DESCRIPTION

A Fast Frequency Pulsed TIG Welding System

Technical Field

The invention relates to the technical field of welding equipment, and more specifically to a fast frequency pulsed TIG welding system.

Technical Background

In the field of welding, tungsten inert gas welding (in short TIG welding) is widely used for its advantages such as stable arc, zero splash, high welding quality, and wide range of weldable metals etc. Pulsed TIG welding technology, starting in the mid-1960s, superimposes a pulse current with a certain frequency on the foundation of a traditional DC electric arc welding. The peak current may keep the electric arc stable and accelerate the melting of a base material to form a molten pool. Not only a base current may control the heat input, but also maintain the continuous electric arc combustion, so that the molten pool is cooled and crystallized. The two cycles alternate to form a weld with good performance. Studies have shown that adding high-frequency pulse current on the foundation of free electric arc may improve arc stability, and a stirring effect of the electric arc pressure with high frequency periodically changing on the molten pool may break the dendrites and promote the refinement of the welded joints. Related researchers have proposed a fast frequency pulsed welding method. The electromagnetic field generated by the fast frequency pulsed current compresses the electric arc, which may form a concentrated electric arc similar to electron beam welding, improve the electric arc energy density, increase the electric arc stiffness, control the heat input in the welding process, reduce the heat affected zone and improve the welding quality.

Therefore, domestic and foreign parties have invested in the research of fast frequency pulsed TIG welding equipment. In the fast frequency pulsed TIG welding system, the quality of the welding power supply is closely related to the performance of the welding electric arc. Not only it needs to accurately provide energy for the welding process, but also needs to achieve coordinated operation with other equipment in the system. However, there is still a big gap between the industrialization level of domestic fast frequency pulsed TIG welding equipment and that of developed countries. Domestic fast frequency pulsed welding power supplies generally use Si-based IGBTs as main power devices, and the switching performance of Si-based power devices has approached the theoretical limit determined by its material properties, which restricts to a certain extent several key indicators affecting the reliability of fast frequency pulsed waveform modulation such as the inverter frequency, response speed etc. of the welding power supply. In addition, due to the addition of high-frequency pulse current modulation in the fast frequency pulsed waveform modulation process, strong

electromagnetic interference may occur to the welding power supply, and problems such as unstable welding current, poor high-frequency electric arc control effects etc. are likely to occur. Therefore, the fast frequency pulsed TIG welding technology has not been widely used in China.

Summary of the Invention

In order to overcome the shortcomings and deficiencies in the prior art, the object of the present invention is to provide a fast frequency pulsed TIG welding system with high inverter frequency, good dynamic characteristics and stability, may reduce power transistor switching loss, may stably output regular fast frequency pulsed flexible current waveforms of 20kHz and above.

In order to achieve the above objects, the present invention is achieved through the following technical solutions: a fast frequency pulsed TIG welding system, characterized in comprising a fast frequency pulsed TIG welding power supply; the fast frequency pulsed TIG welding power supply comprises a main circuit, a control circuit and a human-machine interactive system;

the main circuit comprises a power rectification filter module, a pulse current main circuit, a base current main circuit, and a high-frequency current switching circuit; the pulse current main circuit comprises a first SiC-based full-bridge inverter module, a first high-frequency transformer module and a first SiC-based rectification and smoothing module, which are connected sequentially; the base current main circuit comprises a second SiC-based full-bridge inverter module, a second high-frequency transformer module and a second SiC-based rectification and smoothing module, which are connected sequentially; the high-frequency current switching circuit comprises a high-frequency switching module and an anti-backflow module, which are connected sequentially; the first SiC-based full-bridge inverter module comprises a SiC-based power switch transistor;

wherein, a three-phase AC input power supply is connected to the power rectification filter module; the power rectification filter module is connected to the first SiC-based full-bridge inverter module and the second SiC-based full-bridge inverter module respectively; the first SiC-based rectification and smoothing module is connected to the high-frequency switching module; the anti-backflow module is connected to an external arc load; the second SiC-based rectification and smoothing module is connected to the external arc load;

the control circuit comprises an ARM minimum control system, a human-machine interactive communication module, a SiC-based high-frequency drive circuit, a switch drive circuit and an output voltage and current sampling feedback circuit respectively connected to the ARM minimum control system; wherein the SiC-based high-frequency drive circuit is respectively connected to the first SiC-based full-bridge inverter module and the second SiC-based full-

bridge inverter module; the switch drive circuit is connected to the high-frequency switching module; the output voltage and current sampling feedback circuit is respectively connected to the external arc load and the first SiC-based rectification and smoothing module and the second SiC-based rectification and smoothing module; the human-machine interactive communication module is connected to the human-machine interactive system.

Preferably, the first SiC-based full-bridge inverter module comprises the SiC-based power switching transistors, which means: the first SiC-based full-bridge inverter module comprises SiC-based power switch transistors M101, M102, M103 and M104; the first high-frequency transformer module comprises a first high-frequency transformer T101; the SiC-based power switch transistors M101, M102, M103 and M104 form a full-bridge inverter circuit, then connect to a primary of the high frequency transformer T101 through a DC blocking capacitor C109; the SiC-based power switch transistors M101, M102, M103 and M104 are respectively connected in parallel to a first RC absorption circuit;

the first SiC-based rectification and smoothing module comprises rectifier diodes VD101 and VD102, and an inductor L101; a first output end of a secondary of the high-frequency transformer T101 is connected, through the rectifier diodes VD101 and VD102 connected sequentially, to a third output end of the secondary of the high-frequency transformer T101; a connection between the rectifier diodes VD101 and VD102 is connected to one end of the inductor L101; the other end of the inductor L101 and a second output end of the secondary of the high-frequency transformer T101 are respectively used as output ends of the pulse current main circuit for connecting the high-frequency switching module.

