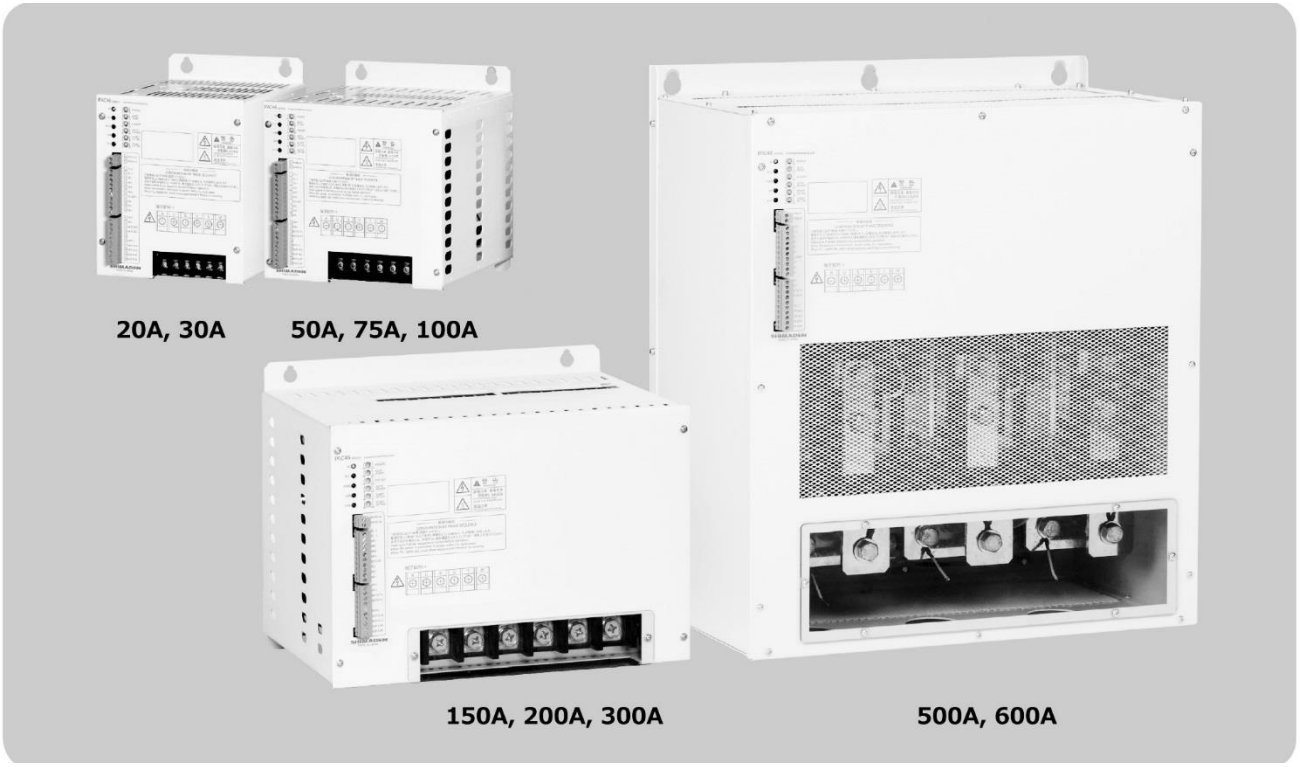
PAC46 Series

THYRISTOR THREE PHASE POWER REGULATOR

Instruction Manual



SHIMADEN CO., LTD.

MPA046-E01-C
Jun. 2022

Thank you very much for purchasing this Shimaden product.
Make sure that the delivered product is the one that you ordered. Carefully read and fully understand this Instruction Manual before use.
For the communication function, refer to the separate PAC46 SERIES COMMUNICATION INTERFACE INSTRUCTION MANUAL.

Notice

Ensure that this manual is handed to the final user of the instrument.

Introduction

This Instruction Manual is written for people who are involved in the installation, wiring, operation, and daily maintenance of the PAC46 series (hereinafter referred to as “the instrument”).
Use the instrument as a built-in component for industrial-use controllers.
Because this manual describes precautions, installation procedures, and wiring information, which are necessary to use the instrument, always keep it at hand during use.
Always operate the instrument according to the instructions contained in this Instruction Manual. Failure to follow the instructions in the Instruction Manual may impair the safety of the product.
Note that safety precautions, precautions for equipment and facility damage prevention, and additional explanations and notes on exceptions are given under the following headings.

◎Failure to comply may result in personal injury or death.

⚠ WARNING

◎Failure to comply may result in damage to equipment and/or facilities.

⚠ CAUTION

◎Additional explanations, notes on exceptions, and other necessary information.

NOTE

⚠ WARNING

The PAC46 series is designed for the purpose of controlling the power of heaters and other facilities for industrial use. Never use it for a nuclear power plant, transportation, communication, medical care, or other critical facilities. If it is anticipated that a failure of this instrument or peripheral equipment can lead to a significant loss, be sure to take appropriate safety measures before use.
Please understand that we assume no responsibility for any accident that may occur as a result of use without safety measures.

⚠ WARNING

1. Do not use the instrument as a switching device. Since the output circuit is continuous through capacitors and resistors even when the output is zero, there is a risk of electric shock, which may cause fatal or serious injury.
2. Radiator fins and the housing become hot when power is supplied. Never touch them. There is a risk of burn injury if you touch them.
3. Never perform wiring when power is supplied. Electric shock may result.
4. Be sure to ground the earth terminal.
5. Do not touch terminals and other live parts with your hands when power is supplied. In addition, do not put foreign objects inside the instrument. If a foreign object gets inside by accident, be sure to turn off the power supply and ensure safety before attempting to remove the foreign object with your hand or a tool.

