Energy saving, Reliability and Intellectualization

1200kW Solid State HF Welder
(Contact welding with PSM technology)

Technical Proposal

For M/S Sepanta Ahwaz

Prepared by

Baoding Sanzheng Electrical Equipment Co., Ltd.

November 3, 2021

Content

1. Equipment Configuration

1.1 Technical requirements

- Maximum O.D. of the pipe: 460 mm, minimum O.D. : 324 mm;
- Maximum wall thickness of the pipe: 15 mm;
- Speed: 10-15m/min for specification 460mm×15mm
- I.D. scarfing (inside burr removal): required;
- Material of the pipe: X42 up to X80 Steel grade.
- Type of welding: contact welding.
- Model of HF welder: GGP-1200/0.2-HC

1.2 Supply list

Description	Composition	Qty.
GGP-1200/0.2-HC 1200kW Solid state HF contact welder	Switching rectifying unit (with PLC)	1
	Inverter output unit	1
	Control desk (with PLC)	1
	3-D full electric positioning table	1
	Water-water cooler	1
	Air conditioner	1
	Optical fiber	1
	Contact welding unit	1

1.3 Technical parameter

HF welder:

- Nominal power: 1200kW
- Rated DC power: P_d=1200kW
- Rated DC voltage: U_{dN}=450V
- Rated DC current: I_{dN}=2670A
- Whole efficiency: $\eta \geq 85\%$
- Output power: $P_{out} > 1200$kW
- Designed frequency: f=150~200kHz
- MOSFET inverter: 100kW×12
- Line incoming cable: 300mm^2×4 psc/phase

Water-water cooler:

- Adopt water-water heat exchanger
- Cooling capacity: 500kW
- Rated power of in-line pump: 22kW
- Working flow of in-line pump: 150m^3/h
- Lift of in-line pump: 32m
- Soft water tank volume:1.5m^3
- Heat exchanger area: 45m^2
- External circulation water inlet temperature: ≤35℃
- Water inlet pressure: 0.25～0.45MPa

2. Technology Introduction

2.1 Topological structure

Solid state H.F. welder main circuit structure is shown in Fig.1 and Fig.2, which is a typical AC-DC-AC variable frequency structure. Rectifier adopts 3-phase bridge style thyristor phase-control rectifier circuit, DC side adopts inductor and capacitor to compose LC filter which meet the working requirements of voltage source inverter. The voltage source inverter adopts modularization parallel structure to extend the power, each inverter module is single phase MOSFET bridge style circuit connected with series resonance tank circuit by matching transformer. On one hand, the matching transformer realizes power combination and impedance matching; on the other hand it realizes electric isolation of load and power supply. The welder has the advantages of compact structure, small volume, convenient maintenance and low failure rate. In order to effectively and quickly protect the voltage source inverter for over-current fault, we adopt a unique, stable and reliable over-current protection circuit to ensure the safe and reliable operation of inverter.