Preferably, the SiC-based power switch transistors M101, M102, M103 and M104 form the full-bridge inverter circuit, then connected to a primary of the first high-frequency transformer module through the DC blocking capacitor C109; the SiC-based power switch transistors M101, M102, M103 and M104 are respectively connected in parallel to the first RC absorption circuit, which means:

the capacitors C101, C102, C103, C104 and C109, and the resistors R101, R102, R103 and R104 are further comprised;

after the SiC-based power switch transistors M101 and M103 are connected in series, a circuit formed by a series connection of the SiC-based power switch transistors M102 and M104 is connected in parallel to a power frequency rectifier filter circuit; the capacitor C101 and the resistor R101 are connected in series and then connected in parallel to the SiC-based power switch transistor M101; the capacitor C102 and the resistor R102 are connected in series and then

connected in parallel to the SiC-based power switch transistor M102; the capacitor C103 and the resistor R103 are connected in series and then connected in parallel to the SiC-based power switch transistor M103; the capacitor C104 and the resistor R104 are connected in series and then connected in parallel to the SiC-based power switch transistor M104; a connection point of the SiC-based power switch transistors M101 and M103 is connected in series with the capacitor C109 and then connected to a first input terminal of the primary of the first high-frequency transformer module; a connection point of the SiC-based power switch transistors M102 and M104 is connected with a second input terminal of the primary of the first high-frequency transformer module.

Preferably, a circuit structure of the second SiC-based full-bridge inverter module is the same as that of the first SiC-based full-bridge inverter module; a circuit structure of the second high-frequency transformer module is the same as that of the first high-frequency transformer module; a circuit structure of the second SiC-based rectification and smoothing module is the same as that of the first SiC-based rectification and smoothing module.

Preferably, the high-frequency switching module comprises modulating switch transistor IGBTs Q202 and Q201; the anti-backflow module comprises a rectifier diode VD201; the modulation switch IGBT Q201 is connected in parallel to the first SiC-based rectification and smoothing module; the first SiC-based rectification and smoothing module is connected to the external arc load through the modulating switch transistor IGBT Q202 and the rectifier diode VD201, which are connected sequentially; the modulation switch transistor IGBT Q202 is connected in parallel to a first peak voltage absorption module; the modulation switch transistor IGBT Q201 is connected in parallel to a second peak voltage absorption module.

Preferably, the first peak voltage absorption module comprises a capacitor C202, a resistor R202, the diodes D204 and D203; the resistor R202 and the capacitor C202 are connected in parallel and then connected to the diode D204 in series to form a circuit connected in parallel to the modulation switch transistor IGBT Q202; the diode D203 is connected in parallel to the modulation switch transistor IGBT Q202;

the second peak voltage absorption module comprises a capacitor C201, a resistor R201, the diodes D202 and D201; the resistor R201 and the diode D202 are connected in parallel and then connected to the capacitor C201 in series to form a circuit connected in parallel to the modulation switch transistor IGBT Q201; the diode D201 is connected in parallel to the modulation switch transistor IGBT Q201.

Preferably, the ARM minimum control system is connected to the SiC-based high-frequency drive circuit through a first isolation; the ARM minimum control system is connected to the switch drive circuit through a second isolation.

Preferably, the ARM minimum control system is connected to the SiC-based high-frequency drive circuit through the first isolation, which means:

the ARM minimum control system is connected to the SiC-based high-frequency drive circuit through an ISO5451 isolation drive chip, and the isolation drive chip is further connected to a first driving power supply circuit;

the SiC-based high-frequency drive circuit comprises the capacitors C304 and C305, a Zener transistor ZD301, the diodes D302 and D303, the resistors R310, R311, R312 and R313; the pin CLAMP of the isolation drive chip is connected to the gate of the SiC-based power switch transistor; the gate of the SiC-based power switch transistor is connected to a ground through the resistor R313 and the capacitor C305 which are connected in parallel; the pin OUT of the isolation drive chip is connected to the gate of the SiC-based power switch through the resistor R312; the diode D303 and the resistor R311 are connected in series and then connected in parallel to the resistor R312; the pin OUT of the isolation drive chip is connected to the drain of the SiC-based power switch transistor through the resistor R310 and diode D302 which are connected in series; the pin OUT of the isolation drive chip is further connected to the ground through the capacitor C304 and Zener diode ZD301 which are connected in parallel; the pin DESAT of the isolation drive chip is connected to the pin OUT of the isolation drive chip.

Preferably, the ARM minimum control system is connected to the switch drive circuit through the second isolation, which means: the ARM minimum control system is connected to the switch drive circuit through an optocoupler isolation chip; the switch drive circuit comprises the NPN transistors Q401, Q402 and Q404, and a PNP transistor Q403 and a second driving power supply circuit;

an output terminal of the optocoupler isolation chip is connected to the base of the NPN transistor Q401 through the resistors R402 and R403 and a diode D402 which are connected sequentially; the resistor R403 is connected in parallel to a capacitor C401; the diode D402 is connected in reverse parallel to a diode D403; a connection point of the resistor R403 and the diode D402 is connected to the collector of the NPN transistor Q401 through a diode D401; the collector of the NPN transistor Q401 is further connected to a positive node of the second driving power supply circuit through a resistor R404;

a connection point of the resistors R402 and R403 is connected to the base of the NPN transistor Q402 through a resistor R408 and a diode D408 which are

connected sequentially; the resistor R408 is connected in parallel to a capacitor C403; the diode D408 is connected in reverse parallel to the diode D409; a connection point of the resistor R408 and the diode D408 is connected to a collector of the NPN transistor Q402 through a diode D407; the collector of the NPN transistor Q402 is further connected to the positive node of the second driving power supply circuit through a resistor R409; the emitters of the NPN transistor Q401 and Q402 are respectively connected to the negative node of the second driving power supply circuit;

the collector of the NPN transistor Q401 is connected to the base of the PNP transistor Q403 through a resistor R405 and a diode D405 which are connected sequentially; the resistor R405 is connected in parallel to a capacitor C402; the diode C405 is connected in reverse parallel to a diode D404; a connecting point of the resistor R405 and the diode D405 is connected to the collector of the PNP transistor Q403 through a diode D406; the base of the PNP transistor Q403 is connected to the positive node of the second driving power supply circuit through a resistor R406; the emitter of the PNP transistor Q403 is connected to the positive node of the second driving power supply circuit through a resistor R407;

the collector of the NPN transistor Q402 is connected to the base of the NPN transistor Q404 through a resistor R410 and a diode D411 which are connected sequentially; the resistor R410 is connected in parallel to a capacitor C404; the diode D411 is connected in reverse parallel to a diode D412; a connection point of the resistor R410 and the diode D411 is connected to the collector of NPN transistor Q404 through a diode D410; the collector of the NPN transistor Q404 is connected to the collector of the PNP transistor Q403; the emitter of the NPN transistor Q404 is connected to the negative node of the second driving power supply circuit through a resistor R411; the collector of the NPN transistor Q404 is connected to the negative node of the second driving power supply circuit through a resistor R412; the collector of the NPN transistor Q404 is connected to the high-frequency switching module.