⚠ CAUTION

Use the instrument according to this Instruction Manual. Failure to follow the instructions in this Instruction Manual may impair the protection performance of the instrument.
If there is a possibility that a failure of the instrument may cause damage and/or loss of peripheral equipment, facilities, or products, provide, on the power supply input side, safety measures such as a rapid fuse, circuit breaker, earth leakage breaker, electromagnetic switch, and overheat prevention device for short-circuit protection and overload protection.
If an electromagnetic switch is used, surge noise may be generated during switching operation, which has a negative effect on the instrument. The instrument tends to malfunction, particularly in circuits to which an inductive load is connected. In such a case, we recommend using a noise filter, or connecting a class-X capacitor (about 0.1 to 0.5 μF) between each phase of the main power supply, or a class-Y capacitor (about 1000 to 3300 pF) between each phase of the power supply and ground, to absorb noise.

⚠ CAUTION

1. About the alert symbol ⚠ The instrument has the alert symbol ⚠ printed on it. This is intended to alert the user of the risk of electric shock from touching live parts of the instrument when power is supplied, and the risk of burn injury from touching hot parts of instrument when power is supplied or immediately after power is cut off.
2. For any external power circuit connected to the instrument, provide a switch or circuit breaker as a means of turning off the power supply. The switch or circuit breaker should be installed in a location near the instrument for ease of operation. Put a label on the switch or circuit breaker saying that it is a power cut-off device for the instrument.
3. Tighten leads securely at the connecting points. Insufficient tightening may cause overheating due to contact resistance, which can result in burnout.
4. Use the instrument at or below the rated supply voltage and power supply frequency.
5. Do not apply non-standard input voltage or current to input terminals. Doing so not only shortens the product service life, but also may cause failure or damage of the instrument.
6. Use the loads connected to output terminals at or below the rated voltage or current.
   Exceeding the rated voltage or current not only shortens the product service life, but also may cause failure or damage of the instrument.
7. After wiring, be sure to install the supplied terminal cover before using the instrument.
8. Never modify or use the instrument for irregular applications.
9. To ensure safety and maintain the functions of this device, do not disassemble this device other than replacing the fuse.
   If this device must be disassembled for replacement or repair, contact your dealer.
10. In order to use the instrument correctly and maintain the reliability of the instrument, follow the precautions provided in this Instruction Manual.
11. If the instrument has the communication function, and data is written from the master equipment, trimmer adjusters and control input terminals may be disabled, making output adjustment by the trimmer adjusters or by input signals from the control input terminals impossible. To be prepared in case the communication settings are incorrect, provide safety measures, such as a circuit breaker, on the power supply input side before using the instrument. Data written by the master equipment is retained even after power is cut off. Write data carefully to prevent incorrect communication settings. To enable input to trimmer adjusters and control input terminals, you need to write and then set the data again from the master equipment.

Note: Please understand that we assume no responsibility and warranty for any accident and/or injury that may occur as a result of failure to observe the warnings and precautions provided in this Instruction Manual.

Contents

1. Checking of Specifications

Check again that the delivered product meets the order specifications. If you have any inquiries, please contact our nearest shimaden agent.

1-1. Code Selection Table

Item	Code	Specification
1. Series	PAC46	Thyristor three phase power regulator

2. Control input		
3	1 – 5 V DC	Input resistance: About 300 kΩ or above
4	4 –20mA DC	Receiving resistance: 100 Ω
6	0 – 10V DC	Input resistance: About 220 kΩ or above

3. Supply voltage (Note 1)	
20-	200V AC
22-	220V AC
24-	240V AC
38-	380V AC
40-	400V AC
44-	440V AC

4. Current capacity	200 – 240 V AC		380 – 440 V AC	
	Code	Current capacity	Code	Current capacity
	021	20A	022	20A
	031	30A	032	30A
	051	50A	052	50A
	071	75A	072	75A
	101	100A	102	100A
	151	150A	152	150A
	201	200A	202	200A
	301	300A	302	300A
	501	500A	502	500A
	601	600A	602	600A

5. Control mode (Six-arm phase control)		
	P0	Phase control and voltage feedback
	P1	Phase control and current feedback
	P2	Phase control and power feedback (Note 2)
	P3	Phase control and voltage square feedback
*	CM	Communication function (Factory-set to voltage feedback) (Note 3)

6. Output limiting function		
0	Without	
1	Start-up time output limit	0 – 60% output for 1 – 60 seconds
2	Current limit	50 – 100% of rated current (External setting device VR3)
3	Start-up time output limit + Current limit (1 + 2)	

7. Output adjustment function			
		N	Without (Standard: Internal power adjuster)
	Please select when combined with voltage/current output type controller.	P	External power
		M	Manual power
		B	Base (residual) power
		W	External power + Manual power
		Y	External power + Base power
	Please select when combined with contact output type controller	C	External power
		H	High-low power

8. Rapid fuse		
0	Without	
1	With	With blown alarm output

9. Automatic power adjustment function (Not insulated from control input)		
0	Without	
4	4 – 20 mA DC	Receiving resistance: 100 Ω
6	0 – 10 V DC	Input resistance: About 220 kΩ or above

10. Remarks		
0	Without	
9	With	

Shaded options are under development.

