同泽电气
TONGZE ELECTRIC

Solid State High Frequency Welder

Operation Manual

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Important Note

Thanks for choosing our products. Please note the following points in order to operate the equipment in a safety, correct and high efficiency way:

1) This manual is only adapted to the solid state high frequency welder that equipped with old type 3# board.

2) Please read this manual carefully, and adjust, test and operate according to relative instructions of this manual. Please take the documents delivery with equipment as standard if have.

3) In order to prevent the device to be destroyed, hot plugging and touching the chips and components on the PCB is not permitted.

4) Please use qualified instrument and device to test the equipment.

5) Please contact us if any malfunction occurs or needs maintenance.

Contents

1 Brief introduction

1.1 General

High frequency welding is originated in 1950s, which is a new welding technics to weld steel or other metal material using skin effect and proximity effect produced by high frequency current. The appearance and mature of high frequency welding technology directly promote the development of straight seam welding tube industry.

GGP series of solid state HF welder is a kind of high frequency inverter power supply to change 3-phase power frequency 50Hz AC to be single phase high frequency AC (100~600kHz), with AC-DC-AC topological structure for the circuit. GGP series of solid state HF welder adopts high voltage large power MOSFET module as switch device of inverter. Take MCU system and intelligent CPLD programmable chip as core to form rectifying and inverter digital control system. GGP series of solid state HF welder has the advantages of high welding quality, simple and reliable circuit, convenient commissioning and operation and energy saving, which is the best choice for enterprises to improve production technics and enhance quality.

GGP series of solid state HF welder includes: switchgear rectifying cabinet, inverter output cabinet, console (optional), positioning table (optional), water cooling system (optional)

a. switchgear rectifying cabinet

b. inverter output cabinet

c. console

d. water cooling system

Fig. 1 GGP series of solid state HF welder compositon

1.2 Main features

(1) technology features

➢ Perfect structure design

- Independent design of switchgear rectifying cabinet and inverter output cabinet, connected by soft cable, which is convenient for layout at user’s site.
- The rectifier adopts 3-phase 6-pulse thyristor rectifying. For large power welder, 12-pulse thyristor rectifying can be selected to eliminate grid side fifth and seventh harmonic, and grid side harmonic current is the lowest.
- Power combination of the inverter bridge is accomplished by the way of power unit superposition. Each MOSFET power unit is designed to be 50kW/100kW/150kW and slideway drawer structure, which is convenient for installation and repair.
- High standard electromagnetism compatibility design, electromagnetism radiation meets national standard.
- Closed cabinet design, meeting rigor environmental requirements on site.

* *The user needs to prepare three winding power transformer.*

➢ **Full digital control system**

- 3-D rectifier adopts high cost performance MCU controlling to realize precise synchronism trigger with high control precision and small grid-side non characteristic harmonic.
- Resonant inverter adopts CPLD to form full-digital control system that is

characterized by their automatic constant angle, high phase-lock precise and wide scope of phase-lock.

- The welder has electronic automatic load matching function with good load adaptability, high electrical efficiency and high power coefficient.
- The welder has perfect protection function with reliable working and low failure rate.

➢ **HMI and fault diagnosis system**

- Adopt PLC and touch screen to form perfect HMI system.
- Realize integrated automatic control of welder system.
- Fault display and diagnosis system.

(2) Main Technical Parameter

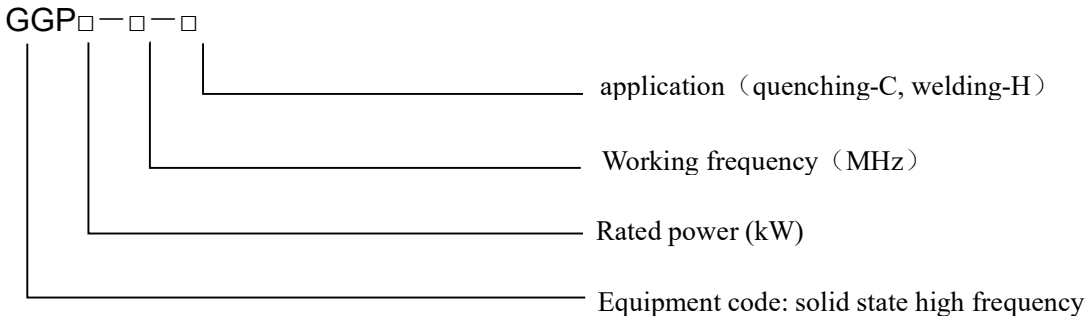
Table 1- Technical parameter of solid state HF welder

model	AC input	Rated DC voltage	Rated DC current	Frequency scope	Electrical efficiency
GGP60-0.8-H	3AC380V 50/60Hz	450V	130A	650~800 kHz	≥85%
GGP100-0.45-H	3AC380V 50/60Hz	450V	220A	400~450 kHz	≥85%
GGP150-0.4-H	3AC380V 50/60Hz	450V	330A	350~400 kHz	≥85%
GGP200-0.35-H	3AC380V 50/60Hz	450V	440A	300~350 kHz	≥85%
GGP250-0.3-H	3AC380V 50/60Hz	450V	550A	250~300 kHz	≥85%
GGP300-0.3-H	3AC380V 50/60Hz	450V	660A	250~300 kHz	≥85%
GGP400-0.3-H	3AC380V 50/60Hz	450V	880A	250~300 kHz	≥85%
GGP500-0.2-H	3AC380V 50/60Hz	450V	1100A	150~200 kHz	≥85%
GGP600-0.2H	3AC380V 50/60Hz	450V	1300A	150~200 kHz	≥85%
GGP700-0.2-H	3AC380V 50/60Hz	450V	1500A	150~200 kHz	≥85%
GGP800-0.2-H	3AC380V 50/60Hz	450V	1800A	150~200 kHz	≥85%
GGP1000-0.2-H	3AC380V 50/60Hz	450V	2200A	150~200 kHz	≥85%
GGP1200-0.2-H	3AC380V 50/60Hz	450V	2700A	150~200 kHz	≥85%
GGP1400-0.15-H	3AC380V 50/60Hz	450V	3100A	100~150 kHz	≥85%

GGP1600-0.15H	3AC380V 50/60Hz	450V	3600A	100~150 kHz	≥85%
GGP1800-0.15-H	3AC380V 50/60Hz	450V	4000A	100~150 kHz	≥85%

Note: Conventional design. Can be customized according to user's grid and welding technics.

⑶ Model



Example:

GGP100-0.4-H: rated power 100kW; frequency: 400kHz; H: for welding.

⑷ equipment composition

Solid state HF welder is composed of switchgear rectifying cabinet, inverter output cabinet, console, positioning table and water cooling system.

➢ switchgear rectifying cabinet

- One-cabinet design of both switchgear cabinet and rectifying part with function of switchgear cabinet and rectifying control of solid state HF welder.
- Install incoming switch, incoming ampere meter and switchable voltmeter and incoming voltage indication light.
- Install 3-phase full-controlled thyristor rectifying bridge to realize power adjustment of solid state HF welder.
- Install flat-wave reactor, flat-wave capacitor and filter to improve the flat-wave coefficient.

➢ inverter output cabinet

- The inverter part is composed of MOSFET single-phase inverter bridge connected in parallel. The power of single-phase bridge is 100kW/50kW; the inverter bridge adopts the building block method to realize power superposition. Every piece of bridge plates is designed to be drawer type, which is very convenient to be installed and repaired.
- Adopt matching transformer to finish power combination. With adoption of secondary resonance and no welding transformer, tank circuit resonant capacitor (low voltage) has a resonance with the inductor directly to realize power transfer through output arm.
- Adopt sealed cabinet with installation of air conditioner.

➢ console

- The console realizes the function of remote operation and power adjustment with installation of LCD screen. Having armature voltage and excitation voltage indication of DC drive and DC voltage and DC current indication of HF welder. Power closed loop control function is optional.
- The design of console will be different as per different type and quantity of DC drive matched with.

➢ positioning table

- 2-D positioning table: for induction welding mode and installation and adjustment of inverter output cabinet. The position of inductor coil can be adjusted manually.
- 3-D positioning table: for induction/contact welding mode, and installation and adjustment of inverter output cabinet. The position of inductor coil can be adjusted manually and electrically.

➢ Water-water cooling system

- For water cooling of switchgear rectifying cabinet and inverter output cabinet, high quality plate-type heat exchanger, water pump and stainless steel pipeline are adopted, having water pressure and water temperature display and protection.
- Water-water heat exchanger will be different as per different welder power, for details please refer to selection guide.

1.3 exterior dimension and structure

The exterior dimension of GGP series solid state HF welder is our standard design (table 2). For special requirement, non-standard design can be made, but min. dimension needs to be negotiated by both parties.

Table 2 exterior dimension of GGP series solid state HF welder (L×W×H)

Power	switchgear rectifying cabinet (mm)	inverter output cabinet (mm)	Console (mm)
60kW	1500×900×2000	1750×700×1100	850×550×1200
100kW	1500×900×2000	1750×700×1100	850×550×1200
100kw double frequency	1500×900×2000	1750×700×1400	850×550×1200
150kw	1500×900×2000	1750×700×1100	850×550×1200
200kw	1500×900×2000	1750×700×1400	850×550×1200
250kW	1800×900×2000	1800×700×1600	850×550×1200
300kW	1800×900×2000	1800×700×1800	850×550×1200
400kW	1800×900×2000	2000×800×1500	850×550×1200
500kW	2000×1150×2000	2000×800×1800	850×550×1200
600kW	2000×1150×2000	2000×800×2000	850×550×1200
700kW	2000×1500×2000	2900×1000×2000	850×550×1200
800kW	2000×1500×2000	2900×1000×2000	850×550×1200
1000kW	2000×1500×2000	2900×1000×2000	850×550×1200
1200kW	2000×1500×2000	2900×1000×2150	850×550×1200
1800kW	2100×1700×2000	3500×1200×2500	850×550×1200

2 Equipment installation

Before or after unpacking of equipment, the components should be checked to see if there's damage or damp during transportation. It should be repaired if such situation occurs, and operated after the defects eliminated. Please inform us in time in order not to miss the time of claim.

2.1 Environmental requirements

（1） Indoor installation with good grounding condition. Grounding wire color should be obviously different from control wires. Sectional area of grounding wire: >6mm^2, grounding resistance: ＜4Ω.

（2） Height above sea level should be no more than 1000m, otherwise rated value should be reduced to be operated.

（3） Ambient temperature: -10℃~+40℃, otherwise rated value should be reduced to be operated.

（4） Air relative humidity: ≤85%.

（5） No severe vibration, no conductive dust, no various causticity gas and explosion gas.

（6） Installation gradient: ≤5°.

（7） Install in the place with good ventilation condition.

2.2 cooling water requirements

Power supply, load inductor and copper strip adopt water cooling method, and the quality of cooling water will directly affect the operation reliability. It is suggested analyze and test the cooling water, the result should meet the following conditions. It should be solved by purification method if differences existed.

⑴ Mechanical property: transparent and not turbid without deposit (screen mesh dimension 0.38mm), total solid content is no more than 250mgL.

⑵ Chemical property:

PH value	6~8
Chlorid	no more than 100mg/L
Nitrite (NO2-)	no more than 0.04mg/L

Fe	no more than 0.3mg/L
Mn	no more than 0.05mg/L
S	no more than 250mg/L

(3) Conductivity: no more than 600μs /cm

(4) Water inlet temperature: no less than 5℃, no more than 35℃. Fogging coatings on the surface of water cooling component should be avoided for high ambient temperature.

(5) Water inlet pressure: 0.18~0.25Mpa (approximately 1.8~2.5kg/cm^2).

2.3 power net requirement

The power net voltage should be sine wave and harmonic distortion is no more than 5%. The power net input is line voltage 380V AC, continuous fluctuation range of power net voltage is no more than ±10%, power net frequency change is no more than ±2% (i.e. between 49~51Hz), the unbalancedness of 3-phase should less than ±5%.

The power supply incoming line adopts copper core cable to connect. The contact of the joint should be in good and reliable condition. Increase the contact area and decrease contact resistance as far as possible.

There's no phase sequence differentiation requirement for power supply incoming line, but it is better connect as per positive sequence (when positive sequence, 1# board displays number and there's no radix point at the bottom right; and there's radix point when negative sequence) so as to check synchronization relationship between trigger pulse and power supply incoming line when maintenance. Power supply incoming line A, B and C should connect yellow, green and red, and clearly marked.

The wire of power supply incoming line should be pressed firmly by screw, and the nominal current of wire is no less than the max DC current in Table 1.

Power supply incoming line is no less than the value listed in Table 3.

Table 3 power supply incoming line and load connection copper strip sectional area

Power	3-phase line incoming copper strip sectional area
60 kW	75 mm^2
100 kW	120 mm^2
150 kW	185 mm^2
200 kW	2 pcs of 120 mm^2 or 1 piece of 240 mm^2
250 kW	1piece of 300 mm^2 or 2 pcs of 185 mm^2
300 kW	1 piece of 300 mm^2 or 2 pcs of 185 mm^2
400 kW	3 pcs of 150 mm^2 or 2 pcs of 240 mm^2
500 kW	3 pcs of 185 mm^2 or 2 pcs of 300 mm^2
600 kW	2 pcs of 300 mm^2 or 3 pcs of 240 mm^2
700 kW	4 pcs of 240 mm^2 or 3 pcs of 300 mm^2
800 kW	3 pcs of 300 mm^2 or 4 pcs of 240 mm^2
1000 kW	5 pcs of 240 mm^2 or 6 pcs of 185 mm^2
1200 kW	4 pcs of 300 mm^2 or 6 pcs of 240 mm^2
1800 kW	6 pcs of 300 mm^2 or 8 pcs of 240 mm^2

2.4 power connection wire between switchgear rectifying cabinet and inverter output cabinet

Copper wire is adopted for connection between switchgear rectifying cabinet and inverter output cabinet. Please refer to the mark inside the cabinet when connection. The contact of the connection should be in good condition, and increase the contact area and decrease contact resistance as far as possible.

Please refer to Table 4 for correspondence relationship between copper wire specification and equipment power.

Table 4 correspondence relationship between copper wire specification and equipment power

Rated power(kW)	Total area of anode plastic copper wire (mm^2)	Total area of cathode plastic copper wire (mm^2)

60 kw	50 mm^2×2	50 mm^2×2
100 kw	70 mm^2×2	70 mm^2×2
150 kw	70 mm^2×3	70 mm^2×3
200 kw	70 mm^2×4	70 mm^2×4
250 kw	70 mm^2×5	95 mm^2×4
300 kw	120 mm^2×3	120 mm^2×3
400 kw	120 mm^2×4	120 mm^2×4
500 kw	120 mm^2×5	150 mm^2×4
600 kw	120 mm^2×6	120 mm^2×6
700 kw	120 mm^2×7	150 mm^2×6
800 kw	120 mm^2×8	150 mm^2×6
1000 kw	120 mm^2×10	185 mm^2×6
1200 kw	120 mm^2×12	185 mm^2×8
1800 kw	120 mm^2×18	185 mm^2×12

2.5 connection of control wire

According to external terminal instruction of external control function of this manual, connect external control wire and check if the connection of outside lead is correct or not and the connection point is loose or not as per electric drawing.

2.6 Zero-connection requirement of induction heating equipment

The power supply of equipment is 3-phase 4-wire system, for null line, copper wire that not less than 2.5mm^2 should be used and connected with “N” on terminal block, to meet the requirement of single phase 220V operation power supply.

Special note: Zero-connection and earthing should not be connected in parallel.

2.7 Ground-connection requirement of induction heating equipment

In order to ensure normal working and security of operator, and considering the equipment shielding needs, the equipment should adopt single ground-connection system, which is composed of earthing electrode and grounding line. The total resistance of grounded circuit should be less than 4Ω.

Special note: equipment ground-connection system should not share ground-connection system with large power equipment such as electric welder or power machine. Grounding line should be far from large power equipment power line and keep a regular check.

⑴earthing electrode requirement

earthing electrode can adopt galvanized angle steel and requirements are as follows:

① the length of earthing electrode is 2.5m galvanized angle steel (45×45mm) at least 3 pieces.

② horizontal or triangle embedded in vertical.

③ space between the angle steel is 2.5m～3m.

④ Embedding depth ≥ 0.6m.