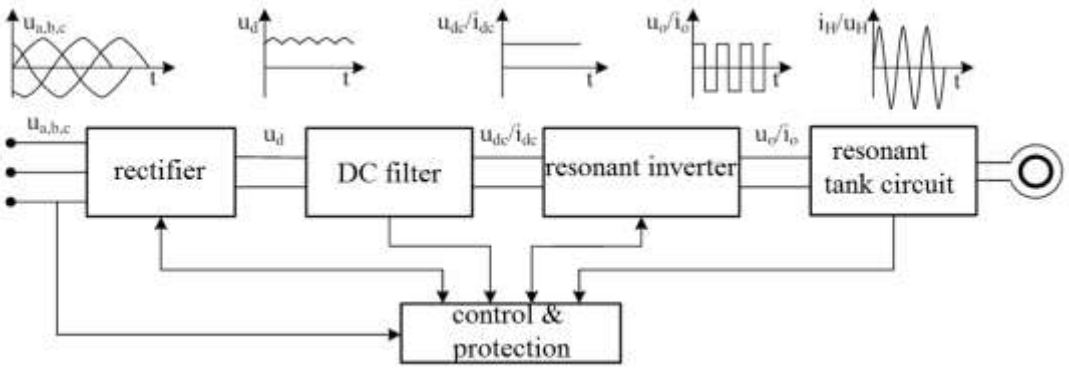

Fig.1 Topological structure block diagram of solid-state HF welder

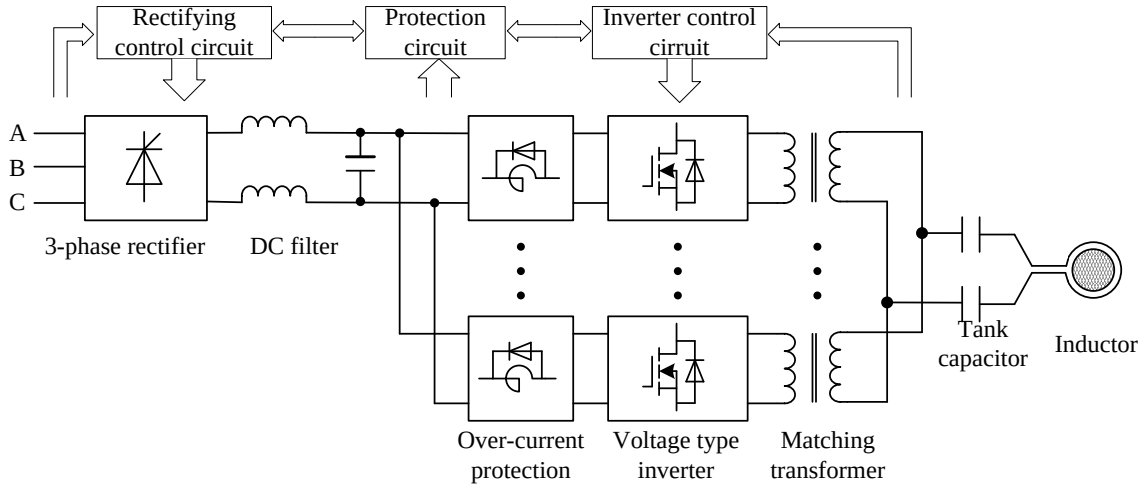

Fig.2 Circuit structure of solid-state HF welder

2.2 Working principle

Voltage source resonant inverter, also called series resonant inverter, is the most critical part of the solid-state HF welder. The structure of the inverter module and its output voltage and current waveforms are shown in Fig 3. By controlling the alternating on-off of S1, S3 and S2, S4 of MOSFET, the output voltage U_H of the series resonant inverter is approximately a square wave. Since the frequency of the inverter output voltage is near the resonant frequency of the resonant tank circuit, the resonant tank circuit has the smallest impedance to the fundamental wave of the inverter output voltage and high impedance to other higher harmonics, so the load current I_H is approximately a sine wave.

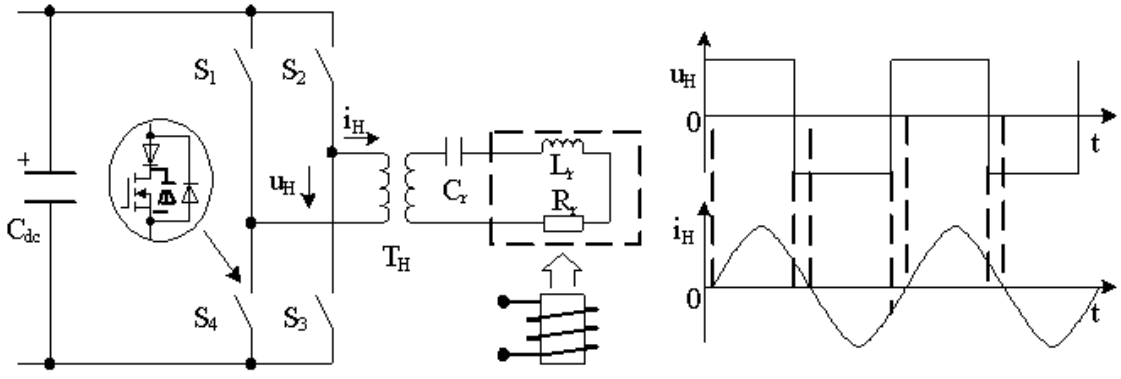

Fig.3 Circuit structure of voltage-type resonant inverter and its output waveform

2.3 Load matching and technical advantages

2.3.1 Load matching

The load matching adopts the inverter side power adjustment method based on PSM (Pulse Shielding Modulation) technology.

The newly developed FPGA full digital inverter card is adopted, and the inverter control adopts pulse shield modulation (PSM for short) technology, which completely solves the load matching problem of the conventional HF welder, improves the adaptability of the welder to different pipe types and different welding methods with excellent performance:

1) At 30% ~ 100% power output, it can always ensure that the DC voltage of the welder is at the rated maximum value of 450V and the current is continuously adjustable. The welder has the highest grid side power factor and the minimum harmonic current within the full power range.

2) When welding steel pipes of different specifications, the welder can ensure the rated power output without any adjustment by the user.

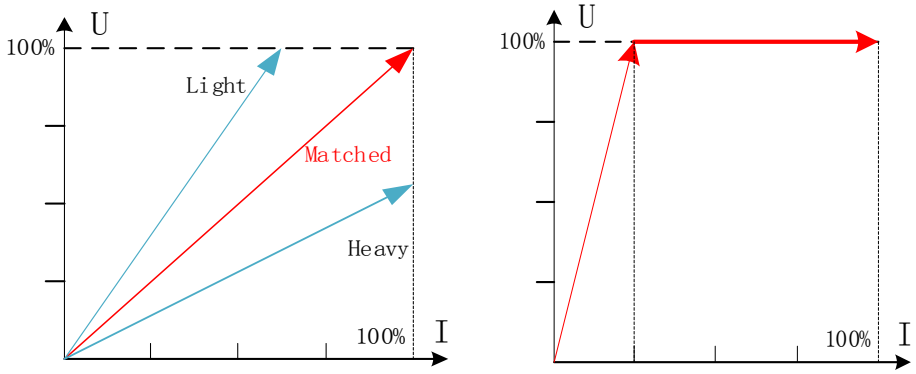

Fig.4 Load matching V-I curve (left: conventional welder; right: PSM technology)

Table-1 Comparison analysis of different inverter power regulations

Items of comparison	PS-PWM power regulation control	Pulse-Shielding-Modulation（PSM）
Power regulation scope	80%~100%	30%~100%
MOSFET switching loss	Big	Small
Water cooling requirement	High	Low
Output frequency	Changed	Unchanged
Power factor	Depend on current & voltage	0.9~0.92
Harmonic current	Big	Small
Load matching regulation	Bad	Excellent
Specification adaptability of steel pipe	Bad	Excellent
Control difficulty	Medium	High

2.3.2 Measures for high efficiency and energy saving

1) PSM technology

With the latest PSM inverter control technology, when welding steel pipes of different specifications, the welder can ensure a constant DC voltage of 450V and output power continuously adjusted. At this time, the welder has the highest grid side power factor, the minimum input current and the best welding efficiency.