Note 1: Please contact us if the instrument must be used at other than the rated voltage.
Note 2: Since the heating element (especially silicon carbide type) of variable resistance type has a high temperature coefficient, the resistance value during temperature rise will be significantly lower than in the normal temperature range. Therefore, if you want to obtain appropriate power in the entire temperature range, determine the current capacity using the following formula. Since the resistance ratio of the silicon carbide heater is approximately 1: 3, select a current capacity that is $\sqrt{3} \approx 1.73$ times the square root of the resistance ratio. If the heater deteriorates, the resistance ratio may increase further, so it is recommended to select one that is about twice as large.
Note 3: Refer to the separate PAC46 SERIES COMMUNICATION INTERFACE INSTRUCTION MANUAL.

* If you select a product with the communication function, you can change the control mode via communication.

1-2. Checking the accessories

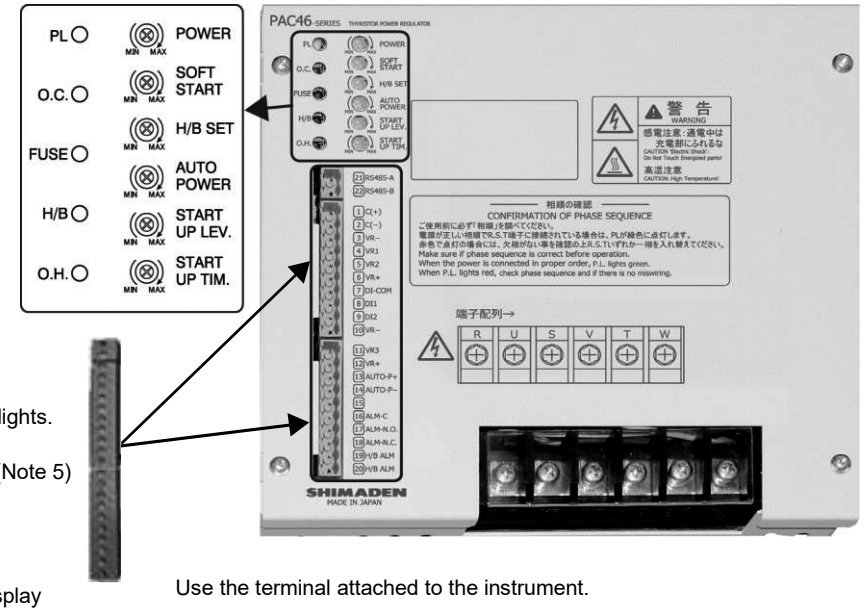
Instruction Manual: 1 copy
Separated type terminals: 2 long terminals + 1 short terminal
(the short terminal is attached when the CM: communication function is selected when the code is selected)
Jumper wire: 1

2. Panel Information and Control Terminals

2-1. Panel information

■ Trimmer adjusters

POWER	: Internal power adjustment
SOFT START	: Soft start time adjustment
H/B SET	: Heater break alarm setting
AUTO POWER	: Automatic power adjustment (Note 4)
START UP LEV.	: Start-up time output limit level (Note 4)
START UP TIM.	: Start-up time output limit time (Note 4)



■ Monitor lamps

PL	: Power supply normal Green lamp lights. Open phase/phase sequence abnormal /frequency abnormal Red lamp lights. (Note 5)
O.C.	: Over-current protection action display
FUSE	: Rapid fuse blown (Note 4)
H/B	: Heater break alarm action display
O.H.	: Internal temperature abnormal alarm display

Use the terminal attached to the instrument.

Note 4: Activate when the corresponding option is added.
Note 5: Abnormal frequency means a power supply frequency of about 44 Hz or below or about 65 Hz or above.

2-2. Control terminals and symbols

No.	Code	Brief Description of Function	Remarks
21	RS485-A	RS-485 communication input/output (+)	When communication function is selected in control mode
22	RS485-B	RS-485 communication input/output (-)	

1	C(+)	Control signal input (+)		
2	C(-)	Control signal input (-)		
3	VR-	External power adjuster (VR1) connection terminal	Base power/manual power adjuster (VR2) connection terminal	
		VR1-Red (1)	VR2-Red (1)	
4	VR1	VR1-White (2)	---	
5	VR2	---	VR2-White (2)	
6	VR+	VR1-Black (3)	VR2-Black (3)	
7	DI-COM	Base power/manual power selection (DI1) and start-up time output limit time synchronization signal (DI2) connection terminals		
8	DI1			
9	DI2			
10	VR-	Current limit setting device connection terminal VR3-Red (1)		Option

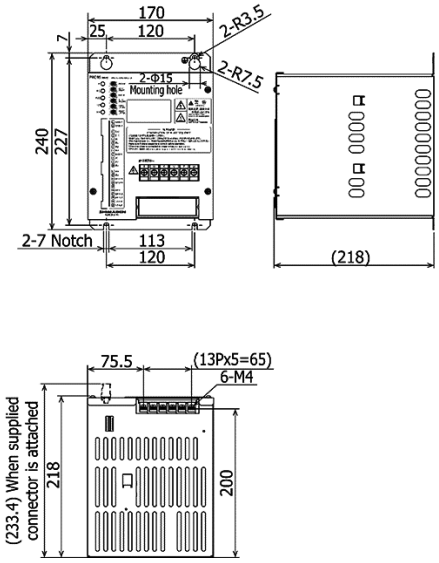
11	VR3	Current limit setting device connection terminal VR3-White (2)	Option
12	VR+	Current limit setting device connection terminal VR3-Black (3)	
13	AUTO-P+	Automatic power signal input (+)	Option
14	AUTO-P-	Automatic power signal input (-)	
15			
16	ALM-C	Over-current protection action /internal temperature abnormal/fuse blown (Option) Alarm output	
17	ALM-N.O.		
18	ALM-N.C.		
19	H/B ALM	Heater break alarm output	
20	H/B ALM		

Wire diameter: 28-12AWG, Use wire with a strip length of 7.0 mm.