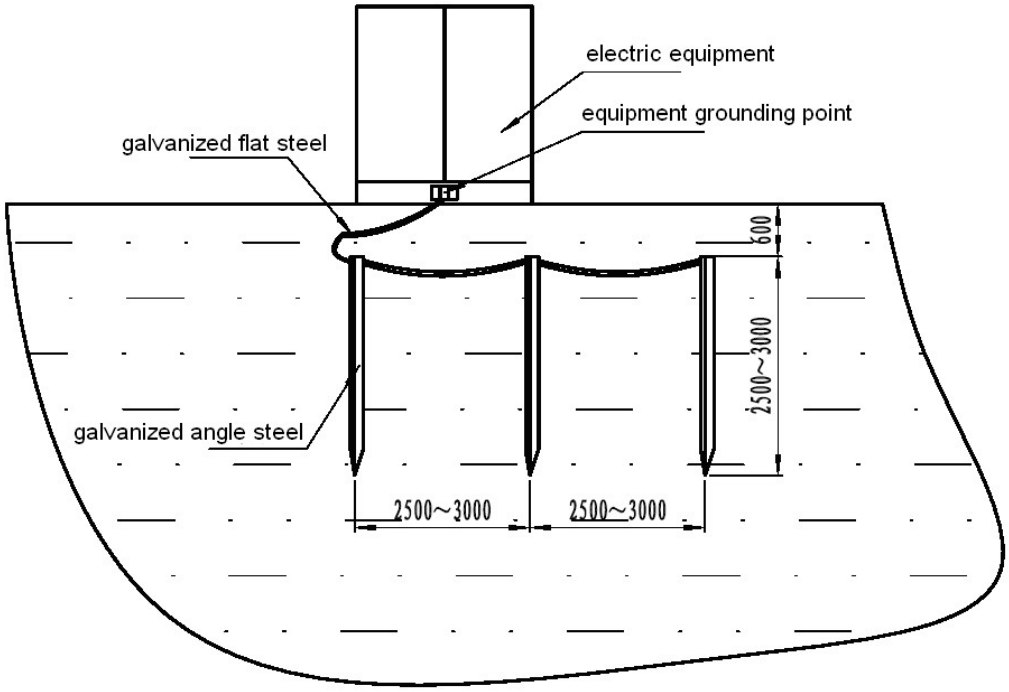
⑤ vertical earthing electrode connection: galvanized flat steel can be welded together. It should be firm and reliable if using screws to connect earthing electrode outlet line and grounding line net. Corrosion preventing treatment should be done for the connect point.

⑥ in order to increase the conductivity of earthing electrode, resistance reducing treatment can be done to the soil environment. Lime, salt, water and wood carbonic can be mixed together as per certain proportion to pour.

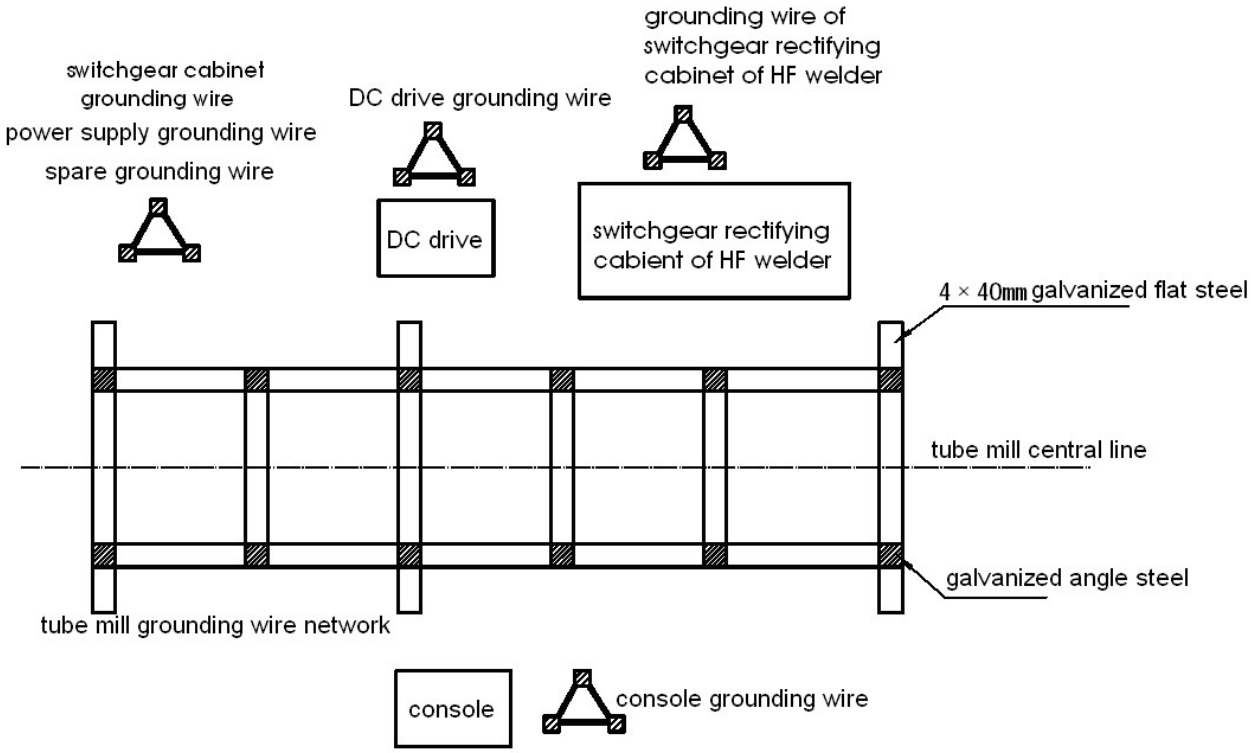
⑵ Grounding line

The grounding line is connected by galvanized flat steel that not less than 4×40mm. Lapping welding method should be adopted for connection to earthing electrode. There’re grounding bolts at the lower part behind the equipment. A3 steel lug plate is welded on galvanized flat steel and fixed on grounding bolts.

⑶ equipment grounding drawing



(4) Grounding wire distribution (for reference)



3 Electric principle

3.1 Equipment main circuit structure

Equipment main circuit structure is shown in Fig. 2 and Fig. 3., the rectifier adopts 3-phase bridge type thyristor full control rectifying circuit. DC side adopts capacitor filter to meet the working requirements of serial resonance inverter (voltage type inverter). The inverter adopts large power single phase H bridge inverter structure; the tank circuit is serial resonance structure. As the voltage type inverter over current protection is very important, our company adopts unique and reliable current protection circuit to ensure a safety and reliable operation of inverter.

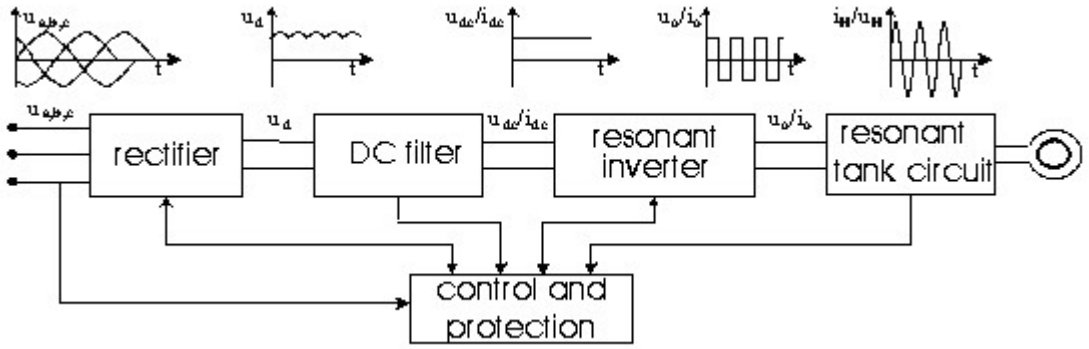


Fig. 2 full solid state induction heating power supply topological structure diagram

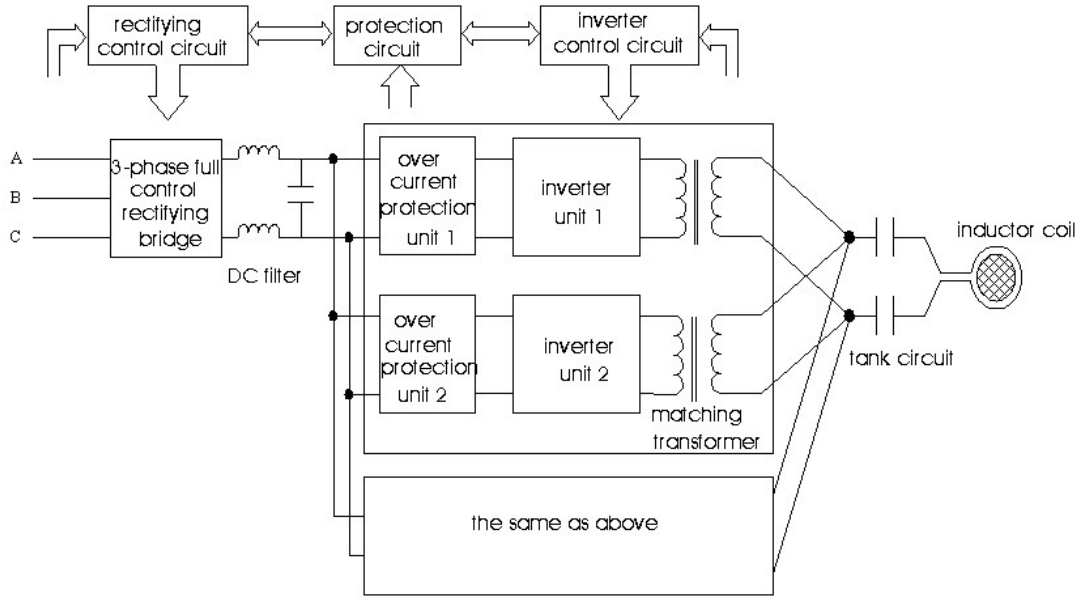


Fig. 3 full solid state induction heating power supply main circuit diagram

3.2 3-phase full control bridge type rectifying circuit

Output voltage of 3-phase full control bridge type rectifying circuit: U_d =1.35$U_l$cosα

AC line incoming current of power supply: I_1＝0.816×I_d

Grid-side power coefficient of power supply: λ＝0.955×cosα

U_d、I_d—— output DC voltage, current average value

U_l、I_1—— AC line voltage and phase current

α—— thyristor trigger delay angle

λ——network side power coefficient

under the condition of given rectifying bridge input line voltage U_l, change the thyristor trigger delay angle α can change output DC voltage. Generally the traditional induction heating power supply adjusts DC voltage by adjusting of rectifying trigger angle, and adjusts the equipment output power. Rectifier circuit structure and trigger pulse is shown in Fig.4. Rectifier network side AC voltage/current and DC voltage wave is shown in Fig. 5. The advantage that choosing thyristor rectifying for the power supply but not diode rectifying is power supply can realize soft start and soft turn off, decreasing voltage and current impact. Faults can be eliminated rapidly when occurs.

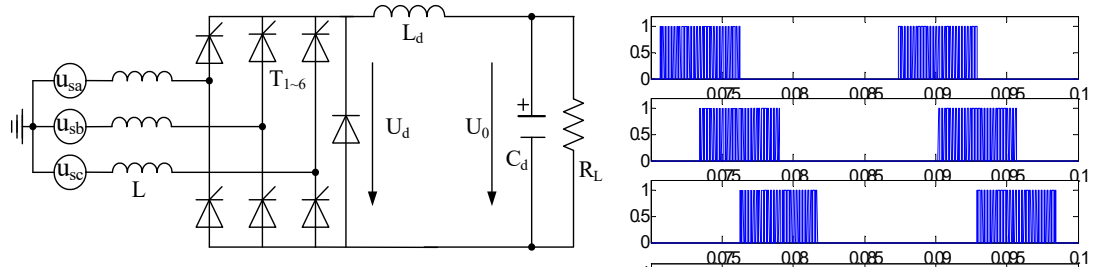
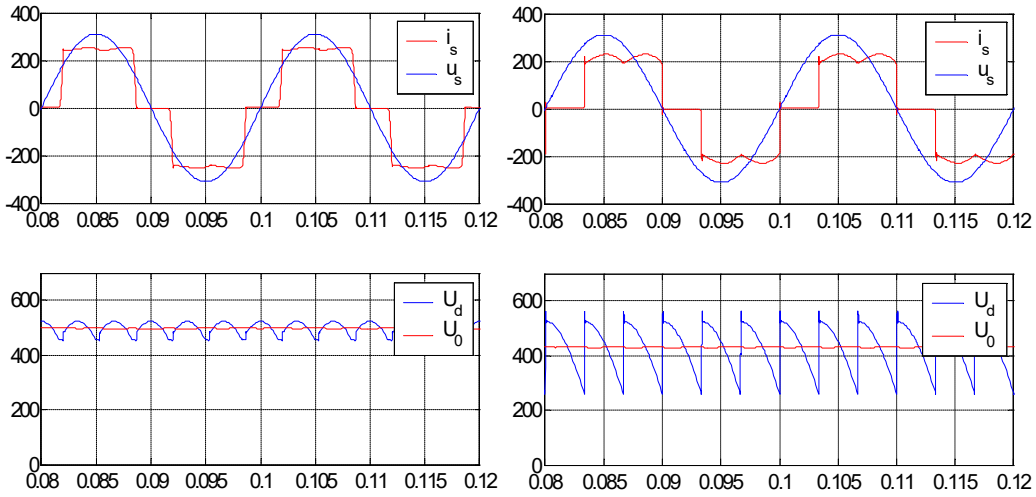


Fig. 4 **3-phase thyristor rectifying circuit structure and trigger pulse**



α=0⁰ α=30⁰

Fig. 5 rectifier wave for different trigger angle

3.3 single phase serial bridge type inverter circuit

Serial resonant inverter is also called voltage resonant inverter, the structure is shown in Fig. 6, the output voltage of serial resonant inverter is a similar square wave. As the circuit works near the resonant frequency, oscillating circuit has the minimum impedance to fundamental wave, so the load current i_H is close to sine wave. Meanwhile in order to avoid direct connection of upper bridge arm and lower bridge arm of inverter, conversion should follow the rules of turn off first and start secondly, enough dead zone time should be left between turn off and start.

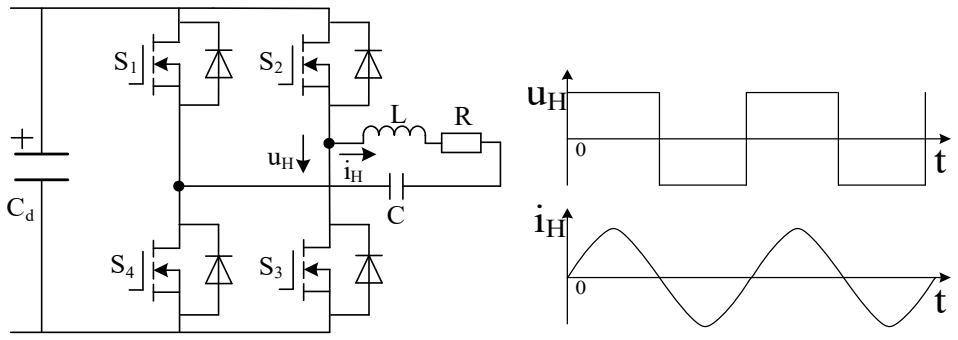


Fig. 6 serial resonant inverter structure and wave

There are four working status in the working process of serial resonant inverter, which is shown in Fig. 7:

(1) status 1:

S1 and S3 are on, S2 and S4 are off. The voltage of C1 and C3 is zero, voltage of C2 and C4 is DC bridge voltage Ud, freewheeling diode D1, D2, D3 and D4 are in the off status. Resonant inverter working status is shown in Fig. 7 (a). C1, C2, C3 and C4 are absorption capacitor of power switching device S1, S2, S3 and S4 (including junction capacitance of switching device with equal capacitance value). D_1, D_2, D_3 and D_4 are antiparallel fast recovery diode of power switching device. Cr is resonant capacitor, Lr and Rr are equivalent inductance and resistance of inductor and heated workpiece. L_0 is equivalent lumped inductance of DC line and stray inductance of components. C_d is DC filtering capacitor.

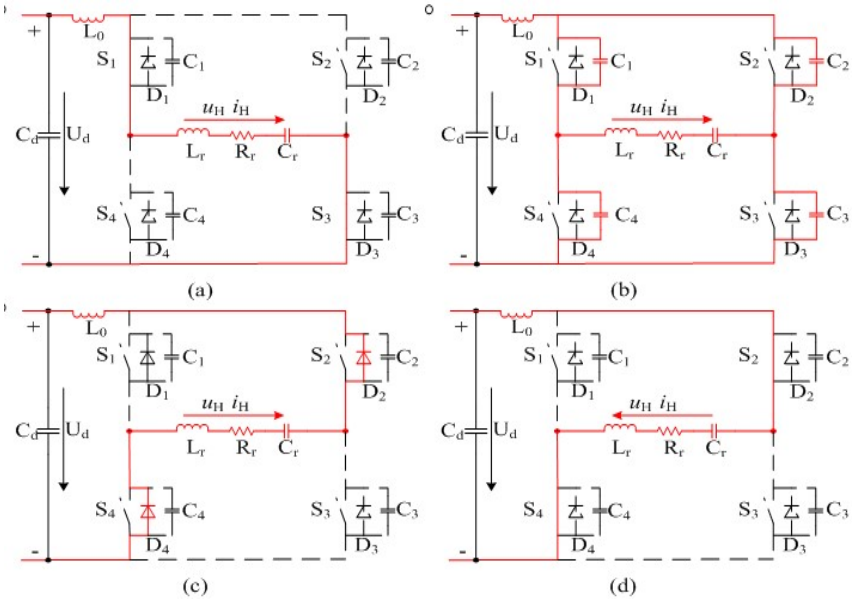


Fig. 7 serial resonant inverter working status

(2) status 2:

The pulse of S_1 and S_3 are turned off at the time of t_0, S_1 and S_3 are rapidly turned off under the condition of small load current and zero voltage. Meanwhile capacitor C_1 and C_3 are charged, capacitor C_2 and C_4 start to discharge to keep continuous flow of load current. During this time, load current continuous keep the same direction. Because of charging and discharging of absorption capacitor, the terminal voltage of switching device S_1 and S_3 start to rise from zero, the terminal voltage of switching device S_2 and S_4 start to drop. At the time of t_1, voltage of absorption capacitor C_1, C_2, C_3 and C_4 are all $U_d/2$, load terminal voltage is zero. At the time of t_2, capacitor C_1 and

C_3 are charged to U_d, capacitor C_2 and C_4 are discharged to zero. In the following short period of time, the energy saved in stray inductance L_0 continuously charge C_1 and C_3 to make the voltage is a little higher than DC power supply voltage U_d, then oscillating and attenuation to be stable value U_d.于 As the current is very small when switching device is turned off, the energy saved in stray inductance L_0 is also very small, so the voltage of capacitor C_1 and C_3 rises not much. Resonant inverter working status is shown in Fig. 7 (b).

