Design of a low pulse high current LLC resonant converter for EDM applications

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Abstract

The design of the LLC resonant converter is presented for use in Electric discharge machining (EDM) applications. The converter is designed to operate with a 3phase ac input voltage and will output controlled dc voltages during the striking and arc conditions of EDM process. The method of the LLC resonant converter can operate at zero voltage and zero current transitions, we change the output current and control the current waveform of the EDM.

Keywords: Electric discharge machining (EDM), LLC, Resonant converter, Frequency control, Sic-MOSFET

1. Introduction

In this general, we have developed and improve the technology of performance equalization control of Electric discharge machining (EDM) applications. We change the output current and control the current waveform of the EDM. To control the current and the loss of the electrodes and increased the processing speed and the processed object will not be too Rough so we have designed a smoothly rising current to let the electrode lossless; and to processing the super-hard alloy we have designed a low pulse high output current.

2. Developments in Power Configurations

The shapes of voltage and current pulses in the discharge gap depend on the chosen power supply. There are two types of power supplies that have received most interest amongst the scientific community. They are Resistance Capacitance (RC) power supply, transistor switching circuit, Figure1 show the two type of power supply.

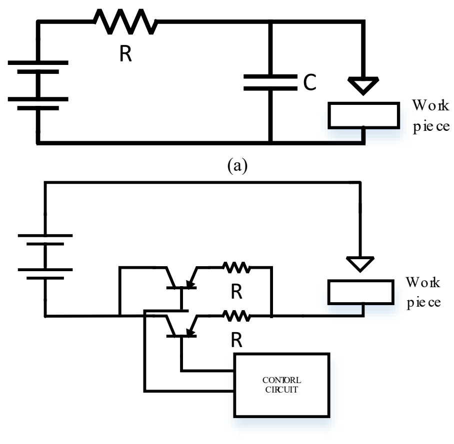


Fig 1(a) Resistance Capacitance (RC) power; (b) transistor switching circuit

Those two type of EDM power supply topology applies a square wave current as shown in Figure 2, the waveform of a fixed current pulse width method is used and control the pulse width of the discharge and keep current certain width to maintain the surface of the work

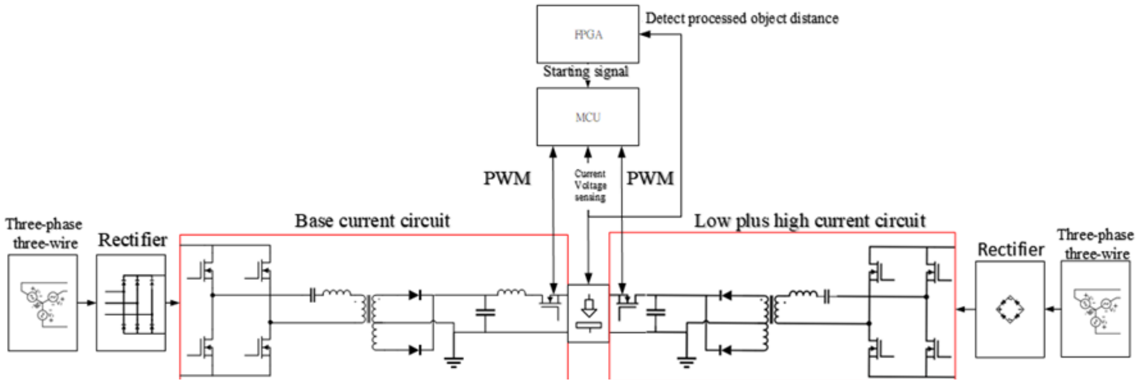


Fig 2 Circuit diagram of the EDM power supply using a full-bridge LLC resonant converter.

piece smooth. However, to increase the processing speed, the peak current Ip of the discharge current pulse will increase, but the processing surface will become rough, and the electrode consumption ratio will also increase. In order to reduce the electrode consumption, the discharge current pulse width T can be increased. At this time, as the discharge current pulse width T increases, the thickness of the work piece surface also becomes rough.