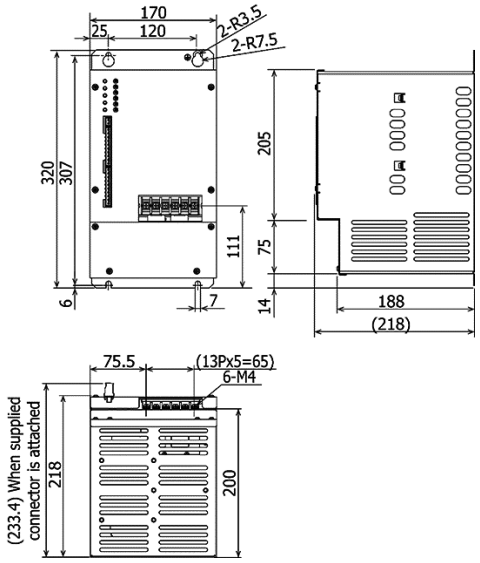
3. External Dimensions and Weight

20A, 30A

200 – 240V / Weight: Approx.5.0 kg

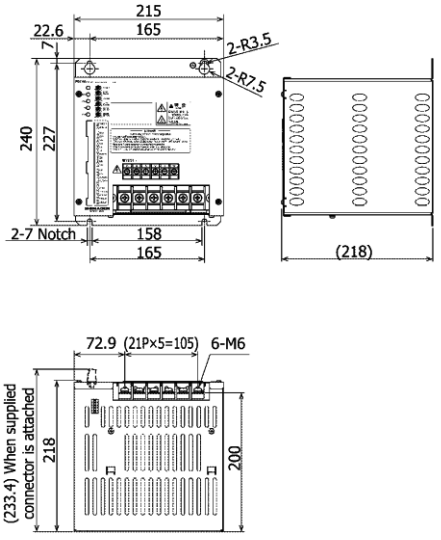


380 – 440V / Weight: Approx.7.5 kg

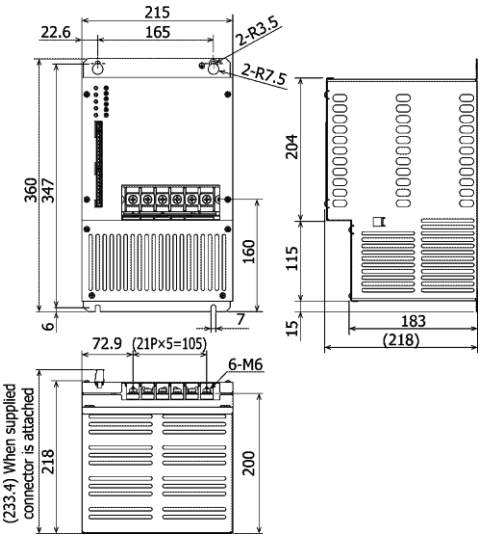


50A, 75A, 100A

200 – 240V / Weight: Approx.6.0 kg



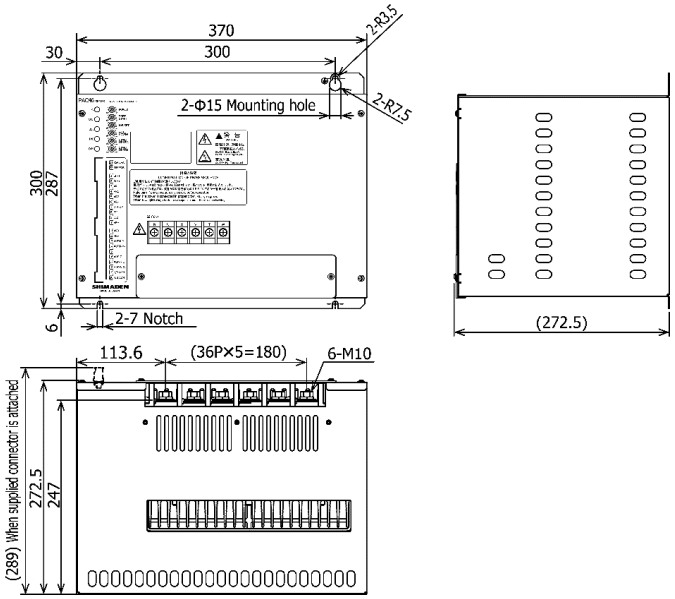
