

Development of high frequency pulse power source using two powers for TIG welding

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Abstract A high frequency pulse power source for TIG welding is developed . The structure of two powers is adopted . The by-pass circuit effectively eliminates the effect of the cable equivalent inductance . The maximum frequency of the output pulse current reaches to 16kHz . The base current and the peak current can be regulated separately .

Key words high frequency pulse , TIG welding , arc welding power source

0 Introduction

With the development of the manufacture , high efficiency and high quality welding methods are needed . One of them is the high frequency pulse TIG welding . The electromagnetic compression effect of the high frequency current makes the arc shrink and stable . So the welding method has following technology merit : (1) High energy density arc makes narrow and deep weld . (2) High frequency oscillation makes crystal particle smaller , which can reduce weld flaw and improve mechanical properties of weld . (3) The high frequency arc has good rigidity , in high speed welding the arc is stable . The welding speed can reach to 2.5 m/min , which is seven times that of shielded arc welding , 2.5 times that traditional pulse TIG welding^[1] .

The frequency of traditional pulse power is very small , which restricts the use of high frequency pulse welding method . Modern power electronic technique provides some high-power switch elements , such as IGBT , which makes it possible to develop new kind of advanced high frequency pulse power source^[2] .

1 Technique specifications

(1) Input voltage	three phase 380 V
(2) Output no-load voltage	60 V
(3) Frequency of output pulse current	5 kHz ~ 16 kHz
(4) Pulse width ratio of output current	50 %
(5) Range of peak current	5 ~ 200 A
(6) Range of base current	5 ~ 200 A

2 Composition of the welding power source

The traditional pulse power takes the structure of one power . Due to following reasons , the maximum output current frequency of this kind of pulse power is small .

(1) This kind of power uses current negative feedback to obtain constant current output characteristic. Some response time is needed from certain current set signal to the corresponding real output current. Now the inverter power is the fastest power in the aspect of dynamic response time. But the simulator analysis and experiment study both shows that the minimum dynamic response time of the inverter power only reaches to the level of some hundred microseconds. So the maximum frequency of the output pulse current just is 1 kHz.

(2) The base current and peak current are from a same power. Due to the effect of cable inductance, some rising time is needed from base current to peak current. Larger the discrimination between base current and peak current is, longer the rising time is. With the increase of pulse frequency, the output current wave becomes misshapen and is not the needed square wave, which limits the maximum value of the pulse frequency.

In order to improve the pulse frequency, our power takes the structure of two powers. The main circuit is shown as Fig.1. The working principle is shown as Fig.2.

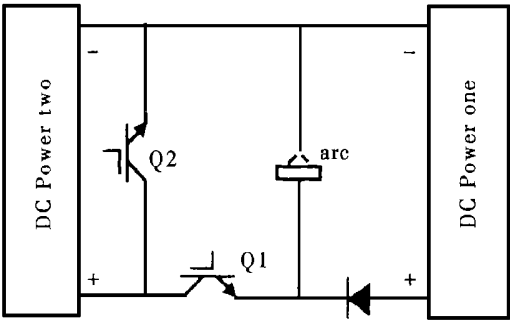
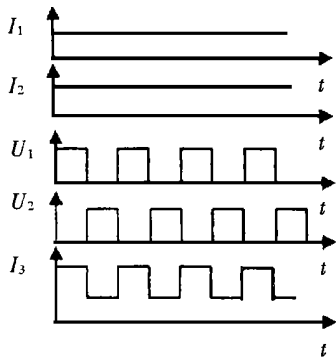


Fig.1 Composition of the high frequency power



I1,I2- output current of power one, power two
U1,U2- driver signal of Q1,Q2
I3- the output current of the whole power

Fig.2 The working principle

The power one always works and provides base current. When the switch Q1 turns on, the power two and the power one together provides the peak current. By controlling the switch Q1 on or off alternately, the whole power thus outputs pulse current. The maximum frequency of the output pulse current is determined by three factors, they are the switch time of Q1, the equivalent inductance of the output cables of power two and the parasitic wave frequency of output current of two powers. The switch Q1 and Q2 adopt IGBT. The switch time of IGBT is 0.5~1 microsecond which can be ignored. The by-pass switch Q2 can effectively eliminate the effect of the equivalent inductance of output cables.