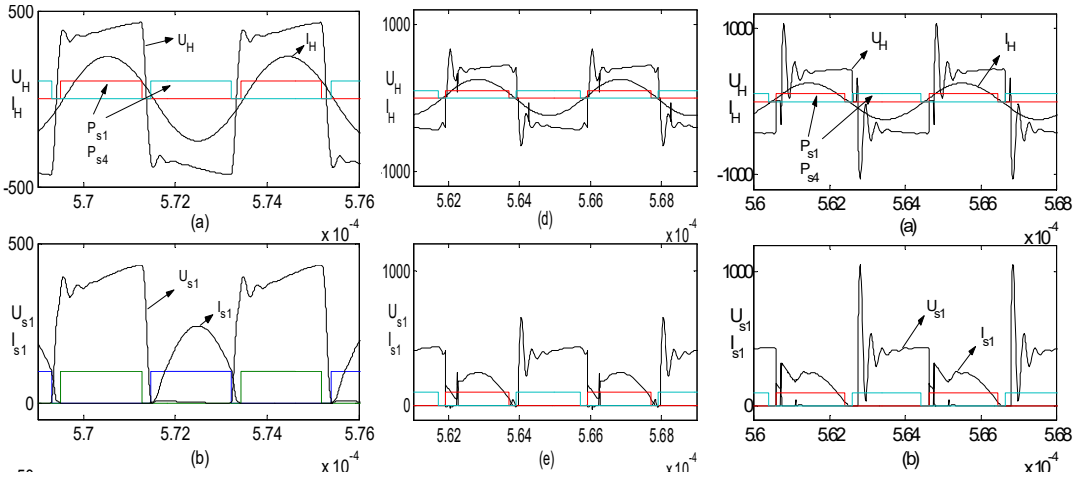
(3) status 3:

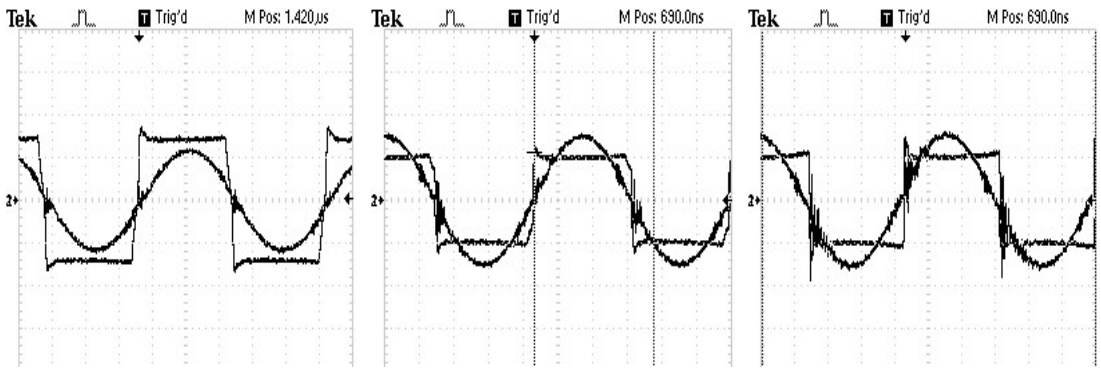
At the time of t_2, as load current has not been commutated, it will continue to flow through diode D_2 and D_4. Although trigger pulse of S_2 and S_4 comes at t_3, as load current has not been commutated, there will be no current in switching device S_2 and S_4. Resonant inverter working status is shown in Fig. 7 (c).

(4) status 4:

The load current starts to commutate at t_4, diode D_2 and D_4 are turned off, and load current begins to flow through S_2 and S_4. As conversion occurs between fast recovery diode and switching device in the same bridge arm, there's no reverse recovery problem of diode, and because both ends voltage of S_2 and S_4 are zero, it is obviously that S_2 and S_4 are zero voltage switching (ZVS) and zero current switching (ZCS). Resonant inverter working status is shown in Fig. 7 (d).

Serial resonant inverter can work at resistance, capacitive and inductive state, seen from the above inverter conversion process, the ideal working state of serial resonant inverter is small inductive quasi resonant.





（a） small inductive （b）resistance （c）small capacitive

Fig. 8 test wave of inverter working state

Fig 8 is the simulation and measured waveform of serial resonant inverter at inductive, resistance and capacitive state. From the above waveform we can see that under the small inductive state, whether load voltage current waveform or component voltage current waveform is ideal. But under the state of non- zero voltage switching, even the inverter works at resistance state of power coefficient is 1, because switching device conversion loses zero voltage switching conditions, from the waveform we can see that there's larger peak current of the component when turned on, and because reverse recovery current of diode and discharging current of capacitor save large power in line stray inductance and lead to line high frequency surge oscillating. Under the capacitive state, the inverter has worse conversion condition, not only switching loss of component increases greatly, but also higher surge impact voltage will threat the safety of switching component. The equipment is only allowed to work at small inductive state but not pure resistance or capacitive state.

Seen from the above analysis we can know that, under suitable working mode, the switching loss of serial resonant inverter is very small, so it can work under higher working frequency. That's the reason why at present serial resonant inverter receives more attention in semi-conductor high frequency induction heating power supply.

3.4 output power adjustment

Output power can be formulated as follows:

$P_{out}=U_dI_d=U_d^2/R$

U_d ——average of rectifying bridge output DC voltage

I_d ——average of rectifying bridge output DC current

From the power expression can know that for given load, the load impedance basically does not change when resonant, so output power of high frequency welder can be adjusted by adjusting rectifying bridge output voltage U_d, and rectifying output voltage is adjusted through controlling rectifying thyristor phase-shift angle.

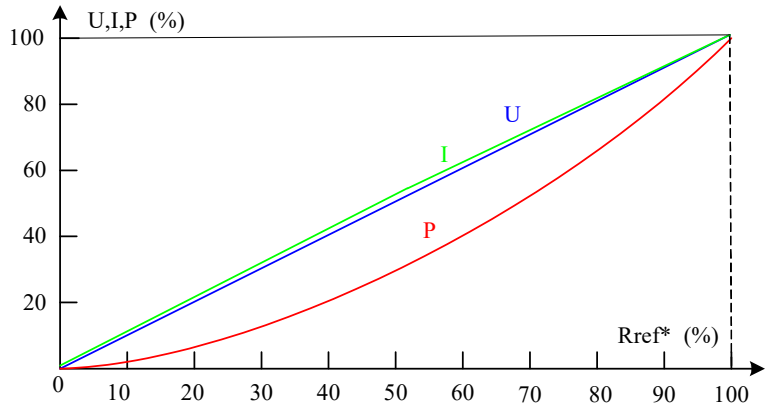


Fig. 9 welder power adjusting curve

3.5 rectifying side control

Welder rectifying side control circuit takes MCS-51 series of MCU as core, matching with peripheral circuit to form rectifier double closed loop PI adjuster, constant power control, fault protection and thyristor trigger etc.

According to the above, change full control rectifying bridge thyristor trigger delay angle α can control rectifying output DC voltage average, and then control equipment output power. As PI adjuster is none-static-error adjuster, so the given is equal to the feedback in static state. When the equipment load changes, to be the feedback signal through sampling voltage and current at double closed loop PI adjuster, closed loop adjust the voltage and current to ensure voltage and current output value will not exceed the setting limitation value, to achieve precise voltage limited and current limited effect. Double closed loop PI control can decrease the influence that grid voltage fluctuation to the power supply, and is very important to the application site of instable grid voltage.

In order to trigger the thyristor reliably, the rectifier adopts high frequency modulation

of trigger pulse with the pulse width of 120 degree, and reduce the pulse transformer volume. Trigger pulse front edge peak current can reach to 1A, the tail of the trigger current extent is more than 300mA, which can trigger thyristor with any specification and no need to considerate its trigger current dispersivity.

3.6 Phase-locked loop and phase angle lock

Serial resonant inverter always hopes to working under small inductive quasi resonant status, i.e. working frequency is always higher than load natural resonance frequency. As the differences and changes of the load, the electricity parameter of load coil will change, which will make the inverter deviate from the optimal operating point, not only increase MOSFET turn off current on inverter bridge and lead to increased turn loss, but also the inverter power capacity can not be fully utilized. So the inverter control circuit needs to set phase lock control circuit to realize phase-locked frequency automatic tracking, i.e. phase locking.

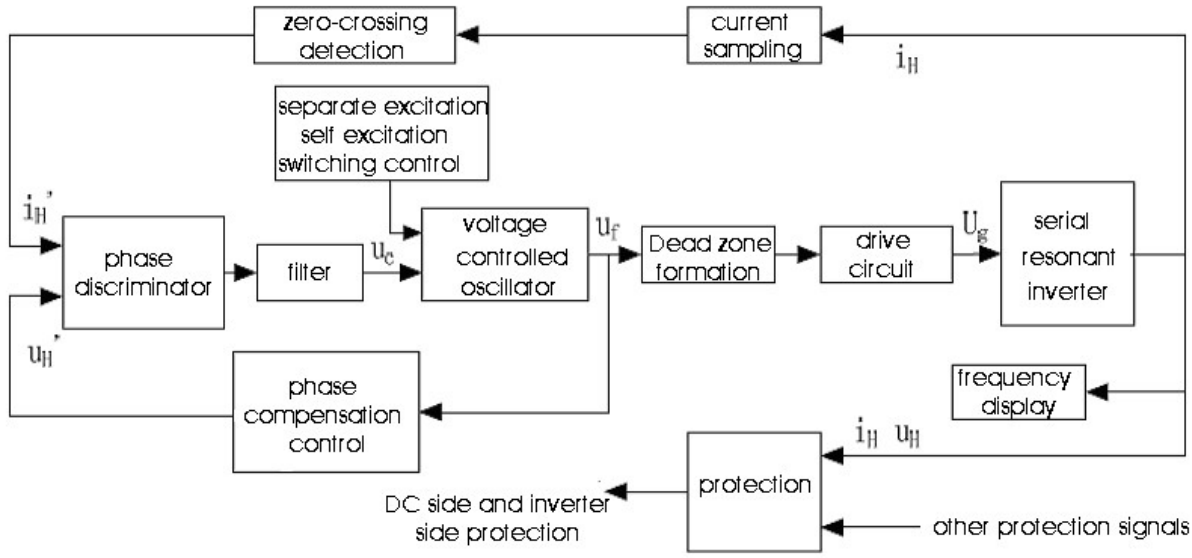


Fig. 10 phase-locked loop diagram

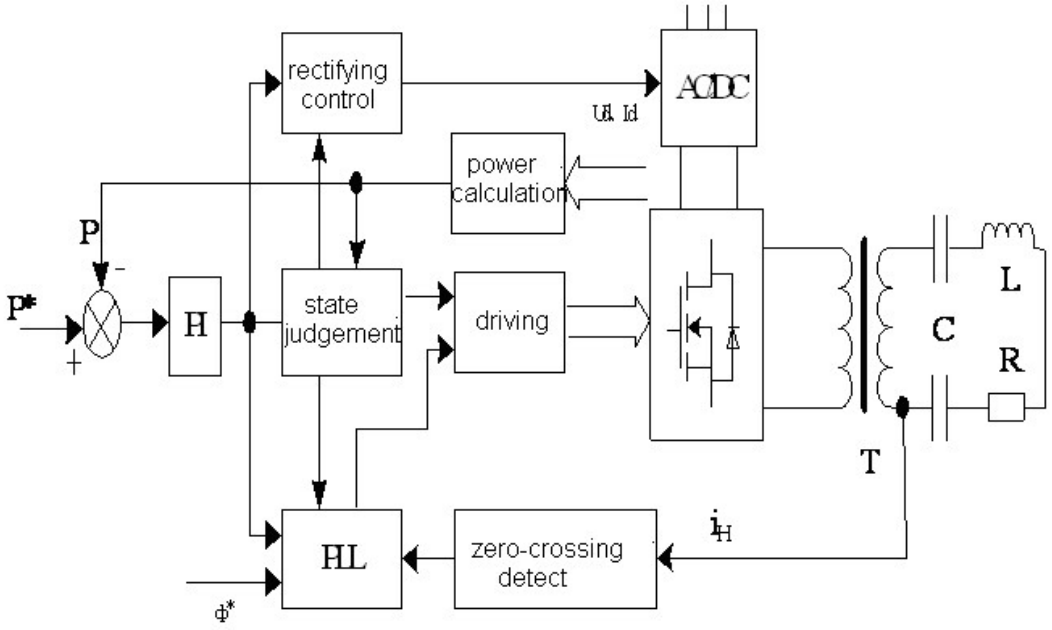


Fig. 11 welder resonant inverter control diagram

3.7 Welder protection

The protection function of the welder is mainly for each abnormal situation and fault of the power supply, except the general protection of control power supply fault and under water pressure protection, there are mainly AC over current protection, DC over current protection, loss of lock protection and heating plate temperature protection.

(1) AC over current protection

The short circuit of power supply rectifying side or abnormal working of control circuit may lead to AC over current protection. Over current protection circuit monitors 3-phase line incoming current, when the current exceeds the setting value, 3-phase thyristor rectifier control circuit protection turns off, meanwhile the integration fault indication light is on, the nixie tube displays the fault reason. If rectifying SCR is bad, AC main circuit breaker will also tripped and cut the connection to the electric grid.

(2) DC over current protection

The short circuit of welder output load or abnormal working of inverter control circuit and driving circuit may all lead to DC over current. As voltage type inverter DC side is large capacitor, DC over current protection has a great harm and easily leads to damage of MOSFET.

Hall current test circuit installed at welder DC side, when test that DC current is large

than setting threshold value, blockade inverter MOSFET driving pulse to protect the welder.

(3) Loss of lock protection

The welder load has terrible conditions, short circuit between inductor coil turns, arcing and grounding fault often occur, sometimes inductor open circuit and short circuit may happen. The occurrence of the above problems to the load will lead to severe fluctuation of tank circuit natural resonance frequency, and cause inverter working state abrupt change to threat the safe and reliable operation of the component.

Loss of lock protection circuit collects load voltage and current phase value, to make a comparison with given threshold signal at actual time. When phase value exceeds setting threshold value, protection circuit judges it as tank circuit fault, further to realize loss of lock protection function. Protection circuit should detect this fault precisely and rapidly to avoid the protection not timely or error protection.

(4) Temperature protection

Inverter switching component of the welder has a severe heating problem, so water cooling method is widely applied. Fixed temperature test switch on each inverter bridge board and the switch will do the protection when the temperature of the board exceeds 55℃.

When temperature protection actuates, please check whether the water pipe is blocked or water pressure is too low.