Preferably, an industrial robot, a wire feeder, a welding gun, an gas supply device and a clamping equipment are further comprised; the industrial robot and the wire feeder are respectively connected to the ARM minimum control system; the clamping equipment is connected to the industrial robot and the welding gun respectively; the fast frequency pulsed TIG welding power supply is further connected to the gas supply device; the welding gun is further connected to the gas supply device and the wire feeder.

Compared with the prior art, the present invention has the following advantages and beneficial effects:

1. Compared with the traditional pulse TIG welding system, the power switch device of the fast frequency pulsed TIG welding power supply of the present invention adopts a new type of SiC-based power switch transistors, and the inverter frequency is as high as 100kHz and above, which is improved almost ten times compared to the current more commonly used IGBT. Not only the size of the whole machine is greatly reduced, but also it has a good dynamic response speed. It is helpful in strengthening the high frequency electric arc control effect, and stably outputting 20kHz fast frequency pulsed current waveform. The waveform is stable without distortion during the welding process;

2. In the present invention, the fast frequency pulsed TIG welding power supply has extremely high energy efficiency; due to the excellent performance of the SiC-based power switch transistors, its switching loss and conduction loss are small, which greatly improves the energy efficiency of the TIG welding power supply;

3. In the present invention, the high-frequency current switching circuit may effectively absorb the spike overvoltage generated by the high-frequency pulse current modulation process without affecting adversely the basic waveform of the fast frequency pulsed current. The structure is simple, low cost and with high reliability;

4. The sampling isolation method of the present invention realizes the ARM minimum control system and the SiC-based high-frequency drive circuit, and the ARM minimum control system is connected with the switch drive circuit; it has multiple protection functions, which may effectively drive the switch transistor while preventing damages to the switch transistor; It may suppress problems of excessively high transient voltage and transient current during the driving of the SiC-based power switch transistor, and generation of electromagnetic interference, prevent the voltage spike from causing a false trigger, and has a good driving effect;

5. The fast frequency pulsed TIG welding system of the present invention combines high-frequency inverter, digital automatic control and other technologies, as well as coordinated operation of various parts of the system through the CAN bus, which makes the system more integrated and more precise in control.

Description of the Figures

Figure 1 is a system block diagram of the fast frequency pulsed TIG welding system of the present invention;

Figure 2 is a structural diagram of the fast frequency pulsed TIG welding power supply in the fast frequency pulsed TIG welding system of the present invention;

Figure 3 is a circuit diagram of the main circuit of the fast frequency pulsed TIG welding power supply in the fast frequency pulsed TIG welding system of the present invention;

Figure 4 is a circuit diagram of the SiC-based high-frequency drive circuit of the fast frequency pulsed TIG welding power supply in the fast frequency pulsed TIG welding system of the present invention;

Figure 5 is a circuit diagram of the switch drive circuit of the fast frequency pulsed TIG welding power supply in the fast frequency pulsed TIG welding system of the present invention;

Figure 6 is a circuit diagram of the output voltage and current sampling feedback circuit of the fast frequency pulsed TIG welding power supply in the welding system of the present invention;

Figure 7 is a structural block diagram of the wire feeder in the fast frequency pulsed TIG welding system of the present invention.

Detailed Description

The present invention will be further described in detail below with reference to the figures and specific embodiments.

Embodiments

The structure of the fast frequency pulsed TIG welding system of this embodiment is shown in Figures 1 to 7, comprising a fast frequency pulsed TIG welding power supply, an industrial robot, a wire feeder, a welding gun, an gas supply device and a clamping equipment; the industrial robot and the wire feeder are respectively connected to the ARM minimum control system; the clamping equipment is connected to the industrial robot and the welding gun respectively; the fast frequency pulsed TIG welding power supply is further connected to the gas supply device; the welding gun is further connected to the gas supply device and the wire feeder.

The industrial robot is used as an executing unit to clamp and hold the welding gun to perform welding operations according to a determined path. The wire feeder is used to realize a precise stepless adjustment of the welding wire feeding speed and the diversification of wire feeding methods to ensure that the feeding of the welding wire may be perfectly matched with the welding process and parameters. The gas supply device is used to provide protective gas. The

clamping equipment is used to realize the function of fixing and repositioning the welding workpiece and connecting the welding gun with the industrial robot.

The fast frequency pulsed TIG welding power supply comprises a main circuit, a control circuit and a human-machine interactive system.

The main circuit comprises a power rectification filter module, a pulse current main circuit, a base current main circuit, and a high-frequency current switching circuit. The pulse current main circuit and the base current main circuit are mainly used to provide energy for the electric arc. The high-frequency current switching circuit is used to modulate a high-frequency current, and the control circuit is used to realize functions such as generation of drive signals for the SiC-based power switch transistor and the modulation switch transistor IGBT, closed-loop adjustment of sampling current, fault protection, cooperative communication with other parts of the system, and human-machine interaction etc.

The pulse current main circuit comprises a first SiC-based full-bridge inverter module, a first high-frequency transformer module and a first SiC-based rectification and smoothing module which are connected sequentially; the base current main circuit comprises a second SiC-based full-bridge inverter module, a second high-frequency transformer module and a second SiC-based rectification and smoothing module which are connected sequentially; the high-frequency current switching circuit comprises a high-frequency switching module and an anti-backflow module which are connected sequentially; the first SiC-based full-bridge inverter module comprises a SiC-based power switch transistor; the high frequency switching module comprises the switch transistor IGBT;

wherein, a three-phase AC input power supply is connected to the power rectification filter module; the power rectification filter module is connected to the first SiC-based full-bridge inverter module and the second SiC-based full-bridge inverter module respectively; the first SiC-based rectification and smoothing module is connected to the high-frequency switching module; the anti-backflow module is connected to an external arc load; the second SiC-based rectification and smoothing module is connected to the external arc load;

the control circuit comprises an ARM minimum control system, a human-machine interactive communication module, a SiC-based high-frequency drive circuit, a switch drive circuit and an output voltage and current sampling feedback circuit, which are respectively connected to the ARM minimum control system; wherein the SiC-based high-frequency drive circuit is respectively connected to the first SiC-based full-bridge inverter module and the second SiC-based full-bridge inverter module; the switch drive circuit is connected to the high-frequency switching module; the output voltage and

current sampling feedback circuit is respectively connected to the external arc load and the first SiC-based rectification and smoothing module and the second SiC-based rectification and smoothing module; the human-machine interactive communication module is connected to the human-machine interactive system.