Two DC powers have constant current output characteristic. More smooth the output current wave is, better it is. The simulative power is the best, but its power dissipation is large. Here, two IGBT switch style DC powers are used. The working frequency of the switch IGBT of each power is set at 25 kHz.

The value of base current and the value of peak current can be regulated separately by separately regulating output currents of power one and power two.

3 Function of the switch Q2

In order to eliminate the influence of the output cable equivalent inductance and to further improve the frequency of output pulse current, we add a by-pass switch Q2 at the output ends of the power two. When the switch Q1 closes, the switch Q2 opens, which provide a by-pass current path for the power two.

The explanation is as follows :

Without the switch Q2, the working state of the power two can be expressed as Fig. 3a. In this figure, the output voltage of the power two is U , the equivalent inductance of the output cables of the

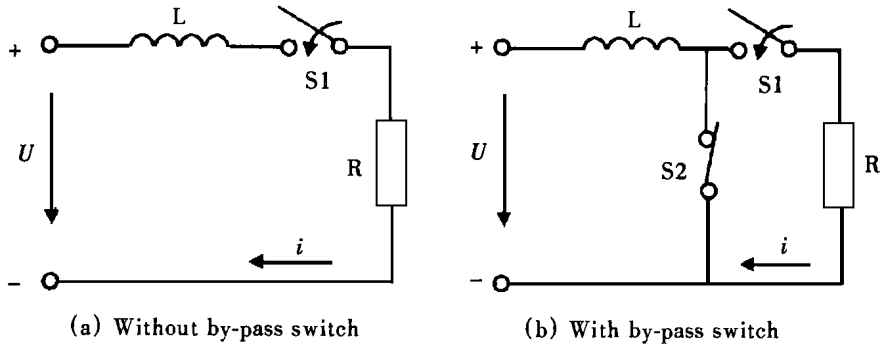


Fig.3 The schematic diagram of the working state of power two with or without by-pass switch

power two is L , the switch $S1$ stands for the switch $Q1$, R is the arc load. Omitting the turn-on and turn-off time of the switch, we can see the L 's effect on the current rising speed. When the switch $S1$ works from off to on, the output current rises from 0 to I . This is a transient process in which the output current i changes as formula (1) :

$$i = I(1 - e^{-\frac{t}{\tau}}) \quad (1)$$

In formula (1), $\tau = L/R$, L approximately is $20 \mu\text{H}$, suppose R is 0.1 ohm , thus $\tau = 200 \mu\text{s}$ and the transient process lasts longer time. So we can see that the inductance L affects the rising speed of the pulse current and limits the maximum frequency of the output current. When the frequency reaches some high value, namely the switch frequency of $Q1$ is high, the switch $Q1$ already closes before the output current raise to stable value, so the output current wave becomes misshapen and is not the needed square wave. Fig.4 is the real output pulse current wave of power two without the by-pass switch. The wave is measured by a LEM current sensor.

With the by-pass circuit, the working state of the power two is shown as Fig.3b. The switch $S2$ stands for the switch $Q2$ of the main circuit of the whole power. When $S1$ is off, $S2$ is on, the switch $S2$ does not turn off until $S1$ has fully turn on and the current passing $S1$ has reached to the stable value I . Thus the current passing the inductance L varies little when the switch $S1$ turns on or turns off. There hardly is a transient process. So the current i can instantly reach stable value after the switch $S1$ turns on. By the aid of the by-pass switch, the maximum frequency of the output current of the pulse power can

reach higher value . The experiment also shows that the output current wave of the power two with by-pass circuit can maintain square wave when the frequency is higher . See Fig.5 .