2) Integrated inverter bridge

Adopt the optimized integrated inverter bridge with small stray loss.

3) Welding frequency optimization

With optimal design of resonance tank circuit, the frequency of the welder is 20% - 30% higher than the original design and effectively improve the welding efficiency.

4) Welding process optimization

According to the tube mill specifications and tube type, optimize the structural design of the output lead.

2.3.3 Technical advantages

1) Energy saving - PSM technology effectively solves the load matching problem of solid-state HF welders and lays the foundation for high efficiency and energy saving.

2) Reliability - the Integrated inverter bridge significantly improve the reliability and stability of the solid-state HF welder.

3) Intellectualization - Full digital control system improves the automatic management level of solid-state HF welder.

2.4 Control technology features

2.4.1 Rectifying control card

1) Field programmable gate array (FPGA) main control chip is adopted, with the main frequency up to 100 MHz; 16-bit A/D conversion chip (the original C51 control card uses 8-bit A/D conversion chip), having a high data resolution.

2) All adjustment potentiometers on the control card are cancelled (there are 12 adjustment potentiometers in the original control card), and the control parameter setting is completed through the color touch screen with simple and intuitive commissioning and operation are.

3) All parameters in the rectifying card can be transmitted to the upper computer for display and recording through communication.

4) It has the characteristics of high control precision, fast adjustment speed, strong flexibility and good interface expansibility to achieve digital control.

Fig. 5 Rectifying control card

2.4.2 Inverter control card

1) Field programmable gate array (FPGA) main control chip is adopted, with the main frequency up to 100MHz.

2) More advanced fixed-angle phase-locked control technology and upper/lower limit frequency phase-locking lose protection technology are adopted to make the equipment run more stable and efficient.

3) It has the function of frequency display and output (the conventional inverter control card does not have this function), and can remotely transmit operation parameters to the touch screen for display and recording.

4) High speed digital logic chip and magnetic isolation technology are adopted to ensure the consistency of driving pulse, and its error accuracy is increased by 6 times, which makes the driving pulse error negligible, and greatly improves the stability and reliability of welder.

Fig. 6 Inverter control card

2.4.3 MOSFET drive card

1) Consistency of driving pulse: the new drive card uses magnetic isolation chip instead of the original magnetic pot pulse transformer, which greatly improves the consistency of driving pulse, the error is improved from more than 25ns to less than 4ns, and the influence can be ignored.

2) Perfect protection function: the new functions of MOSFET negative voltage detection, MOSFET pulse detection and control power supply detection, not only ensure the accuracy and reliability of protection, but also prevent the secondary damage caused by inadequate maintenance and minimize the fault and loss.

3) Structural design optimization: the layout and routing optimization design of the new MOSFET driver card improves the electromagnetic compatibility and stability.

Fig. 7 MOSFET drive card

2.4.4 Faults integration collection card

For ***high-power welder***, the temperature protection of multiple drive cards and bridges adopt alarm output in series, which brings the problem of unclear fault display, and cannot achieve precise location of the fault point, causing difficulty in troubleshooting and increasing the difficulty and time of repair. For this reason, the faults integration collection card with communication function is newly designed.

1) The core component adopts high-speed intelligent programmable device-CPLD: The faults integration collection card optimizes and upgrades the CPLD, and selects the latest MAXV series from Altera. Compared with the previous generation CPLD, the power consumption is reduced by 70%, the capacity is increased by 500%, and the speed is increased by 25%. Since the chip is a hardware device, all the programs are programmed as hardware logic after download, so there are no problems such as program crash and overflow which has obvious advantages over single-chip microcomputer.

2) Powerful input/output: The faults integration collection card has 25 fault input functions and 2 fault output functions, and has the same functions as the Siemens S7-1200 digital input/output module, the input / output signals are isolated by high-speed optocoupler to prevent signal interference and ensure fault response time.

3) The communication function realizes multi-card cascade: The faults integration collection card has standard MODBUS communication function, which is convenient for communication with the touch screen. The communication address adopt dial switch setting, which is convenient for cascading use of multiple fault collection cards and expands the detection range of fault points.

4) Accurate fault location: The faults integration collection card is equipped with a two digits 7-segment nixie tube, which can locally display the corresponding input port information, and convenient for local troubleshooting and maintenance. For example, the nixie tube displays "05" in the fault state, indicating that the card's 5^{th} input terminal signal is faulty. Under normal operation, the nixie tube displays "00".

5) Fault information upload and protection: The high-speed optocoupler output signal of the faults integration collection card is connected with the rectifying control card to ensure the fast shutdown function or alarm function in the fault state. At the same time, the fault information is remotely transmitted to the touch screen through communication to display the specific fault information and clarify the fault location. For example, the alarm "the first drive card on the left side of a certain bridge is faulty", "the right side tank circuit water temperature fault of a certain position".

Fig.8 Faults integration collection card

2.4.5 Ethernet network technology

The switching rectifying unit and control desk are connected as distributed system using Ethernet communications. Compared with control wire connection, it has the advantages of simple connection, lower installation and maintenance cost. Compared with MODBUS communication and DP communication, it has the features of faster speed and stronger anti-interference ability, and can collect and record the data.