The ARM minimum control system uses a 32-bit high-speed ARM microprocessor, which generates three sets of all-digital PWM control signals, which are used on the pulse current main circuit, the base current main circuit and the high-frequency current switching circuit respectively. The UART communication interface circuit of the ARM minimum control system is connected to the human-machine interaction system. The CAN communication interface circuit of the ARM minimum control system is connected with the CAN bus to complete the coordinated operation of each part of the system. The relay module is mainly used to open and close the gas valve.

The first SiC-based full-bridge inverter module comprises the SiC-based power switching transistors, which means: the first SiC-based full-bridge inverter module comprises the SiC-based power switch transistors M101, M102, M103 and M104; the first high-frequency transformer module comprises a first high-frequency transformer T101; the SiC-based power switch transistors M101, M102, M103 and M104 form a full-bridge inverter circuit, and then connect to a primary of the high frequency transformer T101 through a DC blocking capacitor C109; the SiC-based power switch transistors M101, M102, M103 and M104 are respectively connected in parallel to a first RC absorption circuit;

the first SiC-based rectification and smoothing module comprises the rectifier diodes VD101 and VD102, and an inductor L101; the first output end of a secondary of the high-frequency transformer T101 is connected, through the rectifier diodes VD101 and VD102connected sequentially, to the third output end of the secondary of the high-frequency transformer T101; a connection between the rectifier diodes VD101 and VD102 is connected to one end of the inductor L101; the other end of the inductor L101 and the second output end of the secondary of the high-frequency transformer T101 are respectively used as output ends of the pulse current main circuit for connecting the high-frequency switching module. Specifically, the capacitors C101, C102, C103, C104 and C109, and the resistors R101, R102, R103 and R104 are comprised;

after the SiC-based power switch transistors M101 and M103 are connected in series, a circuit formed by a series connection of the SiC-based power switch transistors M102 and M104 is connected in parallel to a power frequency rectifier filter circuit; the capacitor C101 and the resistor R101 are connected in series and then connected in parallel to the SiC-based power switch transistor M101; the capacitor C102 and the resistor R102 are connected in series and then connected in parallel to the SiC-based power switch transistor M102; the

capacitor C103 and the resistor R103 are connected in series and then connected in parallel to the SiC-based power switch transistor M103; the capacitor C104 and the resistor R104 are connected in series and then connected in parallel to the SiC-based power switch transistor M104; a connection point of the SiC-based power switch transistor M101 and the SiC-based power switch transistor M103 is connected in series with the capacitor C109 and then connected to the first input terminal of the primary of the first high-frequency transformer module; a connection point of the SiC-based power switch transistors M102 and M104 is connected with the second input terminal of the primary of the first high-frequency transformer module.

In the base current main circuit, a circuit structure of the second SiC-based full-bridge inverter module is the same as that of the first SiC-based full-bridge inverter module; a circuit structure of the second high-frequency transformer module is the same as that of the first high-frequency transformer module; a circuit structure of the second SiC-based rectification and smoothing module is the same as that of the first SiC-based rectification and smoothing module. The structure and principle of the base current main circuit are the same as the pulse current main circuit. The SiC-based high-frequency drive circuit used to drive the first SiC-based full-bridge inverter module has the same structure as the SiC-based high-frequency drive circuit used to drive the second SiC-based full-bridge inverter module, except that the output drive waveforms and timings are different; the drive waveforms and the timings may adopt existing methods.

The working principle of the main circuit is: the AC input power is connected to the power frequency rectifier filter module and converted into a smooth DC. The DC passes through the first SiC-based full-bridge inverter module of the pulse current main circuit. Two paths complementary PWM signals with dead zone control the two opposing SiC-based power switch transistors at high frequency to turn on or off at the same time, converting the direct current into high-frequency alternating current; after the second SiC-based rectification and smoothing module is converted into low-voltage smooth DC power and input to the high-frequency switching module, two paths complementary PWM signals without dead zone control the two modulation switch IGBTs to turn on and off alternately at a frequency of 20kHz, converting the DC into high-frequency current. After passing through the anti-backflow module, it is superimposed with the base value DC current output by the base current main circuit, and the fast frequency pulsed current generated by the superposition is output to the external electric arc load.

The high-frequency switching module comprises a modulating switch transistor IGBTs Q202 and Q201; the anti-backflow module comprises a rectifier diode VD201; the modulation switch IGBT Q201 is connected in parallel to the first SiC-based rectification and smoothing module; the first SiC-based rectification

and smoothing module is connected to the external arc load through the modulating switch transistor IGBT Q202 and the rectifier diode VD201 which are connected sequentially; the modulation switch transistor IGBT Q202 is connected in parallel to a first peak voltage absorption module; the modulation switch transistor IGBT Q201 is connected in parallel to a second peak voltage absorption module.

The first peak voltage absorption module comprises a capacitor C202, a resistor R202, and the diodes D204 and D203; the resistor R202 and the capacitor C202 are connected in parallel and then connected to the diode D204 in series to form a circuit connected in parallel to the modulation switch transistor IGBT Q202; the diode D203 is connected in parallel to the modulation switch transistor IGBT Q202;

the second peak voltage absorption module comprises a capacitor C201, a resistor R201, and the diodes D202 and D201; the resistor R201 and the diode D202 are connected in parallel and then connected to the capacitor C201 in series to form a circuit connected in parallel to the modulation switch transistor IGBT Q201; the diode D201 is connected in parallel to the modulation switch transistor IGBT Q201.