380 – 440V / Weight: Approx.10.0 kg



Unit: mm

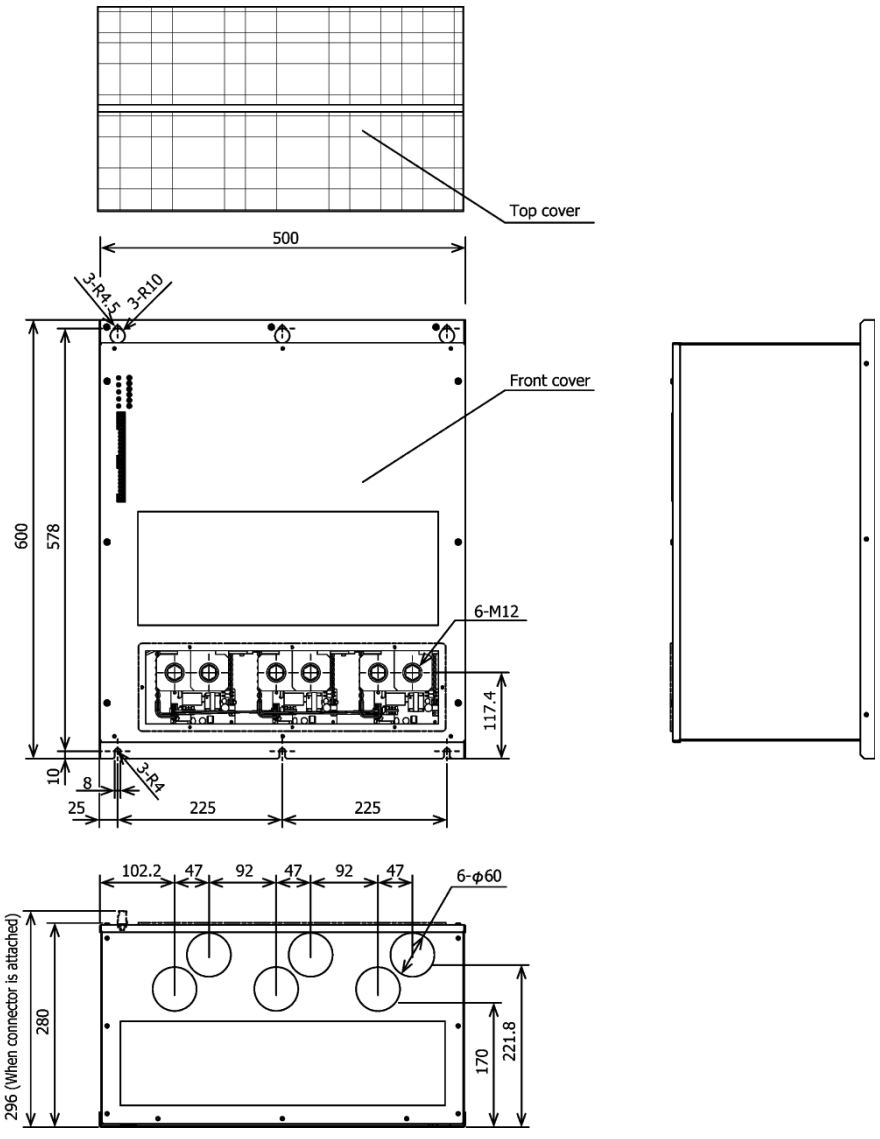
150A, 200A, 300A (200 – 240V, 380 – 440V)

200 – 240V / Weight: Approx.15.0 kg 380 – 440V / Weight: Approx.20.0 kg



500A, 600A (200 – 240V, 380 – 440V)

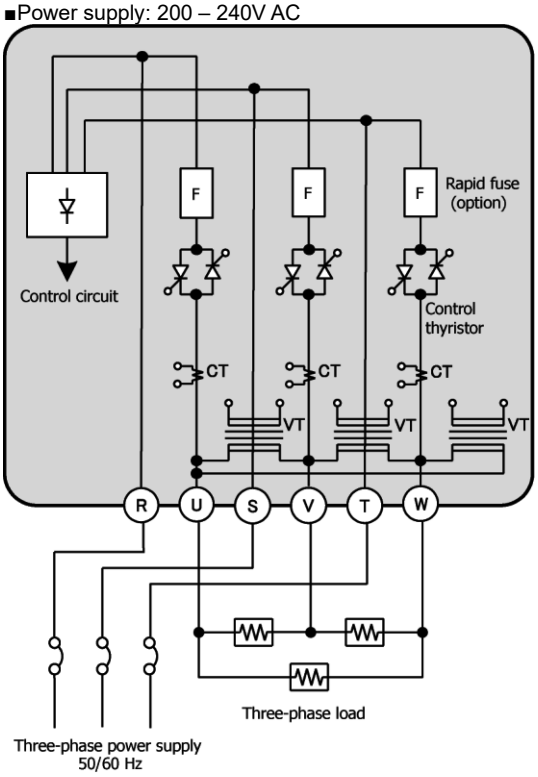
200 – 240V / Weight: Approx.42.0 kg 380 – 440V / Weight: Approx.50.0 kg