Using Siemens S7-1200 PLC to form a distributed Ethernet communication network can build an interconnected big data platform to realize remote monitoring, operation, information collection and analysis, etc.

Optionally equipped with cloud service module, all operation data can be remotely monitored and recorded, and the production line can be remotely controlled. On the one hand, it is convenient for customers to carry out data analysis, product quality control, production arrangement and higher requirements of automatic control. On the other hand, it can realize remote fault diagnosis and maintenance of welding machines.

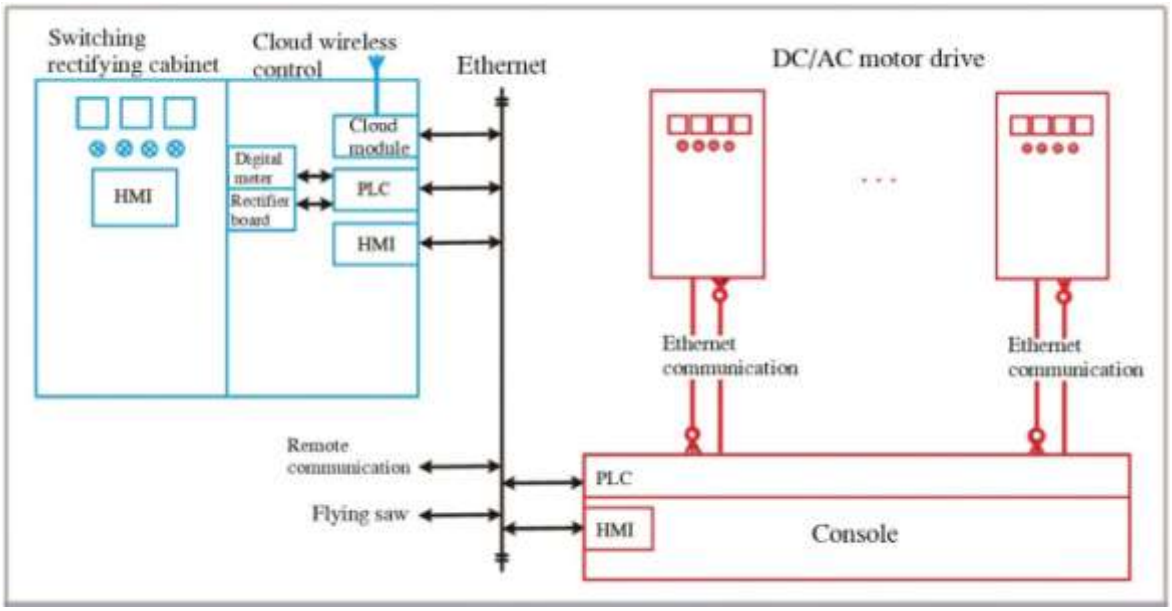

Fig.9 Ethernet Network

2.4.6 Ferrite rod checking system

The ferrite rod checking system can accurately judge whether the ferrite rod is normal by collecting important parameters of the welder such as DC voltage, DC current, tube mill speed and resonance frequency. It has output functions such as alarm prompt or shutdown, which can effectively improve the yield of the tube mill line.

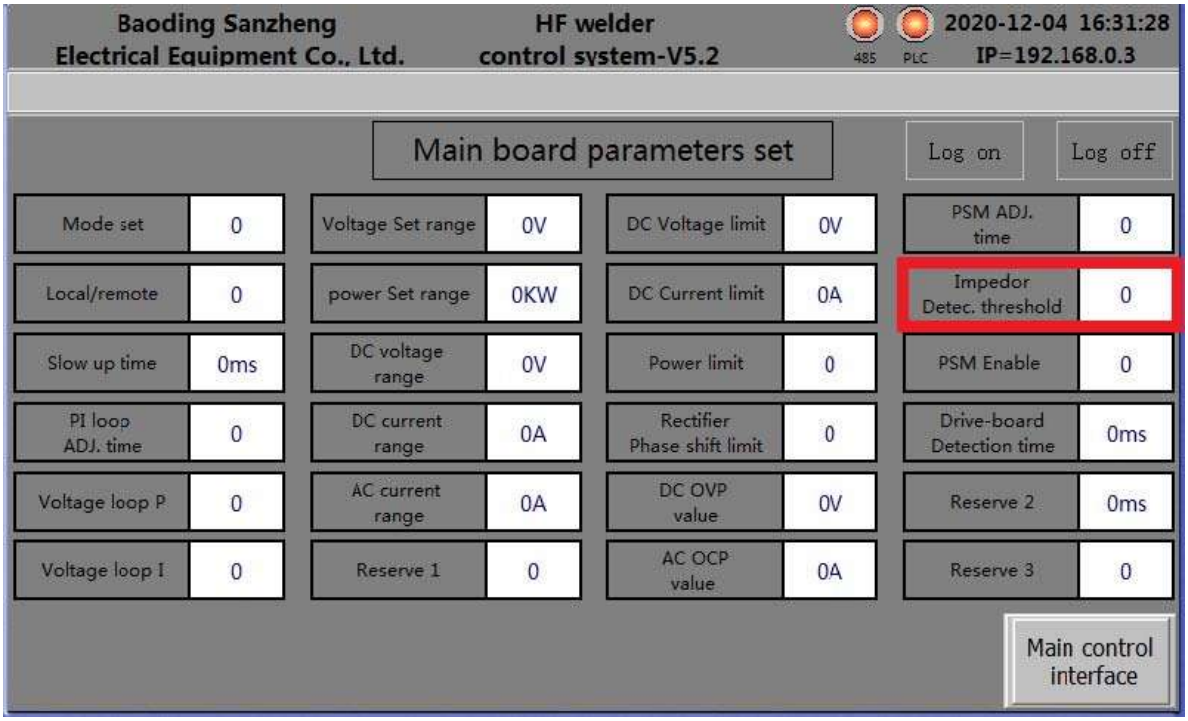

Fig.10 Ferrite rod checking system

2.4.7 Functions of control desk

1) Adopt stainless steel operation penal with beautiful appearance and easy to clean.