In the high-frequency current switching circuit, the low-voltage direct current output by the pulse current main circuit is input to the high-frequency switching module formed by the modulation switch transistor IGBTs Q201 and Q202. Two paths complementary PWM signals without dead zone control the modulation switch transistor IGBT Q201 and the modulation switch IGBT Q202 to turn on and off alternately at a frequency of 20kHz or higher to convert the direct current into a high-frequency current. After passing through the anti-backflow module, it is superimposed with the low-voltage direct current output by the base current main circuit, and the fast frequency pulsed current generated by the superposition is output to the external electric arc load; the first peak voltage absorption module and the second peak voltage absorption module absorb the peak voltage generated in the process of modulating the high frequency current; the rectifier diode VD201 prevents the direct current output by the base current main circuit from being back flowed into the pulse current main circuit through the internal resistance of the high-frequency current switching circuit to avoid affecting the precise output control of the power supply.

The ARM minimum control system is connected to the SiC-based high-frequency drive circuit through the first isolation.

Specifically, the ARM minimum control system is connected to the SiC-based high-frequency drive circuit through an ISO5451 isolation drive chip, and the isolation drive chip is further connected to the first driving power supply circuit;

the SiC-based high-frequency drive circuit comprises the capacitors C304 and C305, a Zener transistor ZD301, the diodes D302 and diode D303, and the resistors R310, R311, R312 and R313; the pin CLAMP of the isolation drive chip is connected to the gate of the SiC-based power switch transistor; the gate of the SiC-based power switch transistor is connected to the ground through the resistor R313 and the capacitor C305 which are connected in parallel; the pin OUT of the isolation drive chip is connected to the gate of the SiC-based power switch through the resistor R312; the diode D303 and the resistor R311 are connected in series and then connected in parallel to the resistor R312; the pin OUT of the isolation drive chip is connected to the drain of the SiC-based power switch transistor through the resistor R310 and diode D302 which are connected in series; the pin OUT of the isolation drive chip is further connected to the ground through the capacitor C304 and Zener diode ZD301 which are connected in parallel; the pin DESAT of the isolation drive chip is connected to the pin OUT of the isolation drive chip.

The ARM minimum control system is connected to the switch drive circuit through the second isolation. Specifically, the ARM minimum control system is connected to the switch drive circuit through an optocoupler isolation chip; the switch drive circuit comprises the NPN transistors Q401, Q402 and Q404, a PNP transistor Q403 and a second driving power supply circuit;

an output terminal of the optocoupler isolation chip is connected to the base of the NPN transistor Q401 through the resistors R402 and R403 and a diode D402 which are connected sequentially; the resistor R403 is connected in parallel to a capacitor C401; the diode D402 is connected in reverse parallel to a diode D403; a connection point of the resistor R403 and the diode D402 is connected to the collector of the NPN transistor Q401 through a diode D401; the collector of the NPN transistor Q401 is further connected to a positive node of the second driving power supply circuit through a resistor R404;

a connection point of the resistors R402 and R403 is connected to the base of the NPN transistor Q402 through a resistor R408 and a diode D408 which are connected sequentially; the resistor R408 is connected in parallel to a capacitor C403; the diode D408 is connected in reverse parallel a the diode D409; a connection point of the resistor R408 and the diode D408 is connected to the collector of the NPN transistor Q402 through a diode D407; the collector of the NPN transistor Q402 is further connected to the positive node of the second driving power supply circuit through a resistor R409; the emitters of the NPN

transistors Q401 and Q402 are respectively connected to the negative node of the second driving power supply circuit;

the collector of the NPN transistor Q401 is connected to the base of the PNP transistor Q403 through a resistor R405 and a diode D405 which are connected sequentially; the resistor R405 is connected in parallel to a capacitor C402; the diode C405 is connected in reverse parallel to a diode D404; a connecting point of the resistor R405 and the diode D405 is connected to the collector of the PNP transistor Q403 through a diode D406; the base of the PNP transistor Q403 is connected to the positive node of the second driving power supply circuit through a resistor R406; an emitter of the PNP transistor Q403 is connected to the positive node of the second driving power supply circuit through a resistor R407;

the collector of the NPN transistor Q402 is connected to the base of the NPN transistor Q404 through a resistor R410 and a diode D411 which are connected sequentially; the resistor R410 is connected in parallel to a capacitor C404; the diode D411 is connected in reverse parallel to a diode D412; a connection point of the resistor R410 and the diode D411 is connected to a collector of NPN transistor Q404 through a diode D410; the collector of the NPN transistor Q404 is connected to the collector of the PNP transistor Q403; the emitter of the NPN transistor Q404 is connected to the negative node of the second driving power supply circuit through a resistor R411; the collector of the NPN transistor Q404 is connected to the negative node of the second driving power supply circuit through a resistor R412; the collector of the NPN transistor Q404 is connected to the high-frequency switching module.

The control system and the modulation switch transistor drive circuit are driven by optocoupler isolation. The optocoupler uses IGBT or MOSFET high-speed optocoupler HCPL-3120. The switching delay time is about 0.3μs, and it has a small size and high switching speed, and strong impact resistance, sufficient to meet the driver design requirements. Since the drive circuit of the modulation switch transistor generates two paths complementary drive electric signals without dead zone, the gate drive circuits of the two paths modulation IGBT switch transistors have the same structure. Intercept one of them, isolate the optocoupler and then connect a half-bridge topology structure formed by two MOSFETs, and finally output +15V/-7V voltage to drive the modulation IGBT switch transistor. The advantages of this setting are: it has the advantages of small size, high switching speed and strong impact resistance, which meets the requirements of driver design.

The output voltage and current sampling feedback circuit is used to collect the output voltage and current of the pulse current main circuit and the base current main circuit. As shown in Figure 5, the output voltage and current sampling

feedback circuit comprises a 200A current Hall sensor with model HAS 200-P, an integrated differential amplifier circuit formed by a differential amplifier with model AD629 and its peripheral circuits, a low-pass filter circuit formed by an OP177 chip and its peripheral circuit; the current Hall sensor, the integrated differential amplifier circuit, and the low-pass filter circuit are connected sequentially.

The measured voltage value converted from the current Hall sensor needs to be divided by resistors R501 and R502, and then connected to the integrated differential amplifier circuit where U501 is a differential amplifier AD629 with low offset, low gain error drift and high common mode rejection ratio. The magnification is 1. KRC active low-pass filter is used for filtering. This patent uses a flatter Butterworth filter in the pass band as a model where U502 is a high-precision and low-zero-drift operational amplifier OP177. U502 is combined with external resistors and capacitors R503, R504, C505 and C506, matched in values.