4 Operation instruction

4.1 Brief illustration

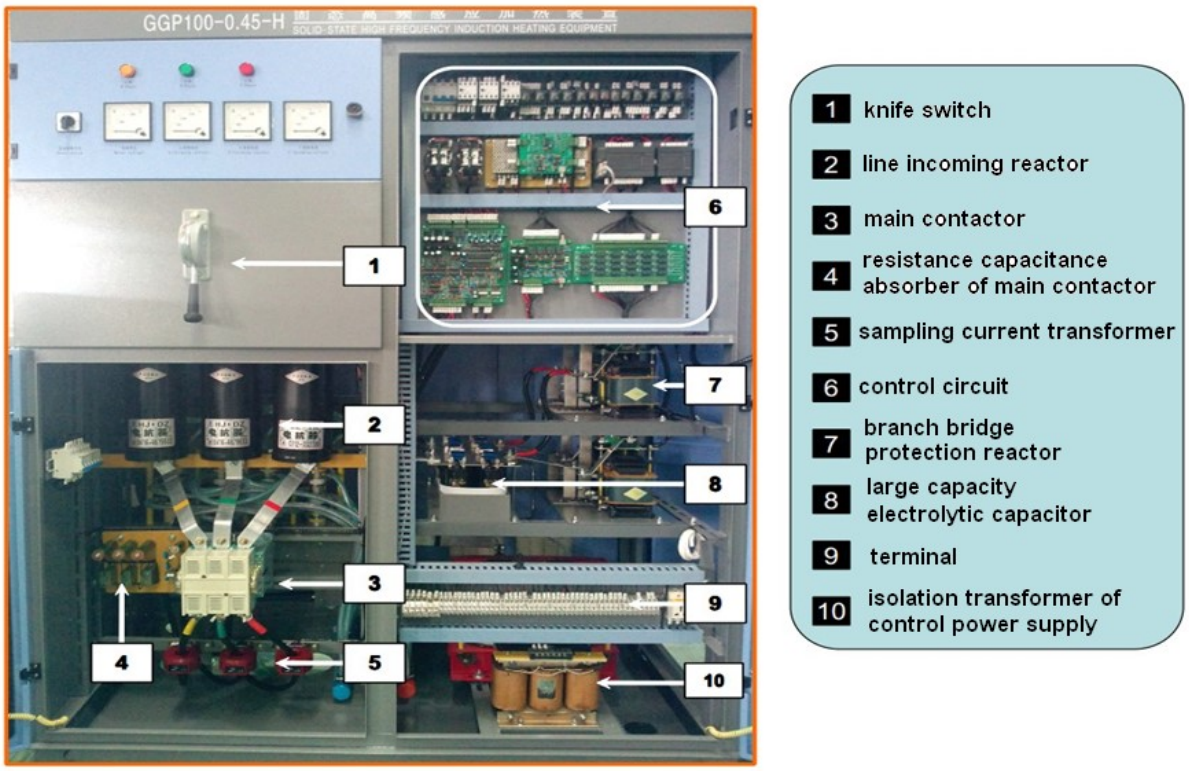


Fig. 12 switchgear rectifying cabinet (front)

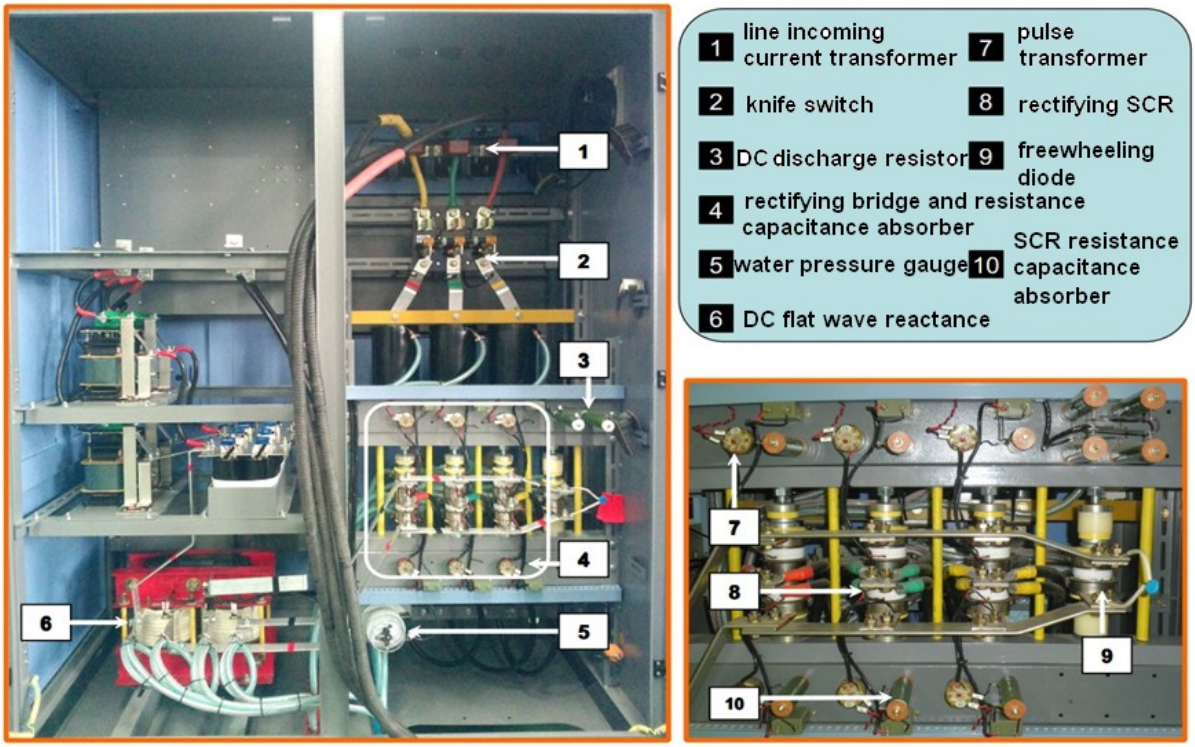
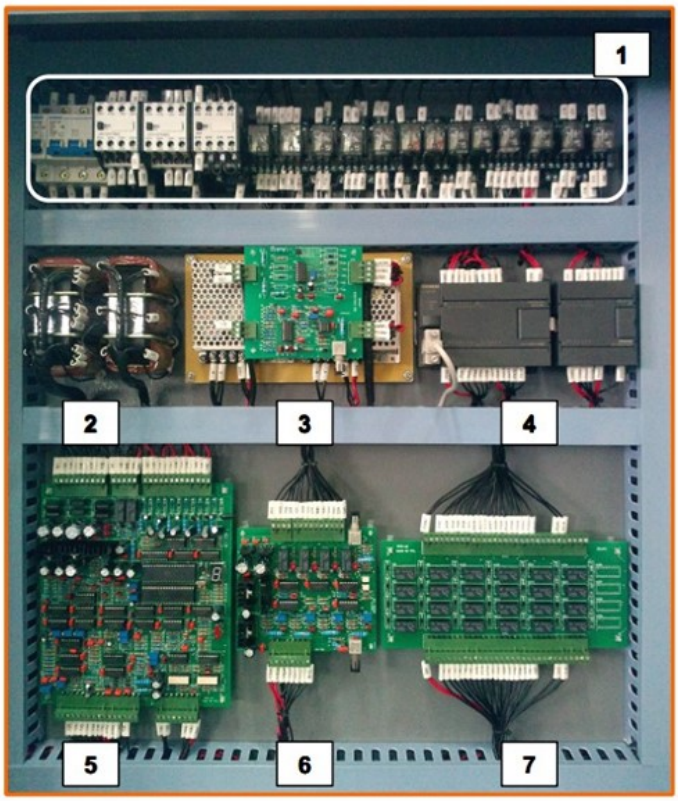


Fig. 13 switchgear rectifying cabinet (back)



1 switch and relay of control circuit

2 power supply transformer: provide power supply for control board

3 voltage feedback board: provide isolated DC voltage signal to 1# board.
switch power supply: provide DC power supply to PLC and relay.

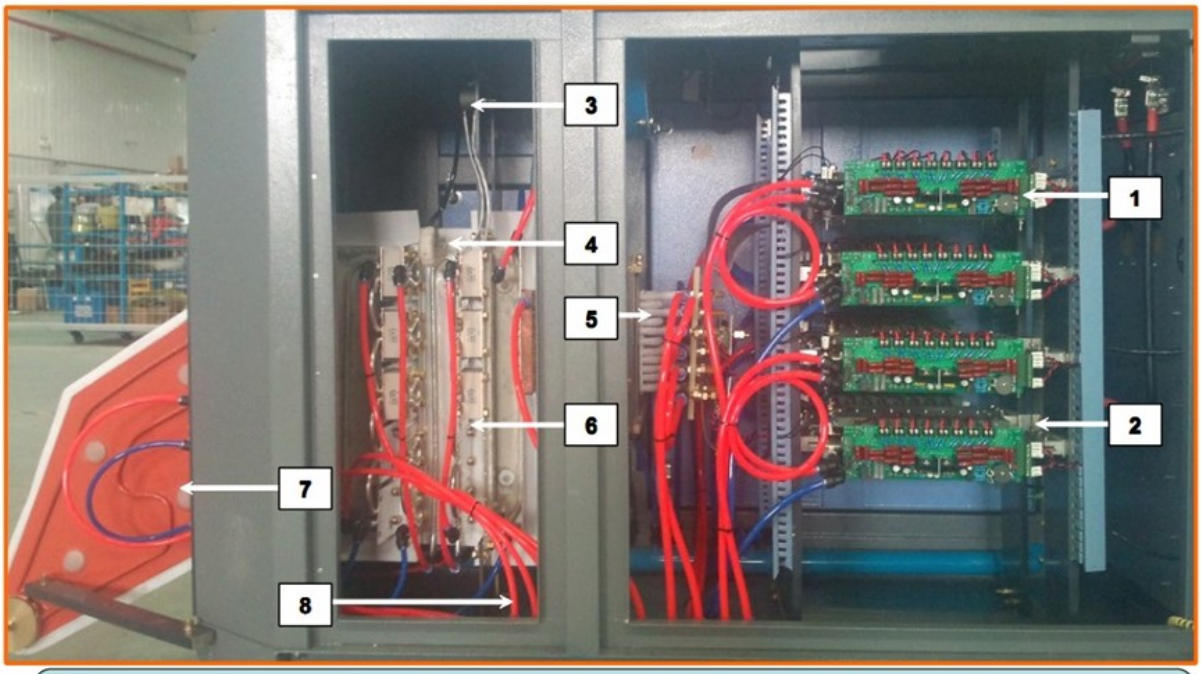
4 PLC: euquipment control and communication

5 1# board: rectifying control, PI adjuster, over current protection, self check and send all sorts of control signals.

6 2# board: DC over current board with the function of DC protection, having interface with PLC and 1# board.

7 10# board: check isolation function of the signal.

Fig. 14 control part of switchgear rectifying cabinet



1 MOSFET driving board
2 inverter power bridge
3 sampling transformer
4 phase lock sampling magnetic ring
5 matching transformer
6 resonant capacitor
7 output arm
8 cooling water pipe

Fig. 15 main loop of inverter output cabinet

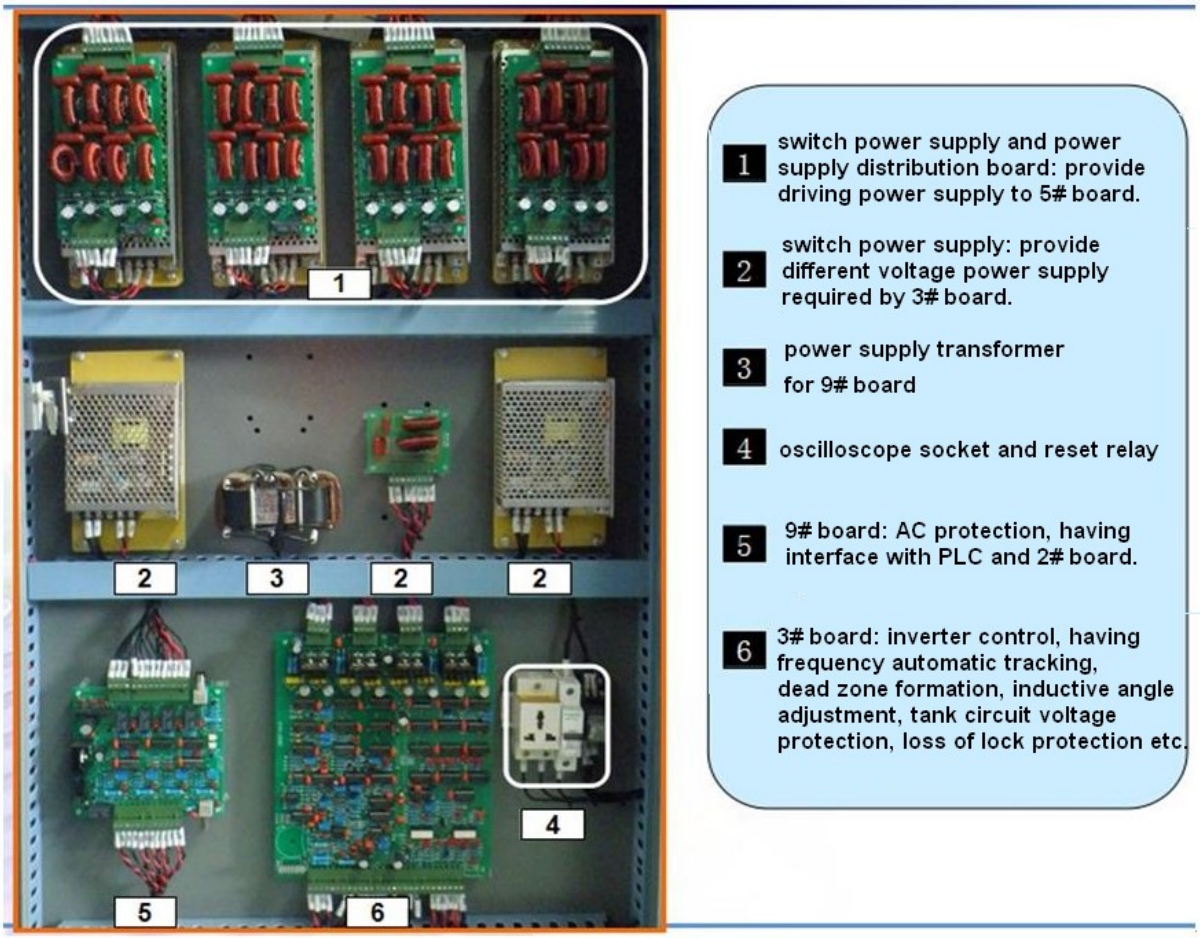


Fig. 16 control part of inverter output cabinet

4.2 Functional classification of control board

Brief introduction of control board function		
Name	**function**	**Position**
1# board	Rectifying control, PI adjuster, over current protection, self check, sending all sorts of control signal.	Switchgear rectifying cabinet
2# board	DC protection, having interface with PLC and 1# board.	Switchgear rectifying cabinet
3# board	Inverter control, having frequency automatic tracking, dead zone formation, inductive angle adjustment, tank circuit voltage protection and loss of lock etc.	Inverter output cabinet
5# board	MOSFET driving and test	Inverter output cabinet
9# board	AC protection, having interface with PLC and 2# board.	Inverter output cabinet

10# board	Test signal isolation function.	Switchgear rectifying cabinet
Voltage feedback board	Provide isolated DC voltage signal to 1# board.	Switchgear rectifying cabinet
Power supply distribution board	Provide driving power supply to 5# board.	Switchgear rectifying cabinet
Speed power tracking board	Realize synchronization adjustment of speed and power.	Switchgear rectifying cabinet

4.3 Function description of 1# board

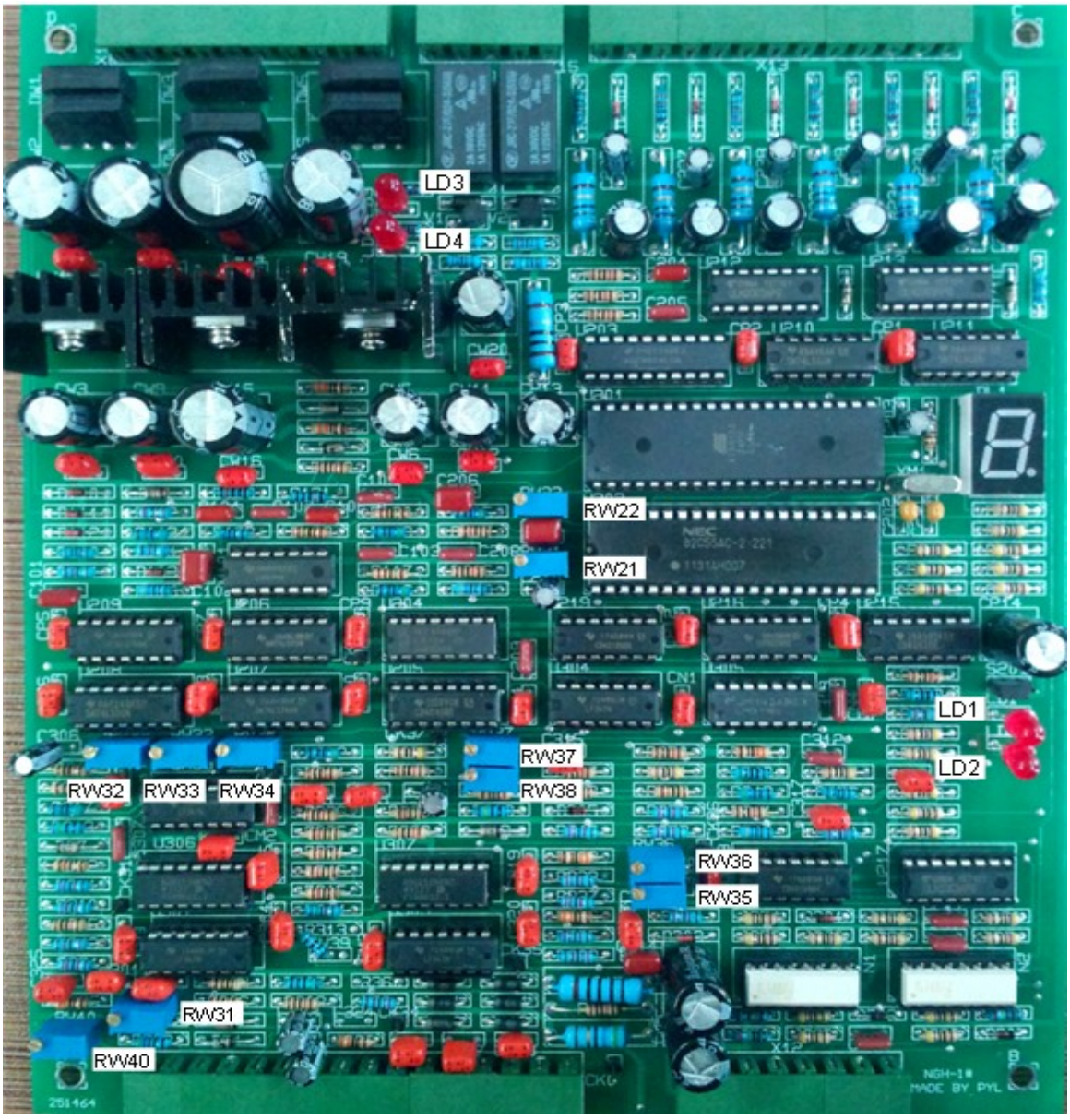


Fig. 17 1# board

Function description of Indication light of 1# board	
Name	**function**
LED1	Heating indication, light is on means heating
LED2	Proportional integral indication, light is on: adjuster is proportion state; light is off: adjuster is proportion-integral state.
LED3	Lack of phase, light is on means lack of phase.
LED4	Line incoming over current indication, light is on means line incoming over current

Function description of potentiometer of 1# board	
name	**function**
RW21	Power network voltage phase lock adjustment potentiometer, important parameter, user should not change it
RW22	Initial phase angle adjustment, DC voltage will increase when unti-clockwise adjustment
RW31	Filter time adjustment of power given signal, unti-clockwise adjustment to extend start time.
RW32	Voltage outer loop magnification adjustment, user should not change it
RW33	Current inner loop magnification adjustment 1, user should not change it
RW34	Current inner loop magnification adjustment 2, user should not change it
RW35	Current feedback magnification adjustment, for current limiting setting, current will increase when unti-clockwise adjustment.
RW36	Over current protection adjustment, for over current protection setting, current will increase when unti-clockwise adjustment.
RW37	Voltage feedback magnification adjustment, for voltage limiting setting, voltage will increase when unti-clockwise adjustment.
RW38	Over voltage protection adjustment, for over voltage protection setting, user should not change it.
RW40	Voltage signal treatment.