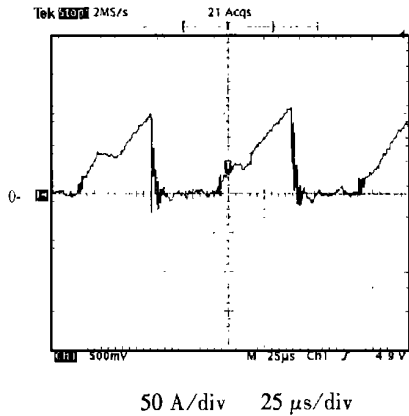


Fig.4 The output current wave of the power two without by-pass switch

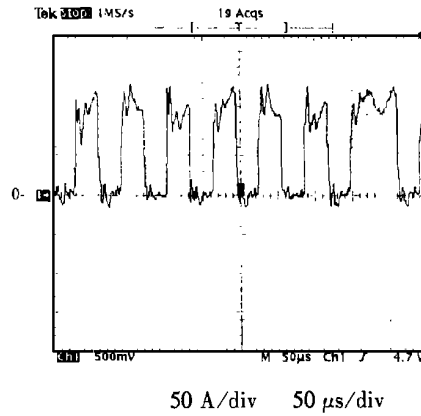


Fig.5 The output current wave of the power two with by-pass switch

Additionally, with the by-pass circuit, the current passing the inductance L varies little when the switch $S1$ turns off. So the self-induced electromotive force on the inductance L is small , the voltage on the switch $Q1$ is also small , which makes the switch $Q1$ work more safely .

4 Control circuit

Fig .6 shows the control circuit which controls the power switch $Q1, Q2$ opens or closes alternatively .

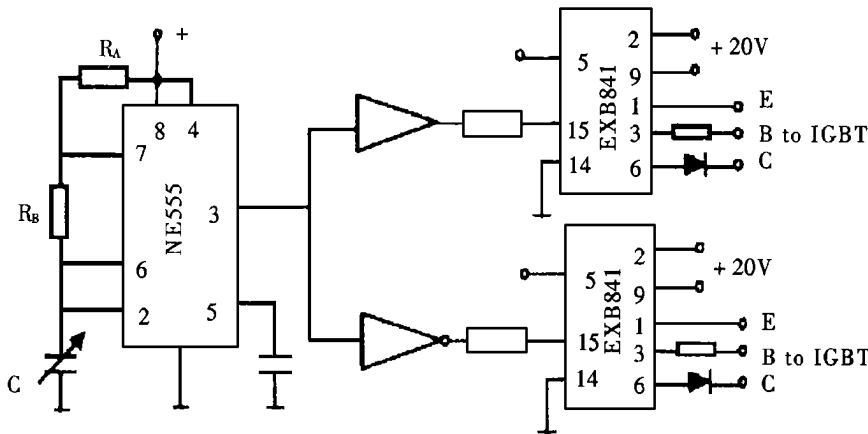


Fig.6 Control circuit

The driver circuit of IGBT adopts the special driver module-EXB841 . The square wave pulse control signal generator is a multivibrator which is made up with 555 timer .

The pulse frequency is
$$f = \frac{1.44}{(R_A + 2R_B)C} \quad (2)$$

The pulse width ratio is
$$D = \frac{R_B}{R_A + 2R_B} \times 100\% \quad (3)$$

Here, the pulse width ratio is set as 50%. The pulse frequency can be regulated by changing the capacitor C.

5 Online experiment

Fig.7 is the real output current waves of the high frequency pulse power source.

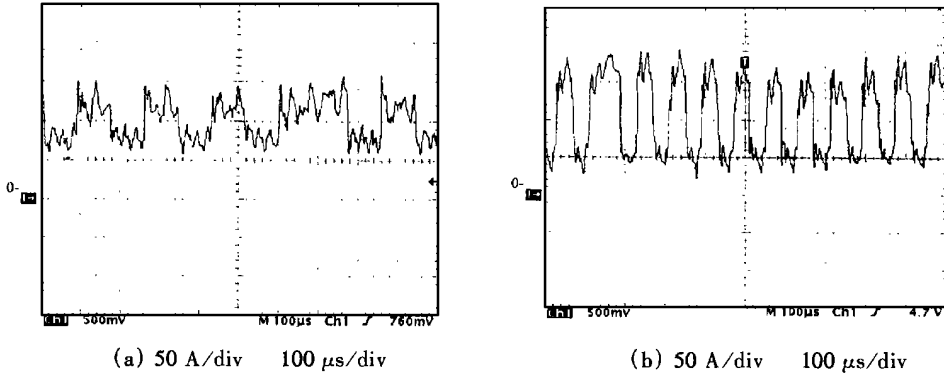


Fig.7 The real output current wave of the power source

6 Conclusions

(1) The structure of double powers has not the dynamic response time restraint which occurs in one power structure, so the new high frequency pulse power source firstly takes this kind of structure.

(2) The by-pass circuit can effectively eliminate the output cable equivalent inductance's effect on the rising ratio of pulse current, which largely improves the frequency of output pulse current.

(3) The high frequency pulse current power source developed in this paper meets the need of practical welding.

References

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- [2] ZHANG Li. Modern power electronic technology. Beijing: Science Press,1992.