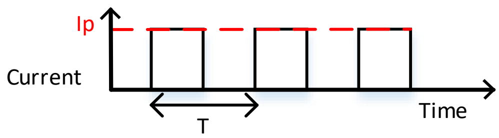


Fig 3 output current waveform

Therefore, a new circuit topology is proposed, and the output waveform is as shown in Figure 3. It consists of a slowly rising base current square waveform t1 to t2 and a low pulse high peak current waveform t2 to t3. These two waveforms are composed to find out whether the characteristics of the processed object can be maintained. The homogenization, acceleration of processing speed, reduction of electrode loss and improvement of the thickness of the machined surface. The relationship of these characteristics to the discharge current waveform and the realization of the current waveform circuit finally proposed.

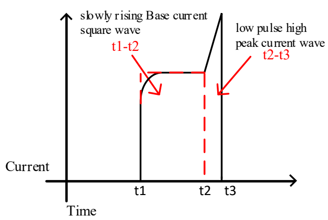


Fig 4 new design output waveform

3. Full-bridge LLC resonate converter experimental Prototype

The designed EDM impulse generator is a full-bridge resonant converter whose switching frequency is far higher than the machining frequency and we using Sic MOSFET as switch. LLC resonant converters are able to achieve the required voltage for the dielectric breakdown and, working above the resonant frequency current lags voltage so this topology achieves zero voltage switching, resulting in minimum switching losses.

3.1. *Full-bridge LLC resonate converter overview*

To achieved two different waveforms, so we set two parallel LLC circuit to create base current and low plus high peak current, these two converters are designed to operate with three-phase three-line ac input voltage and output will be controlled two different dc voltages during the EDM process, the method employed magnitude and frequency control to enable the converter to operate at zero voltage and zero current transitions. During the EDM process will have two different output current first is the base current, the base current is to reduce the electrode the current will be smoothly rising to the base current, when the base current has risen to the stable state, the second LLC will be started output the low pulse high current waveform shows in Figure 4.

3.2. *LLC resonant inverter analysis and design*

LLC resonant converter gain K is the product of the bridge switching gain, the resonance loop gain, and the transformer's primary-side turns (NP) and secondary-side turns (NS). The resonant tank circuit is composed of the element resonant inductor Lr, resonant capacitor Cr, and excitation inductance Lm. The resonant element is used to achieve zero voltage or zero current switching of the power switch, and the switching frequency is adjusted to change the output voltage. The resonance loop gain can be analyzed by analyzing the equivalent resonance The circuit is shown in Figure 5. The equivalent circuit shows that its resonance gain is shown in Equation (1).

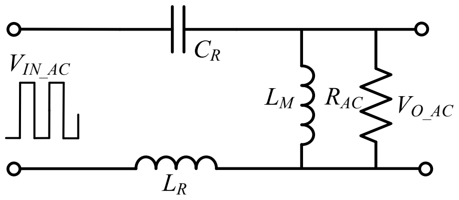


Fig 5 LLC series-parallel resonant tank equivalent circuit diagram

$$K(Q,m,F_x) = \left|\frac{V_{O\_AC}(s)}{V_{IN\_AC}(s)}\right| = \frac{F_x^2(m-1)}{\sqrt{(m\cdot F_x^2-1)^2+F_x^2\cdot(F_x^2-1)^2\cdot(m-1)^2\cdot Q^2}} \quad (1)$$

3.3. *Design the resonant tank*

The circuit parameter design The K value is obtained by the above method, and its verification parameters are already a better design of the circuit. Therefore, the Q value, Fx and fr can be used to solve the equation, and the resonance can be obtained by equations (2) and (3) The resonance inductance and resonance capacitance of the tank are obtained by formula (6) to complete the parameter design of the resonance tank element, the formula is as follows.