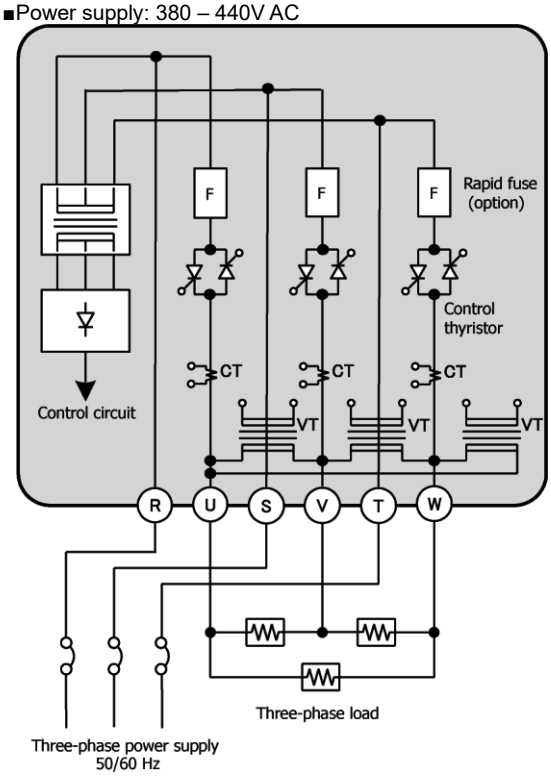
Unit: mm

4. Circuit Block Diagram

■Power supply: 200 – 240V AC



■Power supply: 380 – 440V AC



5. Installation Area

As surrounding conditions affect the reliability and service life of the instrument, a favorable environment should be chosen.
The following conditions are required.

1) Indoors
2) Altitude: 2,000 m or below
3) Temperature range: -10 to 50°C (Refer also to 10-6. 'Ambient temperature and load current'.)
4) Humidity range: 90%RH or below (No condensation allowed)
5) Over-voltage category: II
6) Pollution degree: 2 (IEC 60664)

⚠ CAUTION

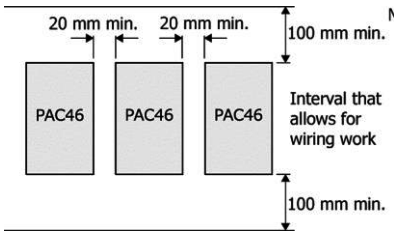
Do not use the instrument in the following locations. There is a risk of failure or damage to the instrument, which may lead to fire or other hazards in the worst case.

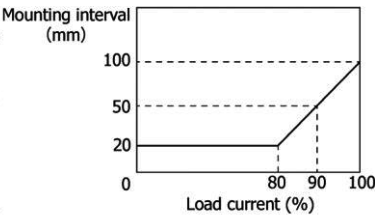
- Locations subject to, or filled with, inflammable or corrosive gas, oily smoke, dust that impairs insulation, etc.
- Locations subject to vibration or shock
- Locations subject to splashing liquid or direct sunlight
- Locations subject to air from heating or air conditioning equipment
- Locations subject to strong noise, static electricity, electric field, or magnetic field
- Locations that prevent safe maintenance work

6. Mounting

6-1. Mounting interval and load current

The instrument should be fixed to a control panel, wall, rack, etc.
For safety's sake, it should not be easily accessible.
A ventilation opening etc. on the installation surface may cause the internal parts of the instrument to be heated, resulting in a functional failure.
Be sure to mount the instrument by sealing the installation surface. In addition, for the purpose of heat dissipation, always use vertical mounting and secure a clearance of at least 100 mm above or below the instrument.





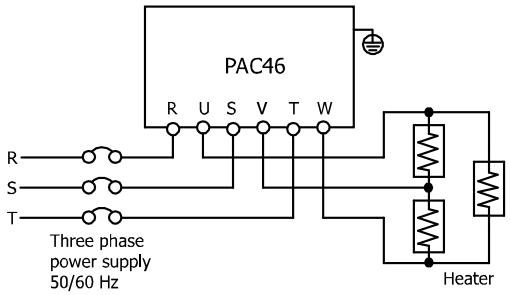
If using horizontal mounting is unavoidable, use the instrument at 50% of the rated current or below.

If ambient temperature exceeds 40°C
If the ambient temperature exceeds 40°C, the load current should be reduced. Refer also 10-6. 'Ambient temperature and load current.'

7. Wiring and Terminal Sizes

7-1. Wiring and terminal sizes of power supply and load

When wiring the power circuit for the instrument, make sure to check the phase sequence (R-S-T). Never make a trial run etc. in an incorrect phase sequence.
When you check the phase order using the monitor lamps of the instrument, set the output to 0%.
If the phase sequence is incorrect, the red PL monitor lamp lights up.
In this case, change the connection of any two lines of the R, S, and T phases.

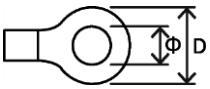


⚠ CAUTION

If the instrument has the communication function, and data is written from the master equipment, trimmer adjusters and control input terminals may be disabled, making output adjustment impossible. For details, refer to the PAC46 SERIES COMMUNICATION INTERFACE INSTRUCTION MANUAL.

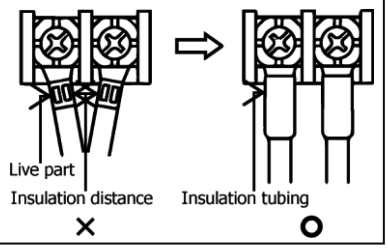
■ Connect the power supply and load wires to the power supply terminals located at the bottom of the panel.

Power supply terminal(R)/ Output terminal (U)	Current capacity			
	20 to 30A	50 to 100A	150 to 300A	500 to 600A
Φ	4.0 or more	6.0 or more	10.0 or more	12.0 or more
D	12.2 or less	18.0 or less	30.0 or less	60.0 or less
Applicable screw	M4	M6	M10	M12
Tightening torque N•m	1.2 to 1.4	2.5 to 3.0	10 to 12	15.5 to18.5



- Screw terminal block -

When using the bare crimp terminals, secure a necessary insulation distance to prevent electrical shock and short-circuit, by using insulation tubing or other means to prevent live parts from being exposed.