Function description of 1# board test point	
CK0	Control power ground.
CK21	Phase lock ring control electrical level, the normal is stable 2.5V voltage.
CK31	Potentiometer given measuring, indicating the input of power given potentiometer.
CK32	Output value of adjusted voltage ring (0～－10V)
CK33	Output value of adjusted double closed loop, to AD conversion chip (0～10V)
CK34	Measuring point of 3-phase line incoming current, which is used for measuring DC voltage and current formation, to judge the conducting state of six MOSFET.
CK35	Measuring of input current feedback, which can be changed by adjustment of RW35.
CK36	Measuring of input current, which can be changed by adjustment of RW36.

CK37	Measuring of DC voltage feedback, which can be changed by voltage feedback board or RW37.

4.4 Function description of 2# board

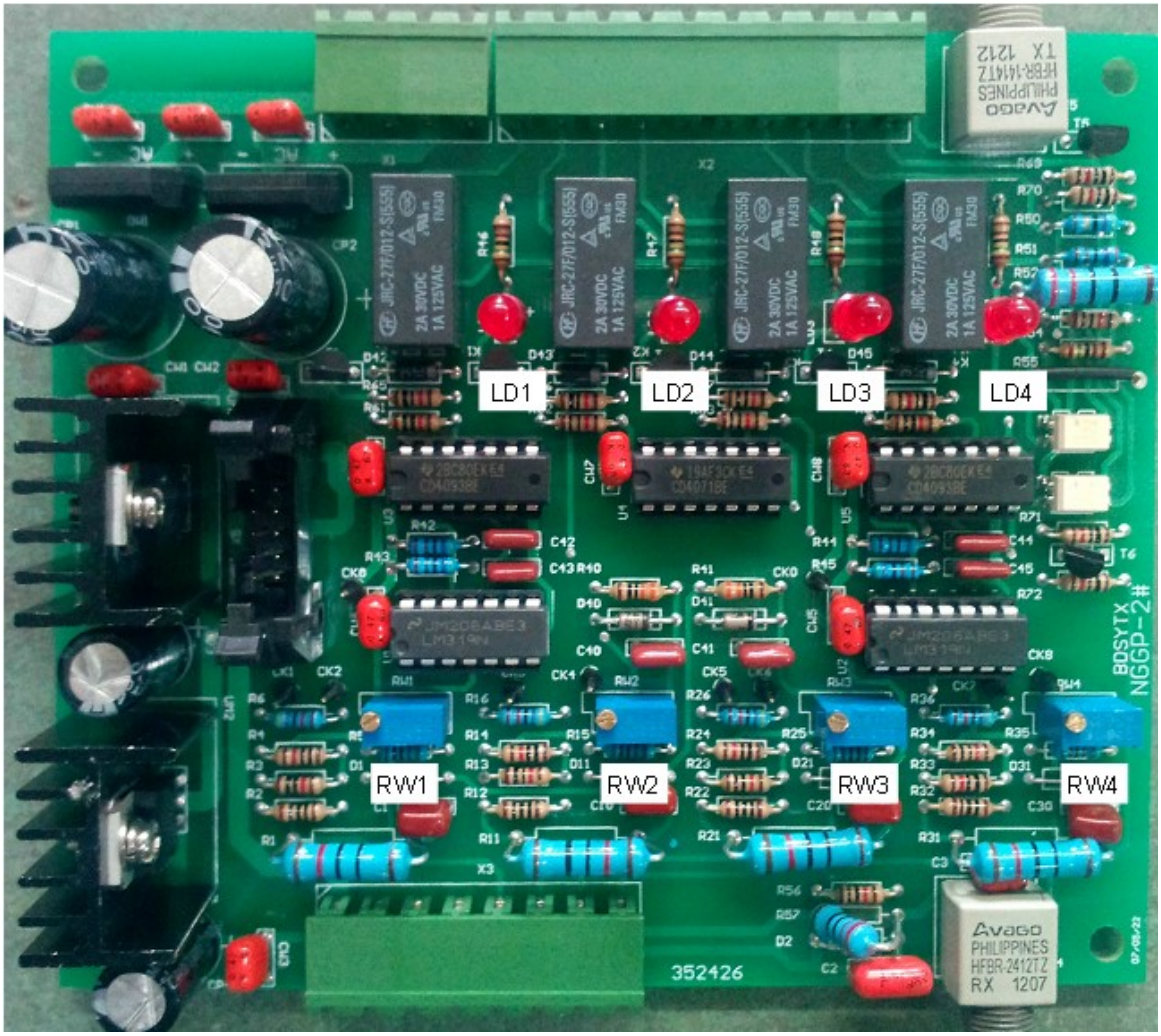


Fig. 18 2# board

Function description of 2# board	
Name	**Function**
LED1, RW1	Light on indicates DC over current of bridge A. RW1 adjusts DC over current threshold of bridge A. clockwise adjustment to increase threshold.
LED2, RW2	Light on indicates DC over current of bridge B. RW2 adjusts DC over current threshold of bridge B. clockwise adjustment to increase threshold.
LED3, RW3	Light on indicates DC over current of bridge C. RW3 adjusts DC over current threshold of bridge C. clockwise adjustment to increase threshold.
LED4, RW4	Light on indicates DC over current of bridge D. RW4 adjusts DC over current threshold of bridge D. clockwise adjustment to increase threshold.

4.5 Function description of 3# board

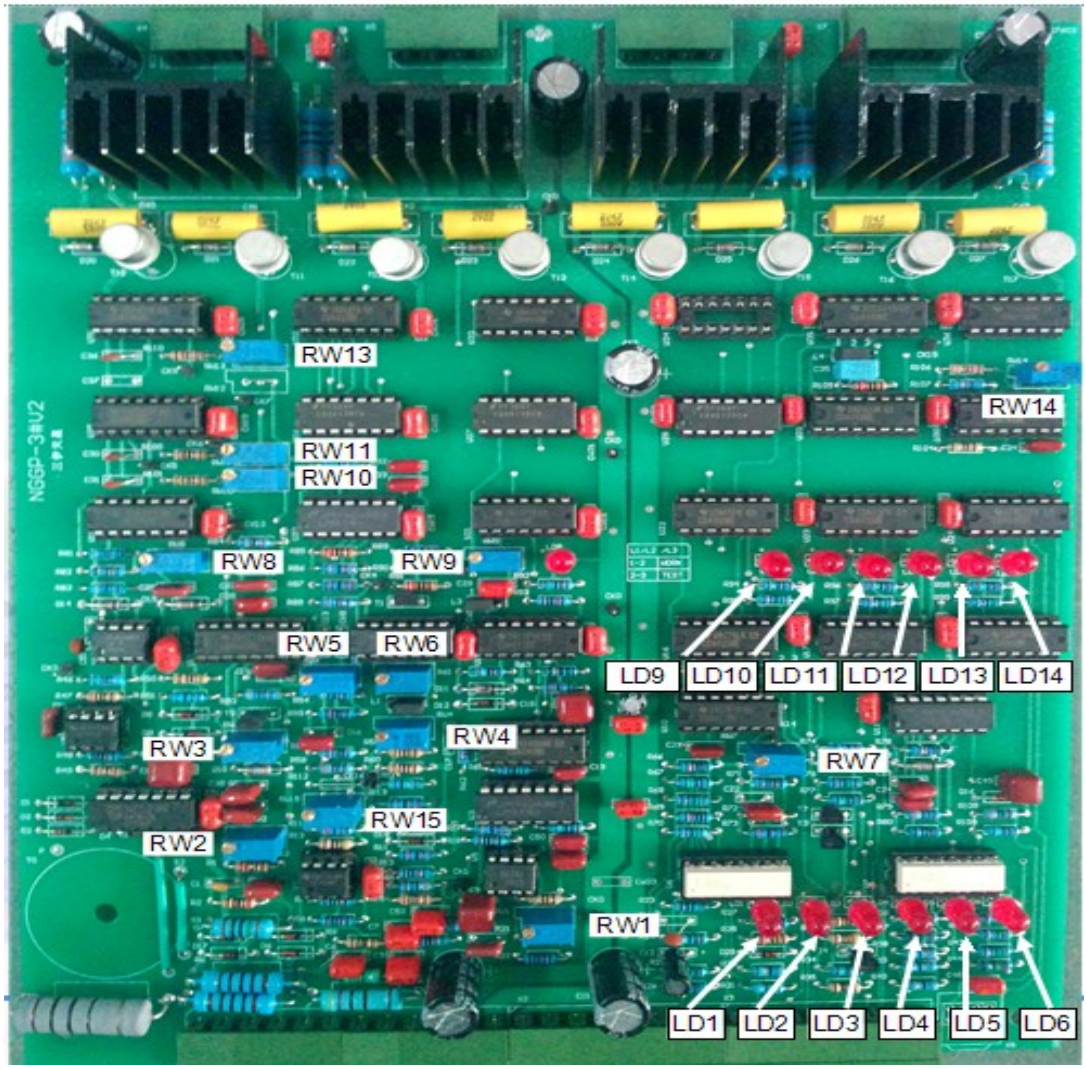


Fig. 19 3# board

Function description of 3# board	
Name	**Function**
RW1	Over frequency protection set value
RW2	Over voltage protection set value
RW3	Phase lock voltage set value
RW4	Separate excitation given frequency
RW5	Lower limit frequency adjustment
RW6	Upper limit frequency adjustment
RW7	Over frequency protection comparison value
RW8	High loss of lock protection set value
RW9	Low loss of lock protection set value
RW10	Dead zone setting
RW11	Spare

RW13	Inverter angle adjustment
RW14	Spare
RW15	Open protection set value

Function description of Indication light of 3# board	
Name	**function**
LED1	Reset indication light, light on is reset.
LED2	Loss of lock protection open indication. Light off when not heating, light on after heating means loss of lock protection has already opened.
LED3	Spare.
LED4	Normal indication of 3# board. Light on means 3# board is normal.
LED5	Phase lock indication. Light off when not heating, light on after heating means equipment is in phase lock working state.
LED6	Loss of lock protection indication. The light should be on after LD5 is on, light off after LD5 is on means loss of lock protection.
LED9	Low loss of lock protection indication. Light on means low loss of lock protection.
LED10	High loss of lock protection indication. Light on means high loss of lock protection.
LED11	Over frequency protection indication. Light on means equipment phase lock frequency is over high.
LED12	External protection indication. Light on means 2# board or 9# board protection.
LED13	Tank circuit over voltage indication. Light on means tank circuit voltage is over high.
LED14	3 # board power supply under voltage indication. Light on means 3# board power supply voltage is too low.

Function description of 3# board test point	
Name	**Function**
CK1	Over frequency protection voltage set point.
CK2	Over voltage protection test point.
CK3	Phase lock voltage PS value. 9.7V.
CK4	Pulse signal measuring point.
CK12	Low loss of lock protection voltage measure point.
CK13	High loss of lock protection voltage measure point.
CK14	Over frequency protection voltage measure point.
CK16	Open protection voltage measure point.

4.6 Function description of 5# board

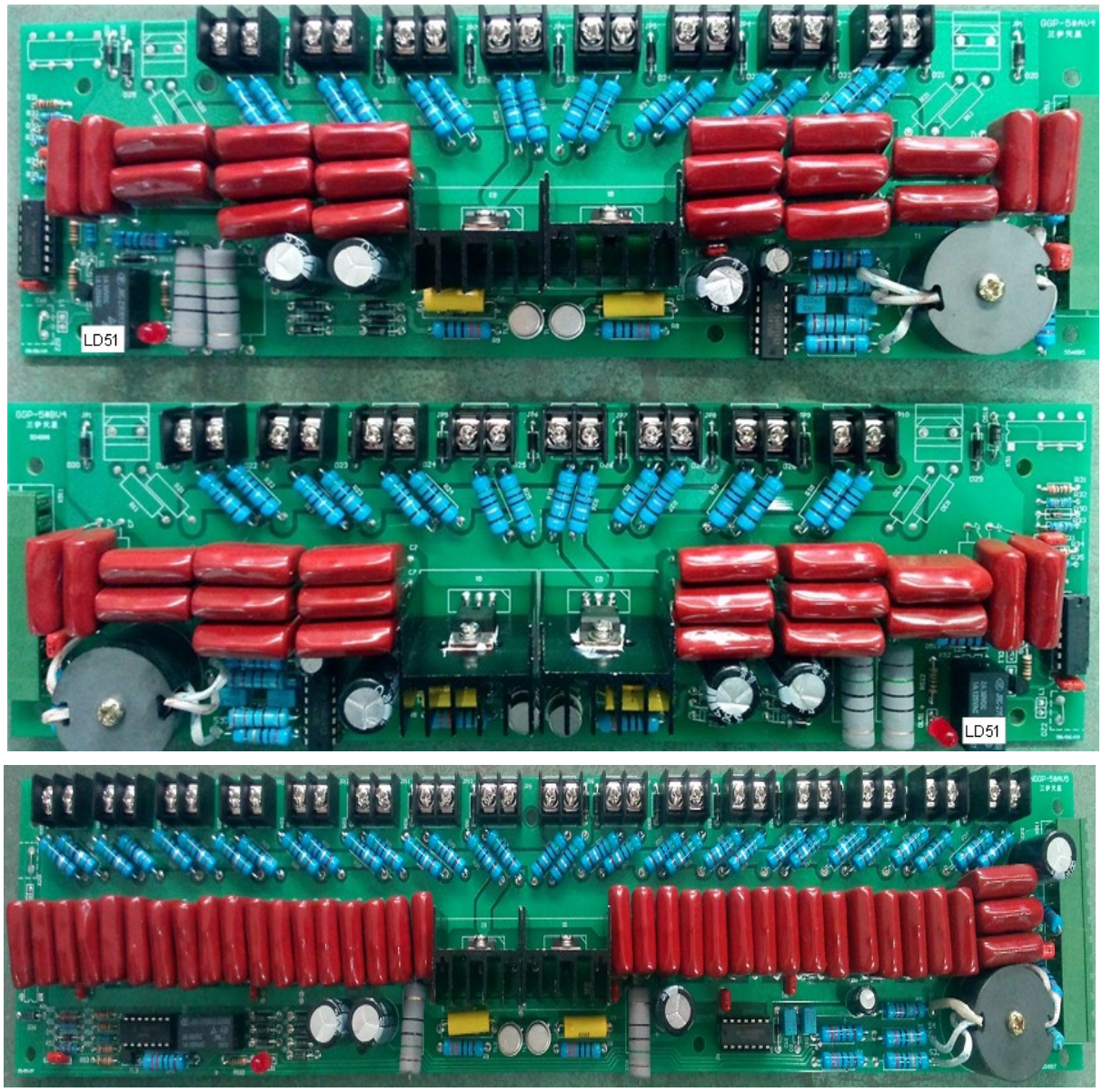


Fig. 20 5# driving board

Function description of Indication light of 5# board	
Name	**function**
LED51	The bridges that connect positive pole and negative pole are called positive bridge and negative bridge. Positive bridge and negative bridge belong to one group, the light of driving board are all off when the group of bridge is normal. When fault happens, light is on means 5# board is normal, light is off means 5# board has fault.