2) Add touch screen protection cover to improve the service life of touch screen.

3) Siemens S7-1200 PLC and 10 inch colorful touch screen are used on the control desk, which can display accurately and intuitively.

4) The touch screen of the control desk has data recording function for important parameters and information, which is convenient for historical query. Meanwhile, it has visual data record, which is convenient for analysis and viewing the status information of the equipment.

5) It has the functions of remote operation, power regulation, state monitoring and fault diagnosis of HF welder.

6) Ethernet interface is reserved to facilitate the user's function expansion and realize remote monitoring and information collection.

7) The function can be added and expanded according to the actual needs of users.

Fig.11 Control desk

2.4.8 Speed-Power closed-loop technology

The digital rectifier control board is used with the digital inverter control board, which can realize the speed-power closed-loop control. By input the speed signal and the steel pipe specifications input through the touch screen, the system can automatically calculate the output power of the welder according to the speed, and automatically adjust the welder power with the speed change of tube mill, which realizes the closed-loop control of tube mill speed and power of the welder to improve the welding yield and production efficiency.

2.5 Process structure characteristics

2.5.1 The new design of inverter bridge

1) The inverter module adopts the new process tinning on the surface with copper tube produced by the full numerical control machine tool. The surface of water-cooled plate (17mm's thick) is smoother with better cooling effect. The temperature of power components is 3-5℃ lower than using the original inverter bridge plate (5mm's thick red copper plate with tinning on surface + cooling mode of copper tube soldered on surface) in the same environment, which improves the safety of power components.

2) The inverter bridge is designed with full bridge compact structure, with small electromagnetic radiation and high efficiency of the whole machine, reducing the failure rate of the equipment.

3) The inverter bridge is designed as 100kW. The inverter bridge adopts modular mode to complete power superposition.

The stacked busbar reduces the electromagnetic radiation and stray loss of the welder busbar. The symmetrical layout greatly improves the current sharing of power devices and enhances the safety of devices. The simple and compact structure significantly reduces the overall volume of high-power welder, and N×M structure makes it possible to manufacture the ***ultra-high power welder***.

Fig.12 Integrated inverter bridge (100KW)

2.5.2 The protection of matching transformer and tank capacitor

The matching transformer and tank capacitor shall be equipped with temperature protection switch to prevent overheating damage of components caused by water pipe blockage or insufficient water flow.

2.5.3 Optimization of output lead

The output lead of the inverter bridge is changed from the multi-layer copper sheet connection to the water-cooled copper tube connection, so as to prevent the damage of the power components of the inverter bridge caused by the overheating of the output lead, reduce the failure rate of the inverter bridge, improve the installation process level of the inverter bridge, and improve the current sharing problem after the inverter bridge connected in parallel.

2.6 The protection and realization method of solid-state HF welder

The protection function of the solid-state HF welder is designed for various abnormal conditions and failures of the power supply. It is divided into main circuit protection, control circuit protection, load protection and water system protection.

The new control system adds a faults integration collection card, which refines each fault point and displays it on the touch screen accurately and specifically, which greatly simplifies the troubleshooting and improves the maintenance efficiency.

2.6.1 Main circuit protection

1) Power phase loss protection: The rectifying control card has the function of detecting the phase loss of the power supply and the alarm output, and the phase voltage sampling card has the corresponding phase sequence indicator light, which is convenient for troubleshooting.

2) AC overcurrent/overvoltage protection: When the rectifying side of the power supply is short-circuited or other work is abnormal, it may cause AC overcurrent/overvoltage protection. When the overcurrent/overvoltage exceeds the setting value, the three-phase thyristor rectifier control circuit protection acts, and the touch screen displays fault information. If the rectifier thyristor is damaged, the main incoming circuit breaker on the AC side will trip synchronously, cutting off the connection to the grid.

3) DC overcurrent protection: The DC side of the HF welder is equipped with a Hall current sensor detection circuit. When the DC current is detected to be greater than the set threshold, the drive pulses of the rectifier thyristor and the inverter MOSFET are blocked to realize effective protection.

2.6.2 Control circuit protection

1) Communication alarm: it has the functions of Ethernet communication and Mudbus communication abnormal alarm.

2) Start-stop logic protection: It has the logic relationship processing and protection functions of control circuit, main circuit, and the heating start/stop signal to prevent failures caused by non-sequential operation or feedback signal fault.

3) MOSFET drive card protection: The MOSFET drive card added the new function of MOSFET negative voltage detection, the MOSFET pulse detection and control power detection. The protection is accurate and reliable and prevents secondary damage caused by improper maintenance.