Quality factor Q:

$$Q=\frac{\sqrt{L_R/C_R}}{R_{AC}} \quad (2)$$

Resonant frequency fr:

$$f_r = \frac{1}{2\pi\sqrt{L_R\cdot C_R}} \quad (3)$$

The reflected load resistance at full load:

$$R_{ac}=\frac{8}{\pi^2}\times\frac{N_p^2}{N_s^2}\times R_o \quad (4)$$

Ratio of switching frequency fs and resonance frequency fr:

$$F_x=\frac{f_s}{f_r} \quad (5)$$

Ratio of primary inductance to resonant inductance m:

$$m = \frac{L_r+L_m}{L_r} \quad (6)$$

The influence of design parameters on voltage regulation and efficiency performance, and the design of resonant tank parameters according to system specifications. The ultimate design goal is to achieve the load to operate at the best performance under any conditions. The detailed design flowchart of the design method is shown in the Figure6

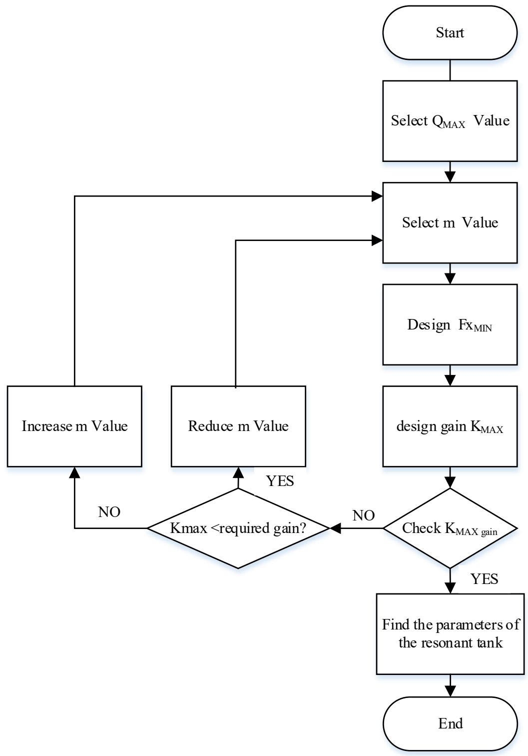


Fig 6 Resonant tank parameter design flow chart

4. Full-bridge LLC simulation results

Follow the step of the flow chart shown in Figure 6 to design the LLC resonant converter. The base current output voltage has design 60v and the low pulse high

Table 1 Base current wave form Specifications

Base current wave form	Specifications
Input voltage 3Φ3W	220V
Output voltage(V_{o1})	60V
Output power(P_{o1})	120W
Switching Frequency	100kHz
Waveform time(t1-t2)	300ms

current designs with 100v, the design data show in Tabel1 and Table2.

Table 2 Low plus high current peak waveform Specifications

Low plus high current peak waveform	Specifications
Input voltage3Φ3W	220V
Output voltage(V_{o2})	100V
Output power(P_{o2})	500W
Switching Frequency	100kHz
Waveform time(t2-t3)	100ms

4.1. *Full-bridge LLC simulation*

In this section, the diagram of the EDM system with ac to dc power supply and transistorized switching circuit as pulse generator designed in PSPICE and PSIM and schematic diagram is shown in Figure 7 there are two LLC converter which private 60v and 100v and the simulation output is shown in Figure 8.

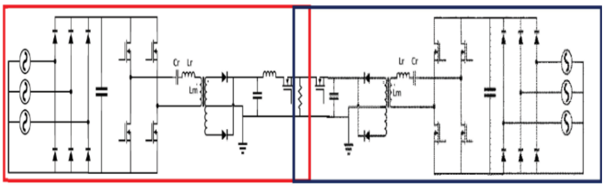


Fig 7 schematic diagram

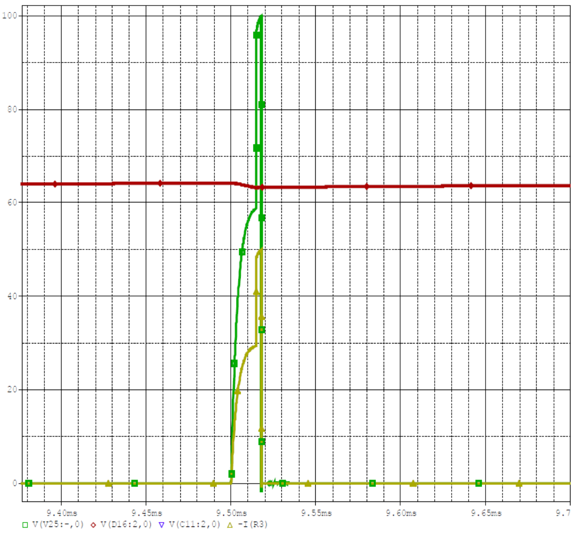


Fig 8 Results of parallel LLC simulation (green is output voltage; yellow is output current)

5. Experimental results

The simulation has approved that circuit can get the output that a smoothly rising current and a low pulse high peak current and next we design a prototype to test the waveform the prototype shown in Figure 9 and the output waveform shown in Figure 10.