In the pulse current main circuit and the base current main circuit, the SiC-based power switch transistor is quickly turned on and off according to the pre-set time sequence to achieve high-frequency DC-AC conversion; the two modulation switch transistors IGBTs of the high-frequency switch module are operated at 20kHz or higher and switch alternately, to realize independent control of high-frequency pulse current modulation of output voltage and current sampling feedback of the two parallel paths pulse current main circuit and base current main circuit; by collecting the output current and voltage at the output terminals of the pulse current main circuit and the base current main circuit respectively and performing signal conditioning, after comparing with the preset value, changing the turn-on and turn-off time of the SiC-based power switch transistor to achieve a duty cycle adjustment, obtain the required waveform output, and complete a closed-loop control.

The wire feeder comprises a motor, a clamping wheel, a fixed bracket and a wire feed control system. The wire feed control system comprises a power supply module, an ARM microprocessor, a motor half-bridge drive circuit, a voltage sampling feedback circuit and a digital control panel. The half-bridge drive circuit may use the existing technology, for example, the wire feed drive circuit disclosed in detail in the Chinese invention “An Intelligent Arc Welding Robot Submersible Wire Feeder” (Publication No. 103706927B). The half-bridge drive circuit is mainly formed by a half-bridge circuit comprising two N-channel FETs Q1 and FETs Q2, a driver chip IR2110, an optocoupler PC817, a relay K1, a voltage regulator chip L7815, and other peripheral circuit connections. The driver chip adopts the model IR2110, and realizes the forward and reverse conversion of the motor through the commutation circuit formed by the relay K1 and the optocoupler PC817 where the two ends of the motor are connected to the

connector P1, and two paths complementary PWM signals with dead zone are respectively input to the driver chip IR2110. The inversion commutation end is kept at high level, and the relay is kept at the forward end. When PWMH is high and PWML is low, due to the bootstrap circuit formed by capacitors C2 and C3 and diode D1, the field effect transistor Q1 is turned on reliably, the field effect transistor Q2 is turned off, the positive and negative ends of the motor are shorted to 24V, and it is in an emergency stop state; when PWMH is low and PWML is high, the field effect transistor Q2 is turned on, and the field effect transistor Q1 is turned off. At this time, the voltage across the motor is +24V, and the motor is in a forward rotation state. When the commutation end of inversion remains low, the transistor of the optocoupler PC817 is turned on, and the relay is kept at the inversion end. When PWMH is high and PWML is low, the field effect transistor Q1 is turned on and the field effect transistor Q2 is turned on. When the motor is turned off, the voltage across the motor is +24V, and the motor is in the reverse state; when PWML is high and PWMH is low, the positive and negative ends of the motor are shorted to 24V, and the motor is in an emergency stop state. Therefore, by controlling the high and low levels of the inversion commutation end, pulsating wire feeding may be realized, and by controlling the duty ratio of PWMH and PWML, the wire feeding speed may be controlled. The combination of the two may easily realize uniform speed feeding, to realise three wire feeding modes: constant speed wire feeding, variable speed wire feeding and pulse wire feeding.

The voltage sampling feedback circuit may use the existing technology, for example, the wire feeding speed detection circuit disclosed in detail in the Chinese invention “An Intelligent Arc Welding Robot Submersible Wire Feeder” (Publication No. 103706927B). The connector P3 of the voltage sampling feedback circuit is connected to the positive and negative ends of the motor. The voltage at both ends of the motor is divided by resistance, amplified differentially, and isolated by linear optocoupler. After further voltage division, it is input to the control chip STM32F405RG, and after conversion of the A/D, it is compared with the given voltage value to adjust the duty cycle of the PWM signal to achieve the purpose of regulating the operating speed of the motor, where the resistors R6, R7, R8 and R9 respectively form a voltage divider circuit of two input voltages, and the voltage is proportionally reduced to the input voltage suitable for the operational amplifier LF353. The inductors L5 and L6, and the capacitor C10 form an LC filter circuit at the input end. The operational amplifier U4 forms a differential amplifier circuit, which amplifies two times the voltage at both ends of the motor after the step-down, and then calculates the difference between the two and outputs it, thereby converting the input differential signal into a unilateral voltage signal output. The diodes D6, D7, D8 and D9 are the protection diodes of the two input ends of the operational amplifier U4. When the absolute value of the input terminal voltage is higher than 15V, one of the diodes is turned on, effectively protecting the operational

amplifier. Since the linear optocoupler U6 is a current-driven optocoupler component, the isolated is the amount of current, so the operational amplifier U5 and the resistor R17 form a voltage-current conversion circuit, which converts the voltage at the input of the operational amplifier into the LED drive current of the linear optocoupler HCNR201, and the operational amplifier U5, the resistor R16, the capacitor C11, and the diode D10 form a closed-loop feedback circuit of linear optocoupler U6 to compensate for the nonlinearity and temperature drift of the LED of U6. The capacitor C11 may also provide the effect of filtering out high-frequency noise signals. Operational amplifier U7, the resistors R22 and R18 form a current-voltage conversion circuit, which converts the output current of the linear optocoupler U6 into a voltage, adjusting the resistance of resistor R22 to a suitable value, and obtaining a voltage value equal to the unilateral output voltage of the operational amplifier U4. After the further step-down of the resistor R18, the output voltage of the operational amplifier U7 is reduced to the appropriate input voltage of the control chip STM32F405RG where the diodes D11 and D12 form the input terminal protection circuit to prevent the voltage at the feedback terminal from being higher than 3.3V.

The ARM microprocessor generates a set of PWM signals. After being amplified and isolated by the drive circuit, they are used to drive the power switch in the motor half-bridge drive circuit to realize the operation of the motor; while the motor speed is controlled by the armature voltage control method. The armature voltage is sampled by the voltage sampling feedback circuit and fed back to the ARM microprocessor. The ADC module of the ARM microprocessor performs analog-to-digital conversion of the fed signal, compares it with the given value and performs PI adjustment, and then outputs the drive signal of corresponding pulse width, to realize the closed-loop adjustment of the armature voltage and realize the precise stepless adjustment of the wire feeding speed; the wire feeder is connected to other equipment of the system through CAN, and the operating parameters of the wire feeder may be set by the fast frequency pulsed TIG welding power source.

Industrial robots, welding guns, gas supply devices and clamping equipment may adopt existing technologies.