4) Inverter power distribution card protection: The power distribution card is composed of completely independent 4-channel three-level L-C filtering, which greatly reduces the common mode interference of the control power supply. Each way of power distribution card adds an independent power detection function, has a passive point output and alarm indicator, which is convenient and fast for troubleshooting.

2.6.3 Load protection

The working condition of the load is relatively bad, and the work coil often have inter-turn short circuits, sparks, and ground faults, and sometimes the inductors open and short circuits. When the load has the above problems, it will cause violent fluctuations in the natural resonant frequency of the tank circuit, which will cause a sudden change in the working state of the inverter, and threaten the safe and reliable operation of the device.

1) Phase-lock lose protection: The phase-lock lose protection circuit collects the phase values of the load voltage and current at the same time, and compares them with a given threshold signal in real time. When the phase value exceeds the set threshold, the protection circuit considers it as a tank circuit failure and phase-lock lose protection acts.

2) Load short circuit/arcing protection: The HF welder realizes the protection of the load inductor short circuit, arcing and other faults by judging the resonant frequency change rate and real-time acquisition of the tank circuit current, so as to ensure the safe and stable operation of the welder.

3) Load open circuit protection: The HF welder realizes the protection of the load inductor open circuit and the inductor burnout by judging the resonant frequency change rate and real-time acquisition of the tank circuit voltage, so as to ensure the safe and stable operation of the welder.

2.6.4 Water system protection

The main circuit components of the HF welder require water cooling for heat dissipation. Whether the water system is normal or not directly affects the stability and failure rate of the welder, so the monitoring and protection of the water system is particularly important.

1) Water pressure protection: Each water collector inlet is equipped with an water pressure gauge, which can conveniently and quickly set the upper/lower limit protection value of the water pressure alarm locally and has the function of fault signal output.

2) Incoming line reactor and flat-wave reactor temperature protection: important components such as incoming line reactor and flat-wave reactor on the rectifier side add temperature detection to prevent overheating and damage to components caused by water pipe blockage or insufficient water flow.

3) Inverter bridge temperature protection: The inverter switching devices of HF welder have serious heating, so water cooling is widely used. A temperature detection switch is

installed on each inverter bridge. When the temperature of the inverter bridge exceeds the alarm temperature, the temperature protection action acts.

4) Matching transformer and tank circuit resonant capacitor temperature protection: important components such as matching transformer and tank circuit resonant capacitor add temperature detection protection to prevent the device from overheating damage caused by water pipe blockage or insufficient water flow.

3. Equipment composition and description

This 1200kW solid-state HF welder is composed of switching rectifying unit, inverter output unit, optical fiber, control desk, 3-D full electric positioning table and water-water cooler. The protection level of the cabinet is IP54.

3.1 Switching rectifying unit

The integrated design of the switch and the rectifier part, in addition to the function of the switch cabinet, also has the rectifying control function of the solid-state HF welder.

1) Installed 3-phase full-controlled thyristor rectification bridge to realize power adjustment of the HF welder.

2) Installed flat-wave reactor, flat-wave capacitor and filter to improve the flat-wave coefficient.

3) Protection reactor, ammeter, and current hall sensor are installed to protect and monitor the inverter bridge.

4) Siemens S7-1200 PLC is installed to realize power logic control and Ethernet communication functions.

Fig. 13 Switching rectifying unit (front side)

1. ACB	2. Control transformer	3. SCR drive card	4. SCR rectifying bridge
5. R-C absorption	6. Flat-wave reactor	7. Relay control part	8. Ethernet switch

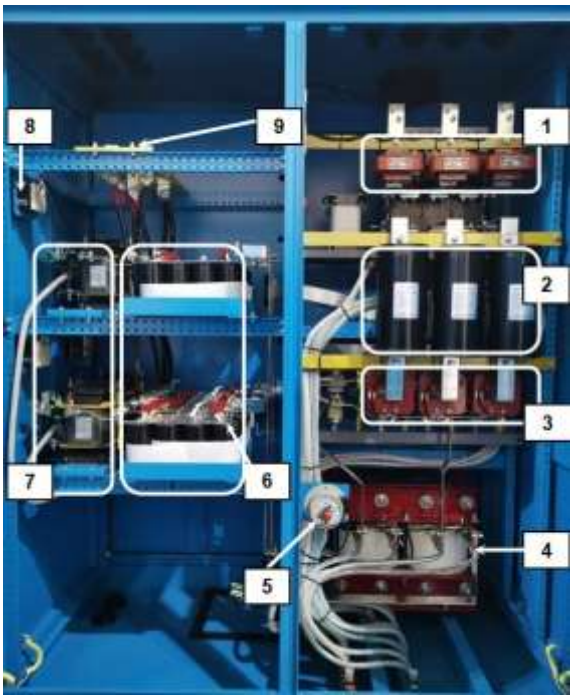

Fig. 14 Switching rectifying unit (back side)

1. line-in sampling transformer	2. line-in reactor	3. control sampling transformer
4. flat-wave reactor	5. water pressure meter	6. electrolytic capacitor bank
7. protection reactor	8. ammeter	9. DC power cable wiring board