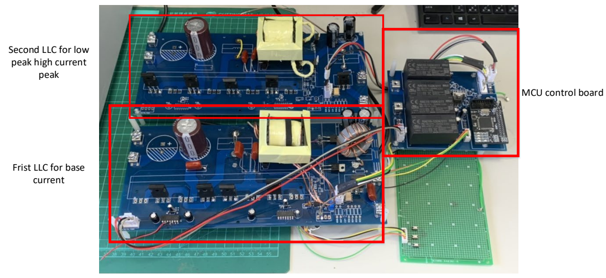
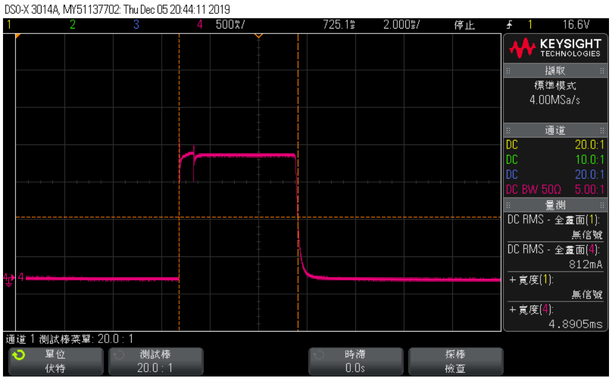
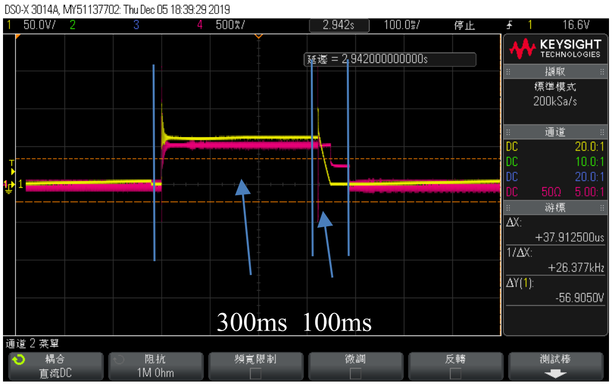


Fig 9 Prototype power system



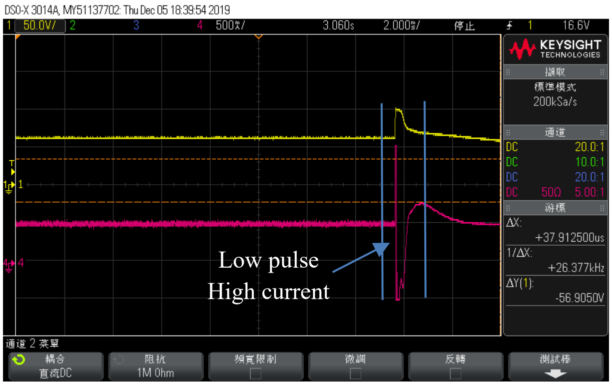
(a)

(I_4:500mA/ div、Time：2ms/ div)



(b)

(V_{O1}:50V/ div、I_4:500mA/ div、Time：100ms/ div)



(c)

(V_{O1}:50V/ div、I_4:500mA/ div、Time：2m s/ div)

Fig 10 output waveform;(a)base current output 2A;(b)two

LLC output waveform(c) low pulse high peak current output

6. Conclusion

Design a parallel LLC circuit, and complete the basic wave circuit and low pulse high peak current output, with four Sic Mosfet. The output waveform still needs to be CLOSER to the simulation output and connected to The EDM machine to teste for electricity consumption and the processing speed.

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