]   Choi S J and Kang B G 2014 Prototype Design and Implementation of an Automatic Control System Based on a BCI *Wireless Personal Communications* **79** 2551-63

[9]   Krampit N.Yu., Krampit M.A. 2015 Pulsed-arc welding with preheating of electrode extension in the break period In: *Welding International.* **29** 210-212

[10]   Bodeker C and Kaminski N 2015 Investigation of an overvoltage protection for fast switching silicon carbide transistors *Iet Power Electronics* **8** 2336-42

[11]   Knyazkov, A.F., Krampit, N.Yu., Krampit, A.G., Knyazkov, S.A. 2005 Device and method of energy dosing at the pulse-arc CO_2 welding *Avtomatizatsiya i Sovremennye Tekhnologii* **10** 19-21