4.7 Function description of 9# board

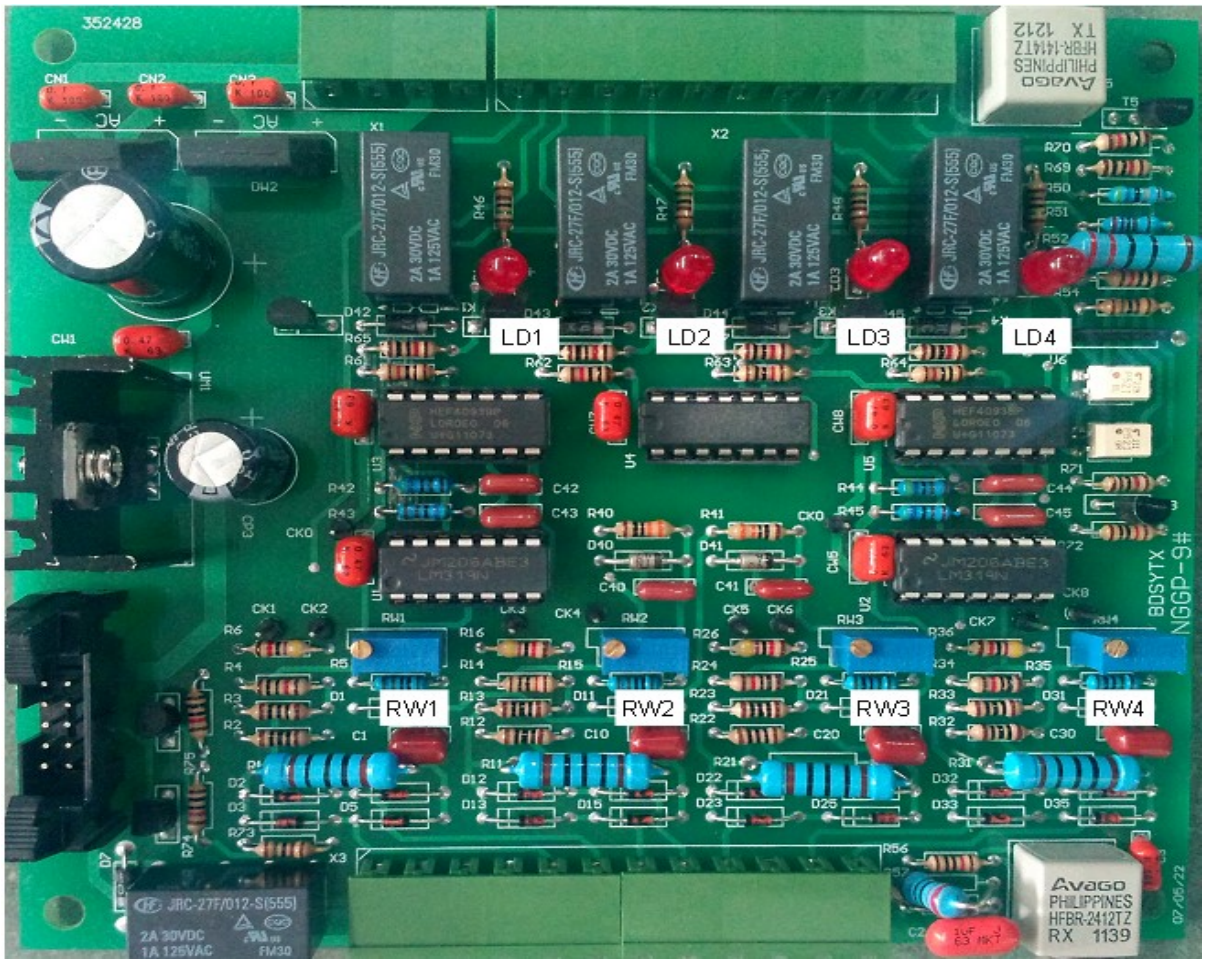


Fig. 21 9# board

Function description of Indication light of 9# board	
Name	**function**
LED1、RW1	Light is on means AC over current of bridge A. RW1 adjusts AC over current threshold value of bridge A. Threshold value increases when clockwise adjustment.
LED2、RW2	Light is on means AC over current of bridge B. RW2 adjusts AC over current threshold value of bridge B. Threshold value increases when clockwise adjustment.
LED3、RW3	Light is on means AC over current of bridge C. RW3 adjusts AC over current threshold value of bridge C. Threshold value increases when clockwise adjustment.
LED4、RW4	Light is on means AC over current of bridge D. RW4 adjusts AC over current threshold value of bridge D. Threshold value increases when clockwise adjustment.

4.8 Function description of speed power tracking board

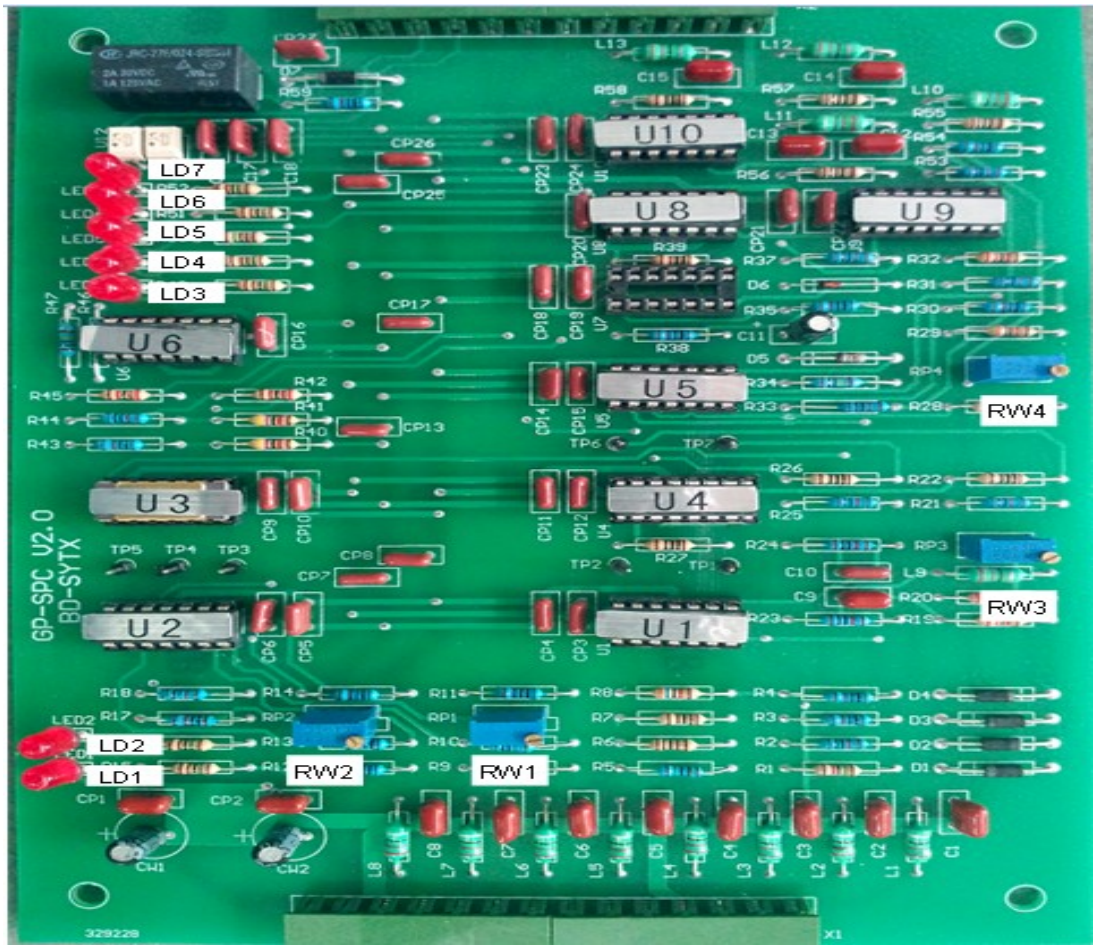


Fig. 22 speed power tracking board

Function description of Indication light of speed power tracking board	
Name	**function**
LED1	+15V power supply indication. Light is on means +15V power supply is normal.
LED2	-15V power supply indication. Light is on means -15V power supply is normal.
LED3	Matching light load indication, light is on means normal.
LED4	Matching heavy load indication, light is on means normal.
LED5	Light is on when speed feedback value is more than 0.7V.
LED6	Manual indication, light is on means manual state.
LED7	Automatic indication, light is on means automatic tracking state.

Function description of potentiometer of speed power tracking board	
Name	**function**
RW1	Voltage input signal calibration adjustment.
RW2	Current input signal calibration adjustment.
RW3	Speed input signal calibration adjustment.
RW4	Power signal calibration adjustment.

Note: it takes 100kW welder as the above example, which is a little different from other power grade circuit board for the installation position, but control boards specification is exactly the same.

4.9 operation procedure

⑴ start-up procedure

① switchgear rectifying cabinet is powered on. Check line incoming voltage value of voltage meter on the panel, and should accord with power net requirement of Part 2 of this manual. Check if there's abnormal inside the cabinet or not.

② connect cooling water system, hydraulic pressure relay normally open point is closed, check whether water pipe in rectifying cabinet and inverter cabinet is normal or not, check water inlet pressure and outlet water flow smooth condition, which should accord with cooling water pressure and water quality requirement in Part 2 of this manual.

③ check tank circuit and inductor coil, check if there's short circuit between the heated and inductor coil, and if the inductor coil is open circuit or not.

④ unticlockwise adjust power regulating potentiometer to the minimum, press control power supply box button, the light is on, 1# board and PLC start to self check, indication light of 3# board and power supply driving board is on. When self check is over without fault, integral fault indication light is off, 1# board nixie tube flashes to display "1", then the PLC on the console displays system state.

⑤ check whether power regulating potentiometer has already been adjusted to the minimum or not, press main loop box button, main contact switches on, main loop box indication light is on, 1# board nixie tube still flashes to display "1".

⑥ press heating start button, heating relay turns on, 1# board display “H”, DC voltage meter and DC current meter has slight display. Clockwise adjust power regulating potentiometer on the panel slowly, then DC voltage meter and DC current meter increase linearly, adjust power regulating potentiometer to required power.

⑵ stop procedure

The stop procedure is contrary operation of start-up procedure, following points should be noted:

① after pressing stop heating button, power output is soft stop, so there’s soft stop time from pressing stop heating button to final output power is zero. It is better that the interval time between stop heating and stop main loop be more than soft stop time.

② stop process: stop heating→stop main contactor of main loop→stop control power supply→stop external switch cabinet power supply, as there’s interlock control among heating control, main loop control and control power supply operation, try to avoid stop external power supply directly.

4.10 Notice

① when changing specification of the pipe, the matching of inductor and workpiece should be paid strict attention. If there’s big difference for the specification of changing heated workpiece, it is better change the matched inductor to improve equipment efficiency and output ability.

② regularly check if the water pipe leaks or not.

③ regularly check if the indication light and meter on the panel is normal or not, including DC voltage meter, DC current meter etc.

④ keep clean of each part of control circuit and components inside the cabinet, and smooth of cooling water pipe.

⑤ multi-protection measures have been taken, when there’s fault, protection circuit is active, fault indication light on the panel is on. Please observe the displaying

content carefully and analyze reason of the fault, power on will be permitted only after the fault is eliminated.

⑥ the equipment is designed with internal/external control transfer switch. For internal control, power regulating is accomplished by potentiometer on the panel, and internal heating start/stop is for the control. For the external control, power regulating is accomplished by external potentiometer, and external heating start/stop is for the control.

⑦ the type of adjuster selected by 1# board S201 short circuit block is proportion/proportion-integral, under proportion mode, LD2 indication light is on, proportion state is test condition. When normal working, adjuster should be switched to be proportion-integral (PI) state to ensure equipment having constant power output and precise voltage limiting and current limiting function.

5 Fault instruction

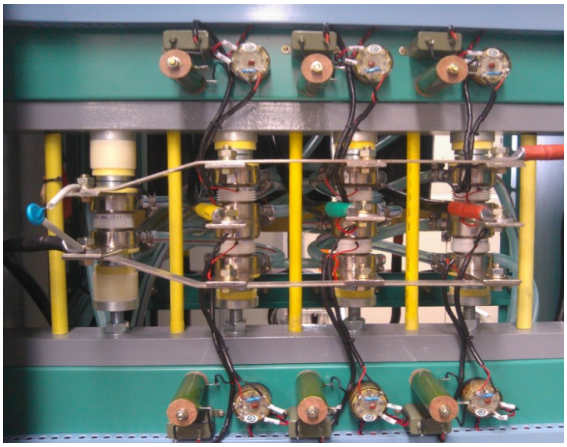
5.1 nixie tube display of 1# board

Nixie tube display state instruction-rectifying board nixie tube display		
display	meaning	measures
0	Lack of phase, 3-phase unbalance, too low line incoming voltage	Check if control power supply is lack of phase or not Check if control power supply fuse melts or not Check if power grid voltage is unbalanced or not Check if power grid voltage is too low (line voltage is less than 340V)
1	Wait for heating	1# board powers on and self check without any fault, waiting for heating start (normal state)
2	Line incoming over current	Check if line incoming current exceeds allowable value or not Check if current transformer is damaged or not
3	Power on self check A/D initial value too large	Replace ADC0804 chip Replace DG212 chip Check if R202 and C205 is separately 10K and 180P
4	Integration protection	Test if 2#, 9# and 3#板 is alarming or not Test if MOSFET and diode is damaged or not
5	Power on heated	Test if 151 wire to GND wire is short circuit or not Test if the corresponding contact to 151 wire on heating relay is good or not.
6	Power on reset	Test if 152 wire to GND wire is short circuit or not
H	heating	Normal working

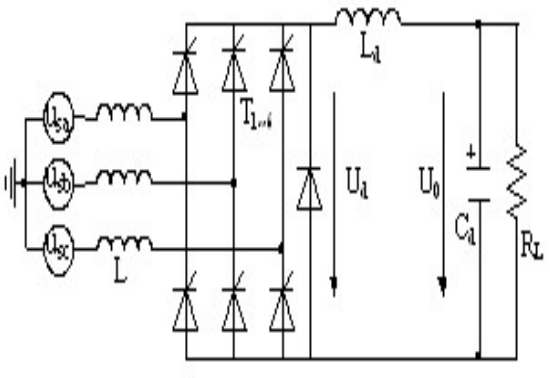
6 Instruction of important wave form

6.1 wave form of rectifying part

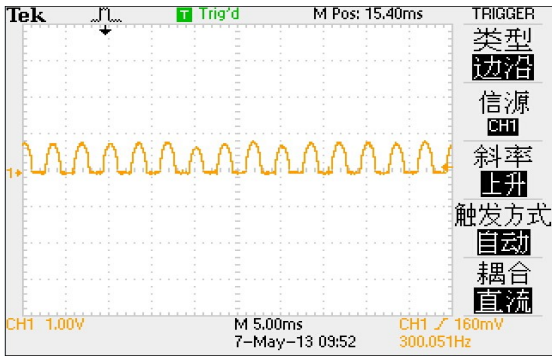
(1) rectifying bridge output wave form



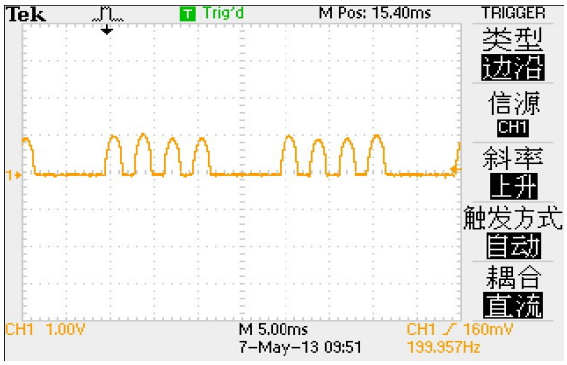
Rectifying bridge SCR



Rectifying bridge SCR principle drawing

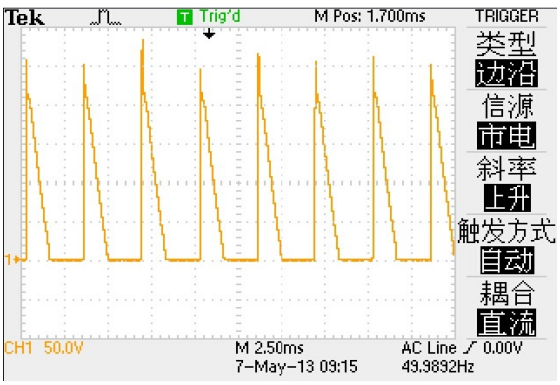


Rectifying bridge SCR passing through instrument transformer sampling wave form (normal)

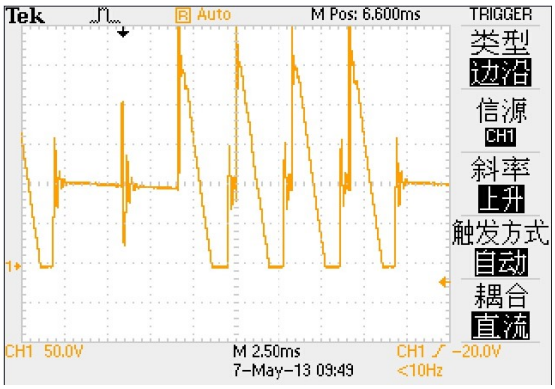


Rectifying bridge SCR passing through instrument transformer sampling wave form (abnormal)

Note: measuring point: on 1# rectifying board, two ends of resistor R332.



Actual output wave form of rectifying SCR (normal)



Actual output wave form of rectifying SCR (abnormal)

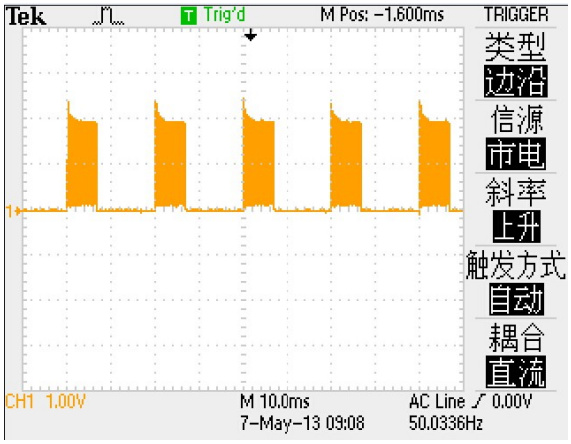
Note: measuring point: rectifying bridge output, two ends of freewheeling diode.