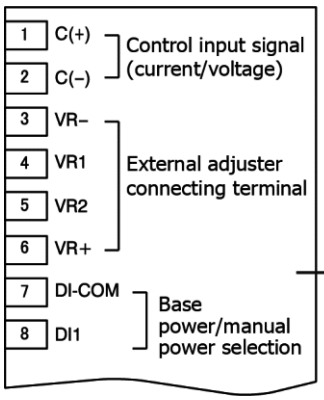


7-2. Protective earthing

The symbol for protective earthing is ⏚.
For electrical safety considerations, be sure to fix the instrument with screws via spring washers or the like to a metal plate that is connected to the earth.

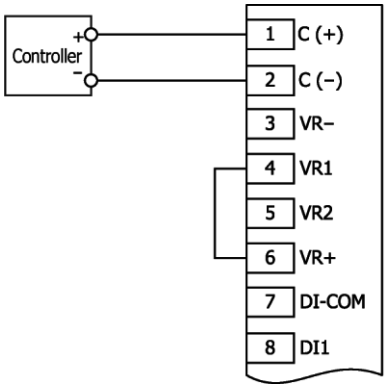
7-3. Wiring of control input signal

Control signals (4–20 mA, 1–5 V, or 0–10 V) from the controller are input into control signal terminals 1 [C (+)] and 2 [C (-)].
While paying attention to the polarity, wire carefully so as to prevent noise from a strong electric circuit.
Countermeasure against lightning surge will be required for signal line over 30m.

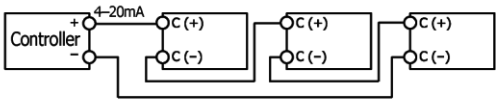


Connection state of 7 (DI-COM) and 8 (DI1)	VR2 function
Open	Base power adjustment
Short-circuit	Manual power adjustment

7-3-1 Connection between 4–20 mA output type controller and instrument (4–20 mA input)

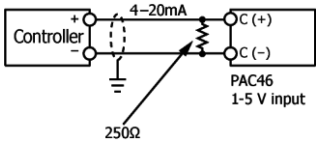


To connect multiple units of the instrument, wire them in series as shown below. The input resistance of the instrument (4–20 mA input) is 100 Ω. Therefore, if the allowable load resistance range of the controller is 600 Ω, up to six units of the instrument can be connected.

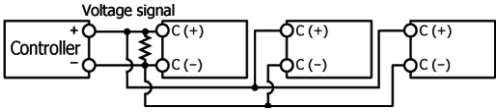


7-3-2 Connection between 4–20 mA output type controller and instrument (1–5 V input)

When connecting a 4–20 mA output type controller and the instrument (1–5 V input), connect a 250 Ω resistor to the input terminals in parallel.



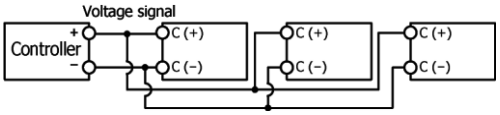
To connect multiple units of the instrument, wire them in parallel as shown below.



When using a voltage input type controller, wire the control signals in parallel.

7-3-3 Connection between 0-10 V output type controller and instrument (0-10 V input)

For this connection, also use the 0-10 V input type instrument.
As the input resistance is high, use two-core shielded cable and prevent the effects of noise by single earthing.
Connect the (+) and (-) terminals of the controller respectively to the input terminals, C (+) and C (-), of the instrument.
To connect multiple units of the instrument, connect them in parallel as shown below. However, resistor connection is not required.

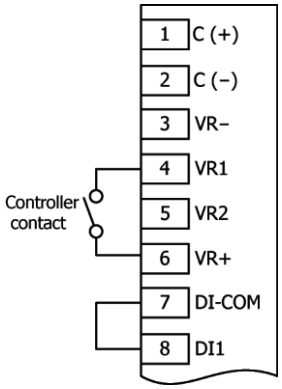


If the maximum load current is 2 mA at 0 to 10 V, up to 44 units can be connected, since the input resistance of the PAC46 is 220 kΩ.

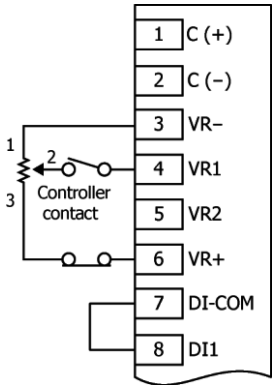
7-3-4 Connection between contact output type controller and the instrument

When connecting the instrument to a contact output type controller, short-circuit terminals 7 (DI-COM) and 8 (DI1).
Leave input terminals 1 [C (+)] and 2 [C (-)] of the instrument unconnected.
When the terminal 4 (VR1) is opened, output turns off.
For connection to a contact output type controller, the instrument can be connected to a two-position (ON/OFF), proportional, or PID system.
In wiring, you need not consider polarity and can use a wiring resistance of up to 10 Ω without problems. However, the controller should be wired separately from a strong electric circuit.