The working principle of the fast frequency pulsed TIG welding system of the present invention is as follows: firstly, the welding path planning is performed, and after the motion path of the industrial robot is set, it moves to the welding starting point and waits for the synchronization signal of the fast frequency pulsed TIG welding power supply; welding parameters is set through the human-computer interaction system and input to the fast frequency pulsed TIG welding power source; after the fast frequency pulsed TIG welding power supply controls and starts the gas supply device, the main circuit of the fast frequency pulsed TIG welding power supply operates first, using high-frequency

and high-voltage electric arc ignition circuit to break down the gas gap between the tungsten electrode of the welding gun and the nozzle, and an electric arc will be formed between the welding workpiece and the tungsten electrode; after the arc start is successful, the fast frequency pulsed TIG welding power supply will output a moving signal to the industrial robot, and the welding gun will move according to the planned path and speed. Among them, industrial robots, human-machine interaction systems, fast frequency pulsed TIG welding power supplies, and wire feeders all perform high-speed digital collaboration through the CAN network, so as to ensure that the components may achieve organic coordination and high-speed collaboration during the entire welding process, which improves the automation and intelligence level of the fast frequency pulsed TIG welding process.

The above-mentioned embodiments are preferred embodiments of the present invention, but the embodiments of the present invention are not limited by the above-mentioned embodiments, and any other changes, modifications, substitutions, combinations, simplifications etc. made without departing from the spirit and principle of the present invention, all should be equivalent replacement methods, and they are all included in the protection scope of the present invention.

CLAIMS

1. A fast frequency pulsed TIG welding system, characterized in comprising a fast frequency pulsed TIG welding power supply; the fast frequency pulsed TIG welding power supply comprises a main circuit, a control circuit and a human-machine interactive system;

the main circuit comprises a power rectification filter module, a pulse current main circuit, a base current main circuit, and a high-frequency current switching circuit; the pulse current main circuit comprises a first SiC-based full-bridge inverter module, a first high-frequency transformer module and a first SiC-based rectification and smoothing module which are connected sequentially; the base current main circuit comprises a second SiC-based full-bridge inverter module, a second high-frequency transformer module and a second SiC-based rectification and smoothing module which are connected sequentially; the high-frequency current switching circuit comprises a high-frequency switching module and an anti-backflow module which are connected sequentially; the first SiC-based full-bridge inverter module comprises a SiC-based power switch transistor;

wherein, a three-phase AC input power supply is connected to the power rectification filter module; the power rectification filter module is connected to the first SiC-based full-bridge inverter module and the second SiC-based full-bridge inverter module respectively; the first SiC-based rectification and smoothing module is connected to the high-frequency switching module; the anti-backflow module is connected to an external arc load; the second SiC-based rectification and smoothing module is connected to the external arc load;

the control circuit comprises an ARM minimum control system, a human-machine interactive communication module, a SiC-based high-frequency drive circuit, a switch drive circuit and an output voltage and current sampling feedback circuit which are respectively connected to the ARM minimum control system; wherein the SiC-based high-frequency drive circuit is respectively connected to the first SiC-based full-bridge inverter module and the second SiC-based full-bridge inverter module; the switch drive circuit is connected to the high-frequency switching module; the output voltage and current sampling feedback circuit is respectively connected to the external arc load and the first SiC-based rectification and smoothing module and the second SiC-based rectification and smoothing module; the human-machine interactive communication module is connected to the human-machine interactive system.

2. The fast frequency pulsed TIG welding system according to claim 1, characterized in that, the first SiC-based full-bridge inverter module comprises the SiC-based power switching transistors, which means: the first SiC-based full-bridge inverter module comprises SiC-based power switch transistors

M101, M102, M103 and M104; the first high-frequency transformer module comprises a first high-frequency transformer T101; the SiC-based power switch transistors M101, M102, M103 and M104 form a full-bridge inverter circuit, and then connect to a primary of the high frequency transformer T101 through a DC blocking capacitor C109; the SiC-based power switch transistors M101, M102, M103 and M104 are respectively connected in parallel to a first RC absorption circuit;

the first SiC-based rectification and smoothing module comprises rectifier diodes VD101 and VD102, and an inductor L101; a first output end of a secondary of the high-frequency transformer T101 is connected, through the rectifier diodes VD101 and VD102 connected sequentially, to a third output end of the secondary of the high-frequency transformer T101; a connection between the rectifier diodes VD101 and VD102 is connected to one end of the inductor L101; the other end of the inductor L101 and a second output end of the secondary of the high-frequency transformer T101 are respectively used as output ends of the pulse current main circuit for connecting the high-frequency switching module.

3. The fast frequency pulsed TIG welding system according to claim 2, characterized in that, the SiC-based power switch transistors M101, M102, M103 and M104 form the full-bridge inverter circuit, and then connect to the primary of the first high-frequency transformer module through the DC blocking capacitor C109; the SiC-based power switch transistors M101, M102, M103 and M104 are respectively connected in parallel to the first RC absorption circuit, which means:

capacitors C101, C102, C103, C104 and C109, and resistors R101, R102, R103 and R104 are further comprised;

after the SiC-based power switch transistors M101 and M103 are connected in series, a circuit formed by a series connection of the SiC-based power switch transistors M102 and M104 is connected in parallel to a power frequency rectifier filter circuit; the capacitor C101 and the resistor R101 are connected in series and then connected in parallel to the SiC-based power switch transistor M101; the capacitor C102 and the resistor R102 are connected in series and then connected in parallel to the SiC-based power switch transistor M102; the capacitor C103 and the resistor R103 are connected in series and then connected in parallel to the SiC-based power switch transistor M103; the capacitor C104 and the resistor R104 are connected in series and then connected in parallel to the SiC-based power switch transistor M104; a connection point of the SiC-based power switch transistors M101 and M103 is connected in series with the capacitor C109 and then connected to a first input terminal of the primary of the first high-frequency transformer module; a connection point of the SiC-based

power switch transistors M102 and M104 is connected with a second input terminal of the primary of the first high-frequency transformer module.

4. The fast frequency pulsed TIG welding system according to claim 2, characterized in that, a circuit structure of the second SiC-based full-bridge inverter module is the same as that of the first SiC-based full-bridge inverter module; a circuit structure of the second high-frequency transformer module is the same as that of the first high-frequency transformer module; a circuit structure of the second SiC-based rectification and smoothing module is the same as that of the first SiC-based rectification and smoothing module.