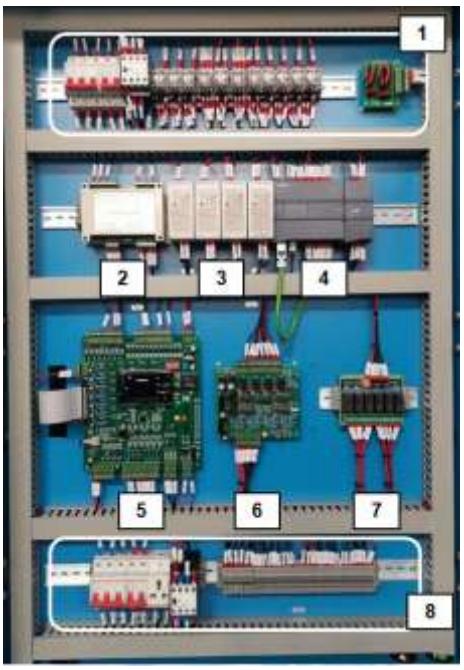

Fig. 15 Relay part of switching rectifying unit (front side)

1. Control circuit switching and relay part	2. phase voltage sampling card
3. Switching power supply: supply DC power supply to PLC and relay part	4. PLC: logic control and communication
5. Rectifying card: rectifying control, PI adjustment, SCR control, AD sampling	6. Single bridge over current card: DC over current protection
7. Relay card: signal isolation	8. External control breaker and terminals

3.2 Inverter output unit

The inverter output unit realizes the integrated design of resonant inverter and series resonant tank circuit, with the advantages of compact structure, high efficiency, convenient maintenance, low failure rate, high efficiency and energy saving.

1) The inverter part is composed of MOSFET single-phase inverter bridges in parallel. The inverter bridge is designed to be 100kW, which completes the power superposition in a modular way.

2) The matching transformer is used to complete the power synthesis, with adopt of the secondary low-voltage resonance and no welding transformer output mode. The tank circuit resonant capacitor (low voltage) and steel tube Vee type inductor resonate directly, to realize the power transmission through the output of the contact welding unit.

3) Use a sealed cabinet and equipped with air conditioners installed on the top.

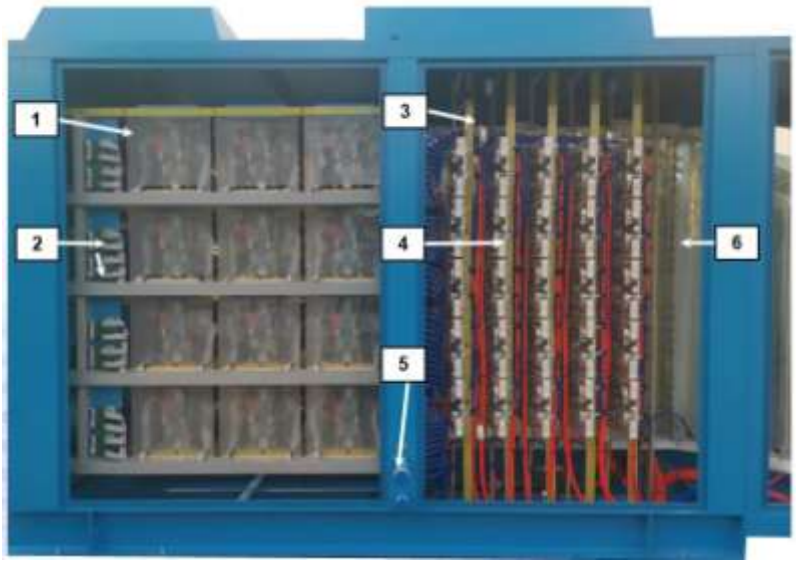

Fig. 16 Inverter cabinet (side 1)

1. Inverter power bridge card	2. Pulse distribution card	3. Acquisition magnetic ring
4. Resonance capacitor group	5. Cooling water collector	6. Output lead

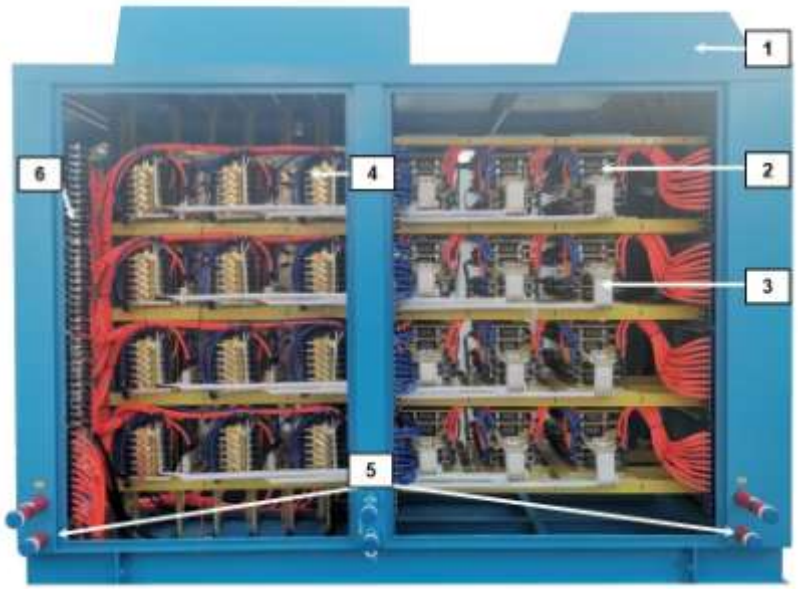

Fig. 17 Inverter cabinet (side 2)

1. DC power line wiring board	2. Inverter power bridge card	3. Output feed tube
4. Matching transformer	5. Cooling water collector	6. Water temperature switch

3.3 Optical fiber

The communication from the switching rectifying unit to the inverter output unit adopts optical fiber connection to ensure that the control system is not interfered by high-frequency signals and improve the reliability of the welder.