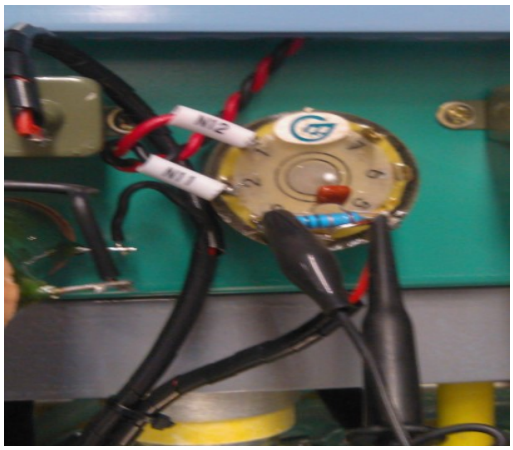
Note: For normal working 3-phase 6-pulse rectifying bridge, its DC output wave form is 300Hz pulse waveform. Observe its DC waveform can judge the working state of rectifier: please check rectifying bridge and its trigger pulse if following situation occurs:

- DC current is large after start heating, till 1# board gives an alarm.
- DC voltage can not reach above 350V after start heating
- DC flat wave reactance gives out heat and abnormal sound; DC electroanalysis capacitor leaks to be damage

Test rectifying output by oscillograph, when abnormal waveform in above figure appears (DC output is short of wave tip). Please check: whether SCR is damaged or not, pulse transformer is damaged or not, the gate of SCR is open circuit or not.

(2)correct waveform of SCR trigger pulse and measuring method



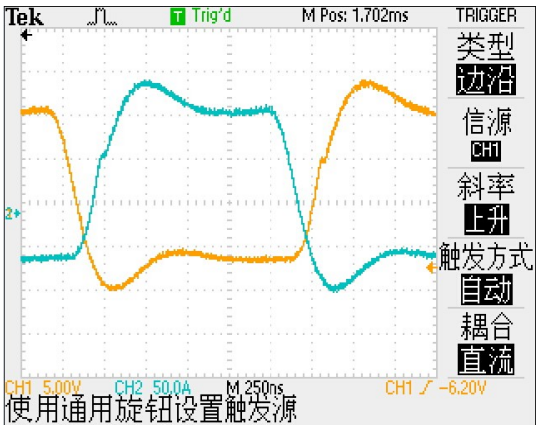


6 trigger pulse waveforms of SCR rectifier are 9.6kHz modulate 120 degree width strong triggering waveform. Mutual difference of 6 trigger pulse waveforms is 60 degree.

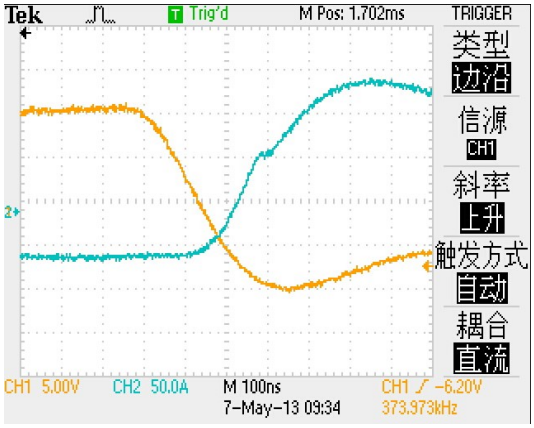
Measuring point: pulse transformer 3 feet is negative, 5 feet is positive.

6.2 wave form of inverter part

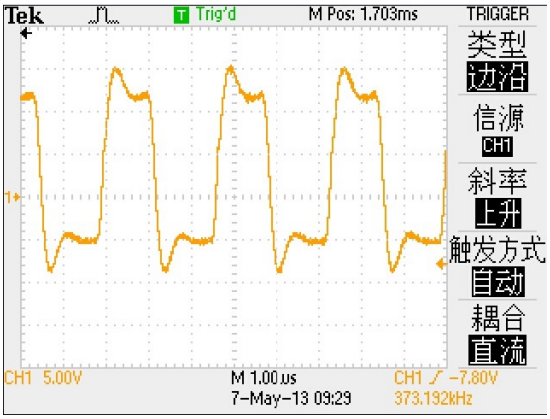
(1) 5# board output MOSFET driving waveform



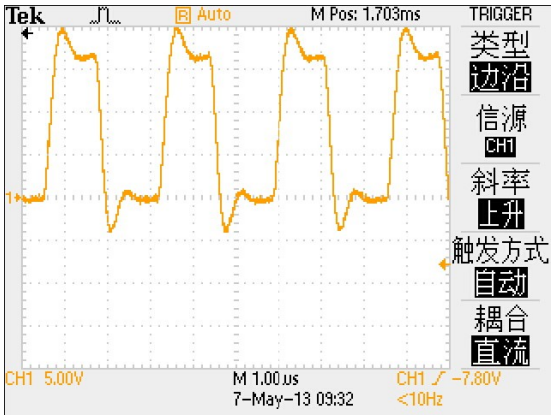
Driving pulse waveform



Driving pulse waveform (dead zone)



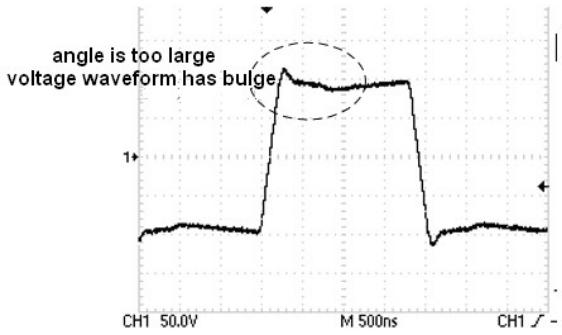
Normal driving pulse waveform (negative pressure)



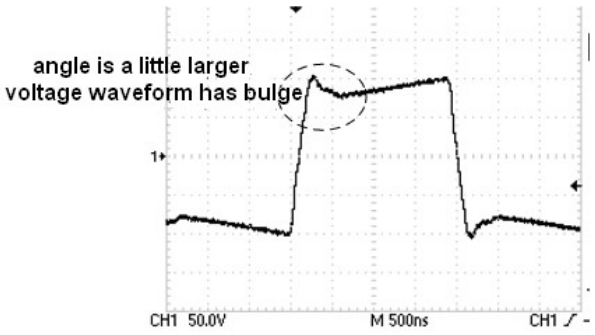
wrong driving pulse waveform (no negative pressure)

Measuring point: two ends of MOSFET pulse wire

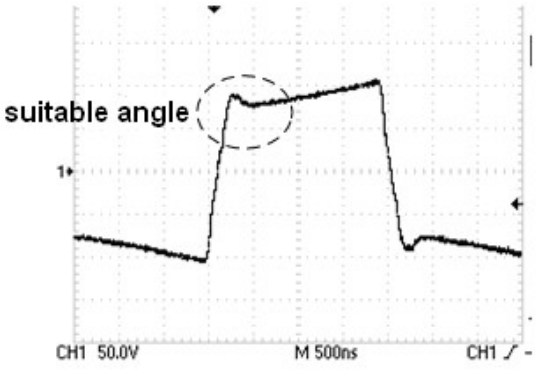
(2) inverter output waveform



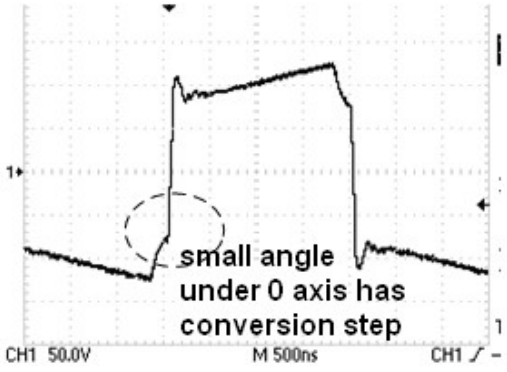
（a）inductive angle is too large



（b）inductive angle is large



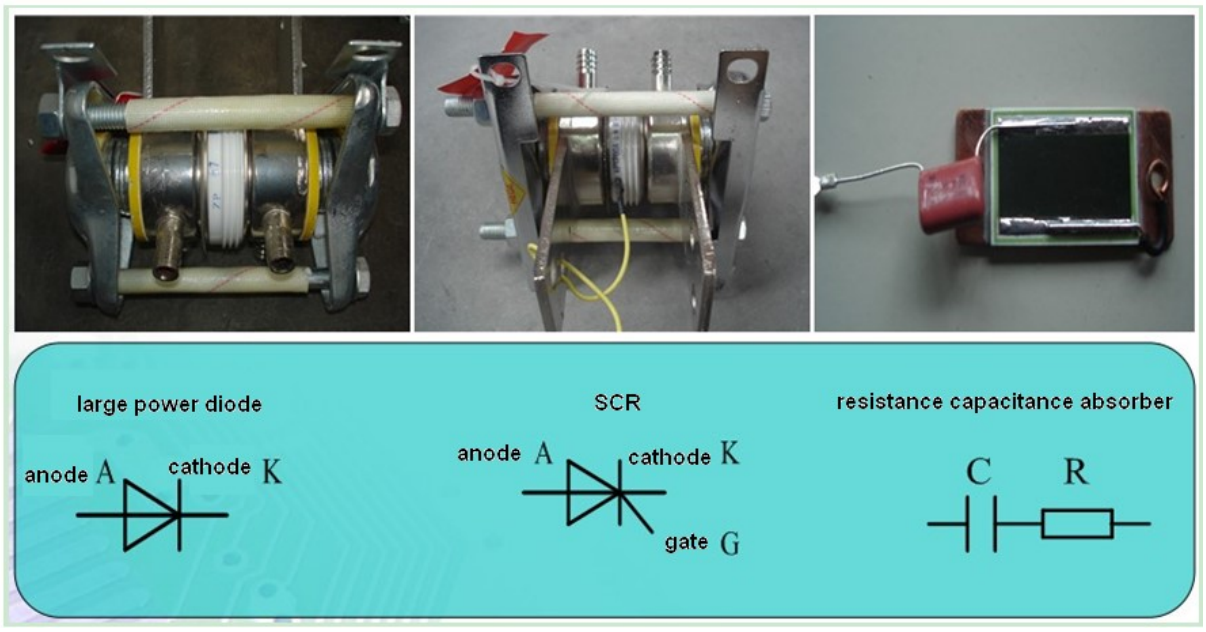
（c）suitable angle

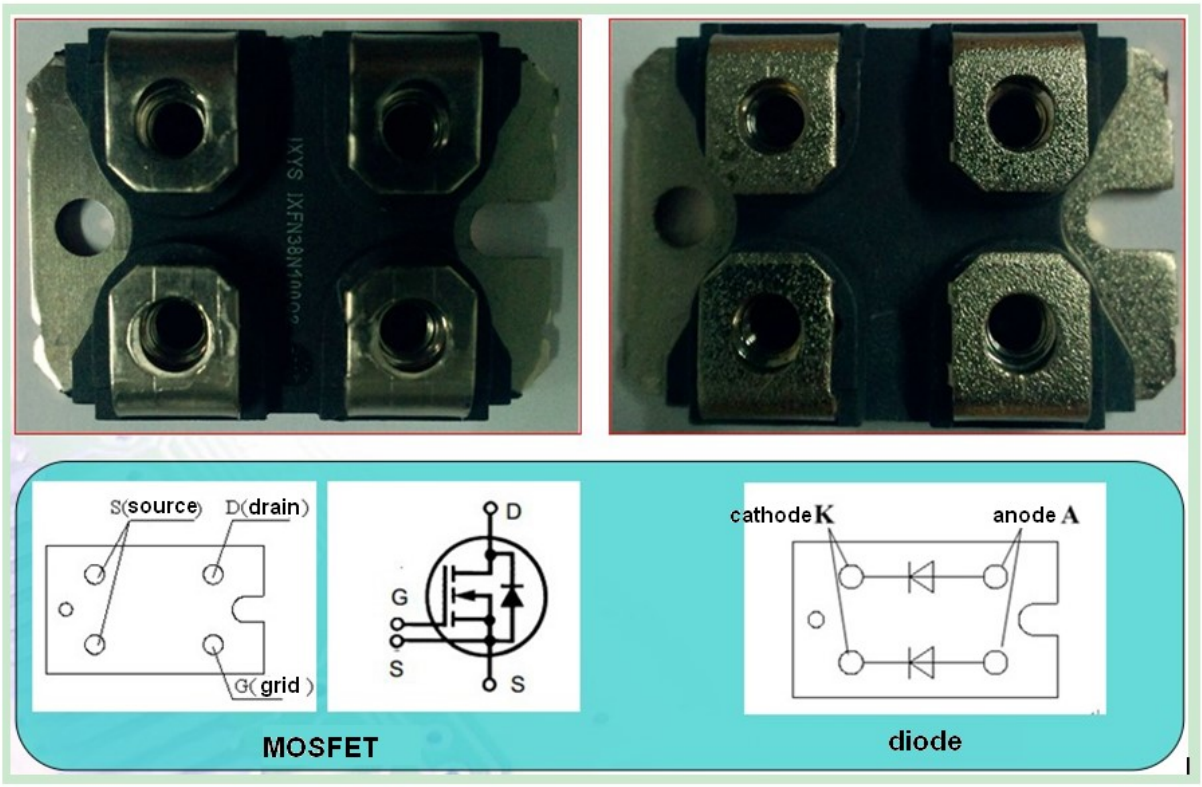


（d）small angle

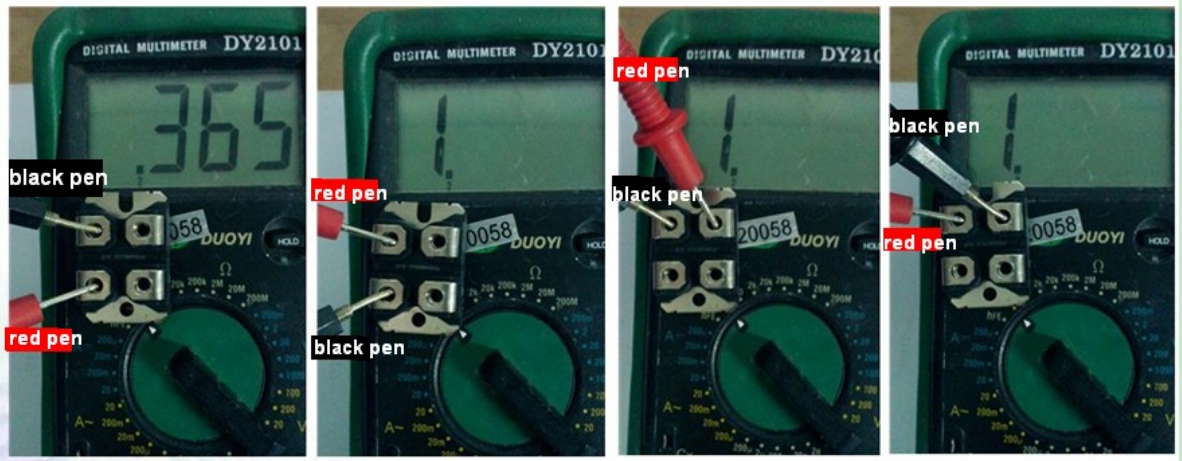
Measuring point: two ends of inverter output bridge board

7 main electronic components and test



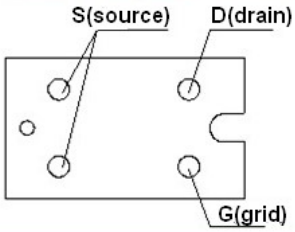


MOSFET measurement

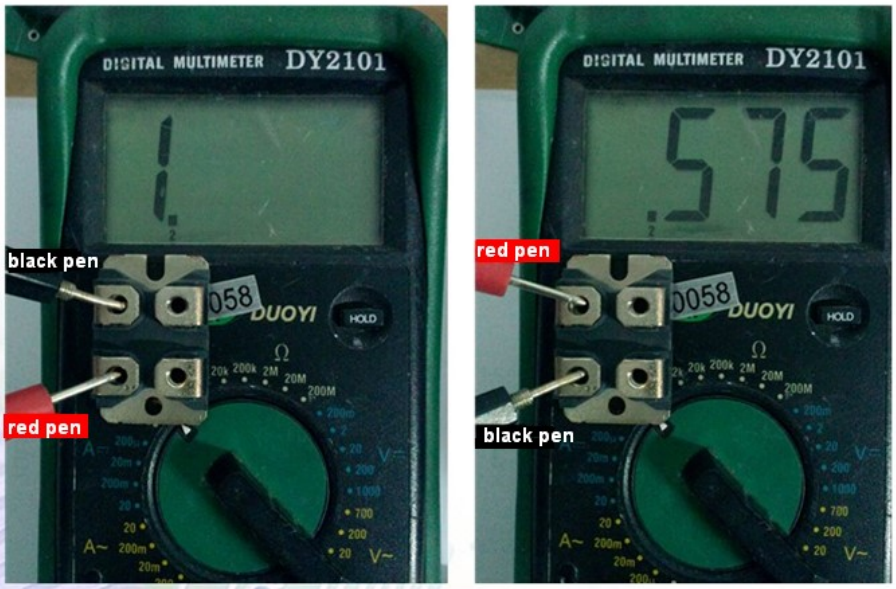


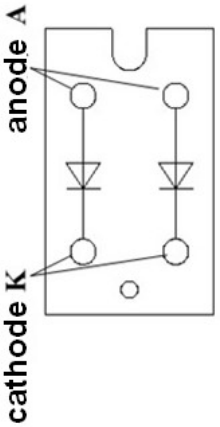
use DIODE of digital multimeter to measure:

G-S, not passble;
G-D, not passble;
D-S, appear to be diode character.
Note: all of the wire on terminal should be dismantled before measuring MOSFET!