5. The fast frequency pulsed TIG welding system according to claim 2, characterized in that, the high-frequency switching module comprises modulating switch transistor IGBTs Q202 and Q201; the anti-backflow module comprises a rectifier diode VD201; the modulation switch IGBT Q201 is connected in parallel to the first SiC-based rectification and smoothing module; the first SiC-based rectification and smoothing module is connected to the external arc load through the modulating switch transistor IGBT Q202 and the rectifier diode VD201 which are connected sequentially; the modulation switch transistor IGBT Q202 is connected in parallel to a first peak voltage absorption module; the modulation switch transistor IGBT Q201 is connected in parallel to a second peak voltage absorption module.

6. The fast frequency pulsed TIG welding system according to claim 5, characterized in that, the first peak voltage absorption module comprises a capacitor C202, a resistor R202, diodes D204 and D203; the resistor R202 and the capacitor C202 are connected in parallel and then connected to the diode D204 in series to form a circuit connected in parallel to the modulation switch transistor IGBT Q202; the diode D203 is connected in parallel to the modulation switch transistor IGBT Q202;

the second peak voltage absorption module comprises a capacitor C201, a resistor R201 and diodes D202 and D201; the resistor R201 and the diode D202 are connected in parallel and then connected to the capacitor C201 in series to form a circuit connected in parallel to the modulation switch transistor IGBT Q201; the diode D201 is connected in parallel to the modulation switch transistor IGBT Q201.

7. The fast frequency pulsed TIG welding system according to claim 1, characterized in that, the ARM minimum control system is connected to the SiC-based high-frequency drive circuit through a first isolation; the ARM minimum control system is connected to the switch drive circuit through a second isolation.

8. The fast frequency pulsed TIG welding system according to claim 7, characterized in that: the ARM minimum control system is connected to the SiC-based high-frequency drive circuit through the first isolation, which means:

the ARM minimum control system is connected to the SiC-based high-frequency drive circuit through an ISO5451 isolation drive chip, and the isolation drive chip is further connected to a first driving power supply circuit;

the SiC-based high-frequency drive circuit comprises capacitors C304 and C305, a Zener transistor ZD301, diodes D302 and D303, and resistors R310, R311, R312 and R313; a pin CLAMP of the isolation drive chip is connected to a gate of the SiC-based power switch transistor; the gate of the SiC-based power switch transistor is connected to a ground through the resistor R313 and the capacitor C305 connected in parallel; a pin OUT of the isolation drive chip is connected to the gate of the SiC-based power switch through the resistor R312; the diode D303 and the resistor R311 are connected in series and then connected in parallel to the resistor R312; the pin OUT of the isolation drive chip is connected to a drain of the SiC-based power switch transistor through the resistor R310 and diode D302 which are connected in series; the pin OUT of the isolation drive chip is further connected to the ground through the capacitor C304 and Zener diode ZD301 which are connected in parallel; a pin DESAT of the isolation drive chip is connected to the pin OUT of the isolation drive chip.

9. The fast frequency pulsed TIG welding system according to claim 7, characterized in that, the ARM minimum control system is connected to the switch drive circuit through the second isolation, which means: the ARM minimum control system is connected to the switch drive circuit through an optocoupler isolation chip; the switch drive circuit comprises NPN transistors Q401, Q402 and Q404, a PNP transistor Q403 and a second driving power supply circuit;

an output terminal of the optocoupler isolation chip is connected to a base of the NPN transistor Q401 through resistors R402 and R403 and a diode D402 which are connected sequentially; the resistor R403 is connected in parallel to a capacitor C401; the diode D402 is connected in reverse parallel to a diode D403; a connection point of the resistor R403 and the diode D402 is connected to a collector of the NPN transistor Q401 through a diode D401; the collector of the NPN transistor Q401 is further connected to a positive node of the second driving power supply circuit through a resistor R404;

a connection point of the resistors R402 and R403 is connected to a base of the NPN transistor Q402 through a resistor R408 and a diode D408 which are connected sequentially; the resistor R408 is connected in parallel to a capacitor C403; the diode D408 is connected in reverse parallel to the diode D409; a

connection point of the resistor R408 and the diode D408 is connected to a collector of the NPN transistor Q402 through a diode D407; the collector of the NPN transistor Q402 is further connected to the positive node of the second driving power supply circuit through a resistor R409; emitters of the NPN transistors Q401 and Q402 are respectively connected to a negative node of the second driving power supply circuit;

the collector of the NPN transistor Q401 is connected to a base of the PNP transistor Q403 through a resistor R405 and a diode D405 which are connected sequentially; the resistor R405 is connected in parallel to a capacitor C402; the diode C405 is connected in reverse parallel to a diode D404; a connecting point of the resistor R405 and the diode D405 is connected to a collector of the PNP transistor Q403 through a diode D406; the base of the PNP transistor Q403 is connected to the positive node of the second driving power supply circuit through a resistor R406; an emitter of the PNP transistor Q403 is connected to the positive node of the second driving power supply circuit through a resistor R407;

the collector of the NPN transistor Q402 is connected to a base of the NPN transistor Q404 through a resistor R410 and a diode D411 which are connected sequentially; the resistor R410 is connected in parallel to a capacitor C404; the diode D411 is connected in reverse parallel to a diode D412; a connection point of the resistor R410 and the diode D411 is connected to a collector of NPN transistor Q404 through a diode D410; the collector of the NPN transistor Q404 is connected to the collector of the PNP transistor Q403; an emitter of the NPN transistor Q404 is connected to the negative node of the second driving power supply circuit through a resistor R411; the collector of the NPN transistor Q404 is connected to the negative node of the second driving power supply circuit through a resistor R412; the collector of the NPN transistor Q404 is connected to the high-frequency switching module.

10. The fast frequency pulsed TIG welding system according to any one of claims 1 to 9, characterized in that, an industrial robot, a wire feeder, a welding gun, an gas supply device and a clamping equipment are further comprised; the industrial robot and the wire feeder are respectively connected to the ARM minimum control system; the clamping equipment is connected to the industrial robot and the welding gun respectively; the fast frequency pulsed TIG welding power supply is further connected to the gas supply device; the welding gun is further connected to the gas supply device and the wire feeder.