3.4 Control desk

Please refer to 2.4.7 for details.

3.5 3-D full electric positioning table

It is used to install the inverter output cabinet and adjust the position of the contact head.

Full electric adjustment for front/back, left/right and up/down directions. The transmission adopts an asynchronous AC motor, and the gearbox adopts a worm gear structure. The drive motor is controlled by inching, the adjustment is stable and reliable to ensure the contact head in the best welding position.

Fig. 18 3-D full electric positioning table

3.6 Water-water cooler

The water-water cooler completes the cooling of heating components such as the rectifying bridge, flat-wave reactor, inverter bridge, and resonance tank circuit, and is designed with water temperature indication and protection. Adopt water-water heat exchanger. The characteristics are:

- Purified water circulates, the water quality is clean without scale in pipelines, which greatly reduces the operation faults of the equipment..
- Closed cycle circulation, no impurities entering, no moss, the pipeline will not be blocked.
- Small size, good integrity and convenient installation.
- Closed water circulation with little water consumption.
- It can avoid the malfunction caused by condensation water in summer.
- Small size water storage tank, and antifreeze can be used in winter to avoid water failure caused by freezing.
- It is more economic than an air-water cooler.
- Adopt stainless steel water tank and in-line pump.

Fig. 19 Water-water cooler

3.7 Contact welding unit

The contact welding unit is for adjustment of contact head together with the 3-D positioning table to meet welding requirement of pipes with different specifications. The contact head can be up and down rapidly driven by the cylinder to keep a closed contact with the steel tube to ensure a reliable welding.

Fig. 20 Contact welding unit

4. Main parts list

S/N	Description	Specification	Make
1	PCB	Rectifying control card, inverter control card, drive card, etc.	Baoding Sanzheng
2	Thyristor assembly	KP_3000A/1400V	Jinzhou Huajing
3	MOSFET	IXFN38N100Q2	IXYS
4	Fast recovery diode	DSEI_2×101-12A	IXYS
5	Switching power supply	LM50-20B15-SZ	MORNSUN
6	HMI	TPC7062Ti, TPC1061Ti	Kunluntongtai
7	Flat-wave reactor	3000A/0.33mH	Baoding Sanzheng
8	PLC	S7-1200	Siemens
9	Main breaker		Schneider
10	Button & indication light	LA39	Siemens
11	Ethernet switch	IES10-SW5, IES10-SW8	Weidmuller
12	Line incoming reactor	3000A/6uH	Baoding Sanzheng

5. Supply scope

5.1 Supply scope of the Seller

- Supply list.

Description	Composition	Qty.
GGP-1200/0.2-HC 1200kW Solid state HF contact welder	Switching rectifying unit (with PLC)	1
	Inverter output unit	1
	Control desk (with PLC)	1
	3-D full electric positioning table	1
	Water-water cooler	1
	Air conditioner	1
	Optical fiber	1
	Contact welding unit	1

- Free fumigation seaworthy anti-dust vacuum package.
- Guidance on equipment installation and in charge of commissioning.
- Perfect after-sales service and permanent technical support.
- Electrical drawings and operation manual in English.

5.2 Supply scope of the Buyer

- Power supply transformer, line incoming power cables and control cables.
- Layout drawing of tube mill line and workshop.
- External circulation water pool, cooling tower and pipelines at site.
- Fundamental facility including fastening pieces, pre-embedded parts, padding iron and etc as per the equipment layout and installation dimension from seller.
- Tools for installation, commissioning, production and maintenance.
- Equipment unloading, installation and adjustment at site.

6. Requirements for Equipment Operation

6.1 Environment requirements

- Indoor installation with good grounding condition. The color of grounding wire should be obviously different from control wires. Sectional area of grounding wire: >6mm^2 grounding resistance: ≤4Ω.
- Height above sea level should be no more than 2000m otherwise rated value should

be reduced to be operated.

- Ambient temperature: -5℃~+40℃
- Air relative humidity: ≦85%.
- No severe vibration, no conductive dust, no various causticity gas and explosion gas.
- Installation gradient: ≤5° and install in the place with good ventilation condition.

6.2 Power net requirements

- Power grid voltage should be sine wave, harmonics distortion: ≤5%.
- Imbalance degree between 3-phase voltage: ＜±5%.
- Power grid input voltage is line voltage AC 380V, continuous fluctuation range: ≤±5%, power net frequency variation: ≤±2% (i.e. between 49 ~ 51Hz).

6.3 Water quality requirements for external circulation water pool

The water quality for external circulation water pool will directly affect the operation of water-water cooling system, and even the reliability of the equipment. So it is suggested to the user that adopts running water for outer pool, and the associated requirements are as below:

- The water quality should be transparent, no turbidity, deposit and scale. The water pipe for water should be prevented from fouling
- The cooling pool should be no impurity so as to prevent the pipeline of water-water cooling system from blocking which can influence the heat exchanging effect.
- Install cooling tower for water pool to guarantee the water temperature of water-water cooling system meets the requirements.
- Inlet water temperature: 20℃~35℃. When supplying water in hot weather, avoid condensation on the surface of the water-cooled element
- Inlet water pressure: 0.25～0.3MPa (approximately 2.5～3kg/cm^2).

7. Free fumigation seaworthy anti-dust packing