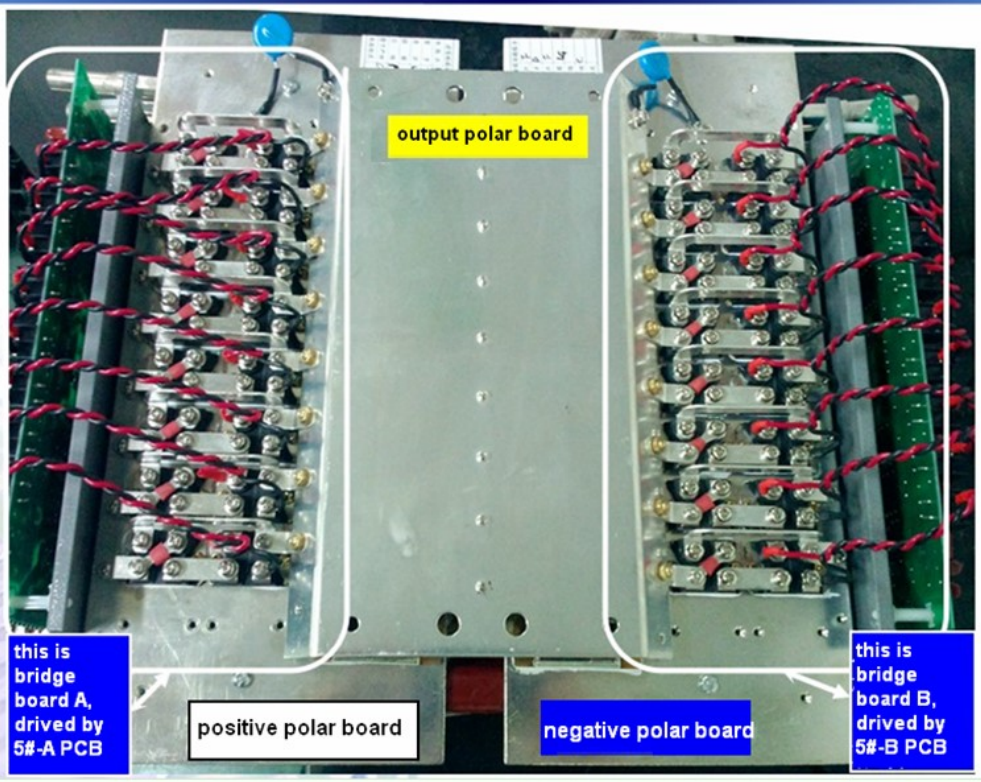
diode measurement



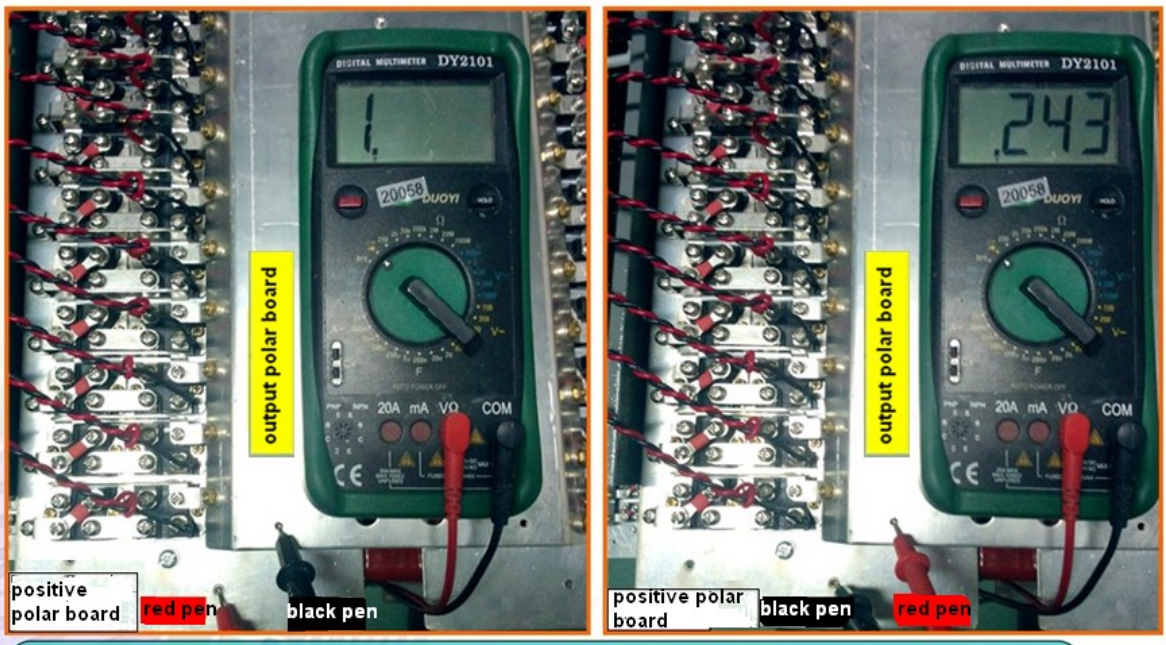


this diode is fast recovery diode, which is composed of two separate diodes in parallel, there's no relationship between the two diodes, the character is just like common diode. The two single diode should be measured separately.

measurement of inverter bridge board

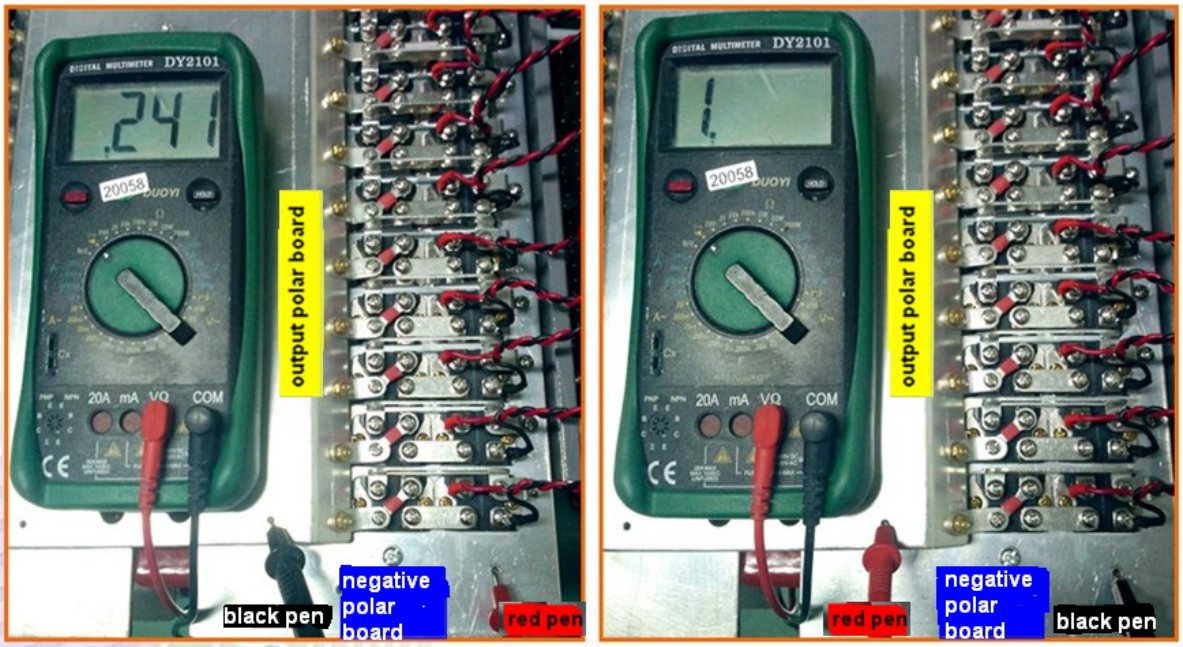


measurement of inverter bridge board-bridge board A



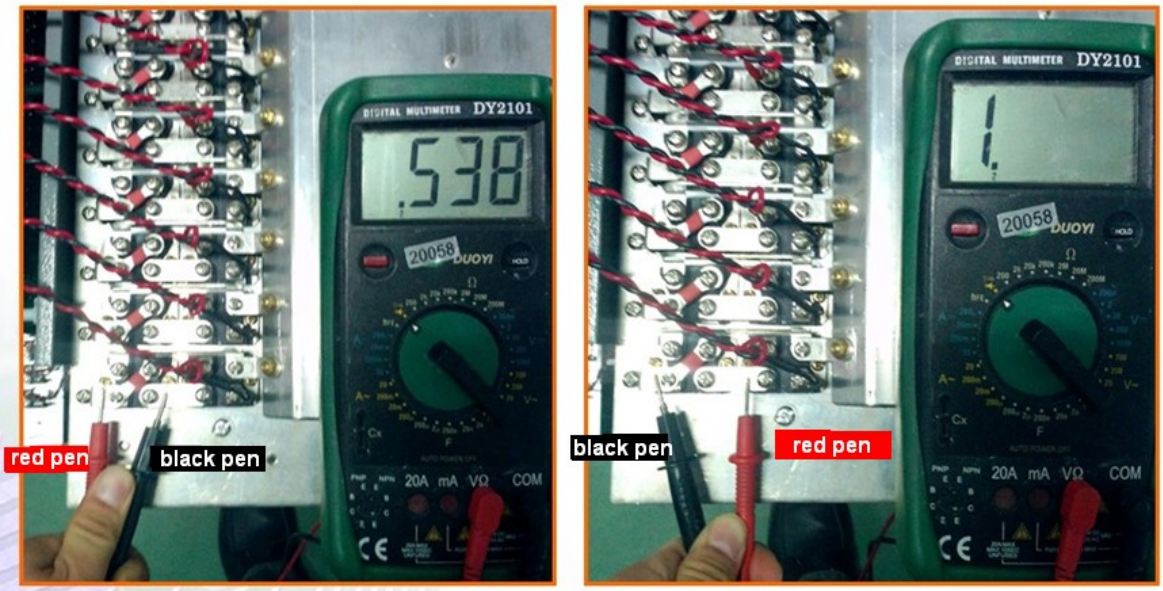
use DIODE of digital multimeter to measure:
between positive polar board and output polar board, appear to be diode character.
Note: If it is not diode character by measurement, check all of the MOSFET and diode in parallel!

measurement of inverter bridge board-bridge board B

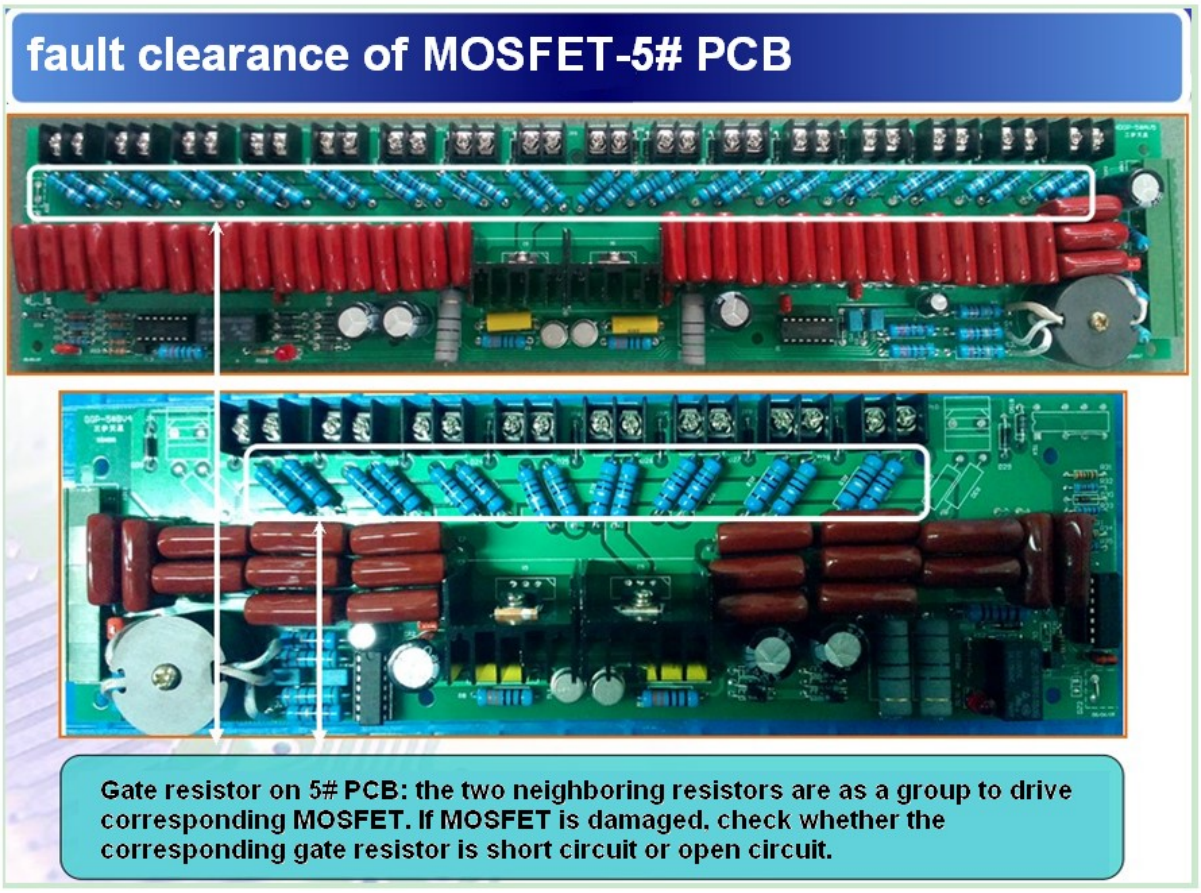


use DIODE of digital multimeter to measure:
between negative polar board and output polar board, appear to be diode character.
Note: If it is not diode character by measurement, check all of the MOSFET and diode in parallel!

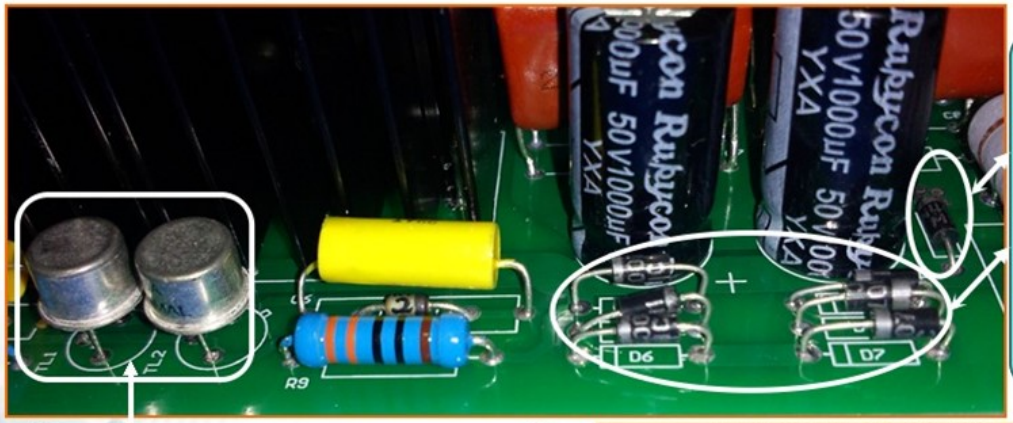
measurement of inverter bridge board-series diode



use DIODE of digital multimeter to measure:
between series diode, appear to be diode character.
Note: If it is not diode character by measurement, check all of the series diodes!


fault clearance of MOSFET-5# PCB
Gate resistor on 5# PCB: the two neighboring resistors are as a group to drive corresponding MOSFET. If MOSFET is damaged, check whether the corresponding gate resistor is short circuit or open circuit.

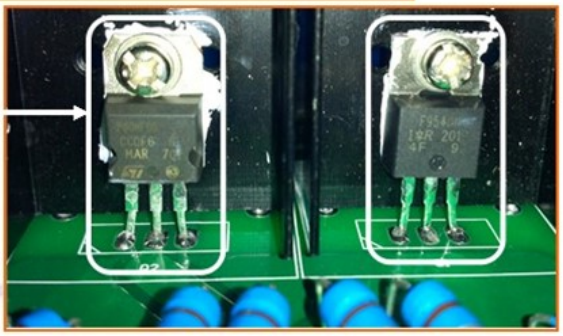
Fault clearance of MOSFET-5# PCB



clamping diode and negative pressure diode: check when drive pulse has no negative pressure!

drive secondary power amplifier: check when drive pulse is abnormal!

drive three-level power amplifier: check when drive pulse is abnormal!



Note: when MOSFET is damaged. after replacement of gate resistor on 5# PCB. the diode and power amplifier marked in the figure should be checked.

Fault clearance of MOSFET-other key points

when MOSFET is damaged due to equipment fault, it needs to check whether the components marded in the circle in the figure are normal or not. If the component is damaged but not be replaced, more MOSFET will be damaged. (it needs to check protection reactance and power distribution board corresponding to the damaged inverter bridge)

protection reactance diode in rectifying cabinet

stabilivolt of power distribution board in inverter output cabinet

8 Appendix

Please refer to attachment for electric drawing.

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