■ Switching between 0 and 100%

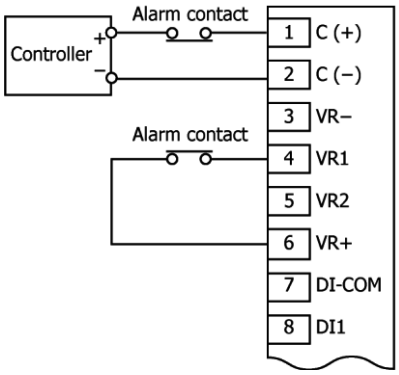


■ Connection to external power adjuster



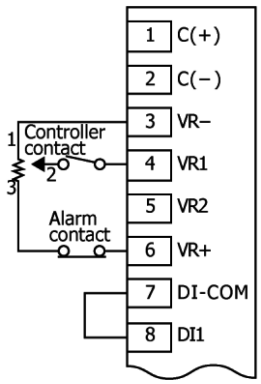
7-3-5 Over-rise protection circuit (for voltage/current input type)

This is a method of cutting off signals from the controller to stop control output.
Cutting off the continuity between terminals 4 (VR1) and 6 (VR+) also causes the output to stop.



7-3-6 Over-rise protection circuit (for contact input type)

In the following wiring diagram, an alarm contact is added to terminal 6 (VR+) to cause the circuit to open, to stop output when the over-rise prevention becomes active.
The same effect is produced when the contact is connected in series to the contact output of the controller.



7-4. Wiring of alarm circuit

When an over-current alarm, rapid fuse break alarm, or temperature abnormal alarm occurs, continuity is established between terminals 16 (ALM-C) and 17 (ALM-NO), while the path between terminals 16 (ALM-C) and 18 (ALM-NC) is opened. If an alarm occurs, check the monitor lamps to identify the type of alarm it is.
When a heater break alarm occurs, continuity is established between terminals 19 (H/B ALM) and 20 (H/B ALM), and the monitor lamp (H/B) lights.

7-4-1 Over-current alarm circuit

If an over-current alarm is detected, output is cut off and the monitor lamp (O.C.) lights up.
The instrument cuts off output at about 110% of the rated current.

7-4-2 Rapid fuse blown alarm (option)

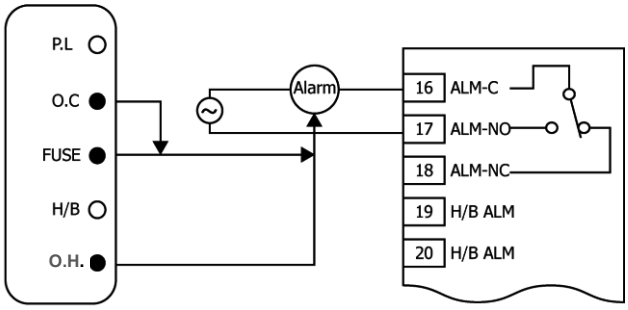
If a rapid fuse blown alarm is detected, output is cut off and the monitor lamp (FUSE) lights up.

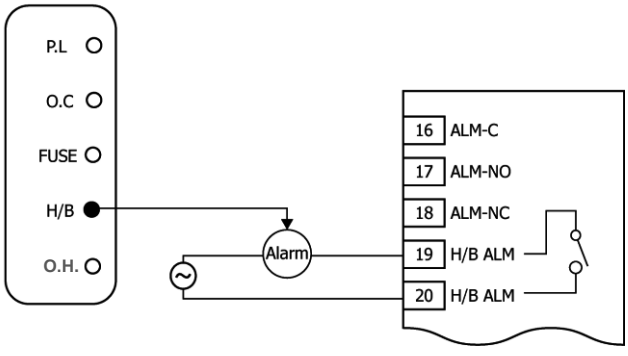
7-4-3 Internal temperature abnormal alarm

If an internal temperature abnormal alarm is detected, output is cut off and the monitor lamp (O.H.) lights up.

7-4-4 Heater break alarm

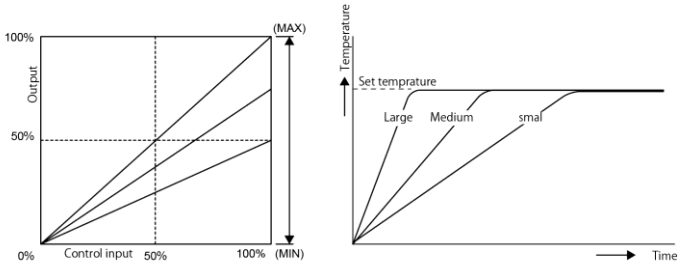
If a heater break alarm is detected, continuity is established between the H/B ALM terminals, and the monitor lamp (H/B) lights up.
In this case, the instrument maintains output.

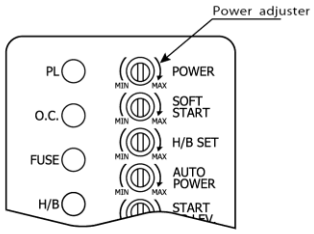




8. Output Adjustment Function

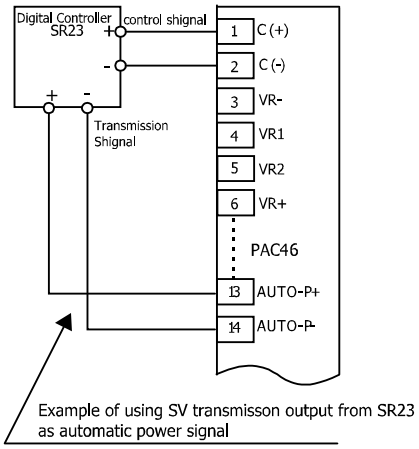
8-1. Power adjustment





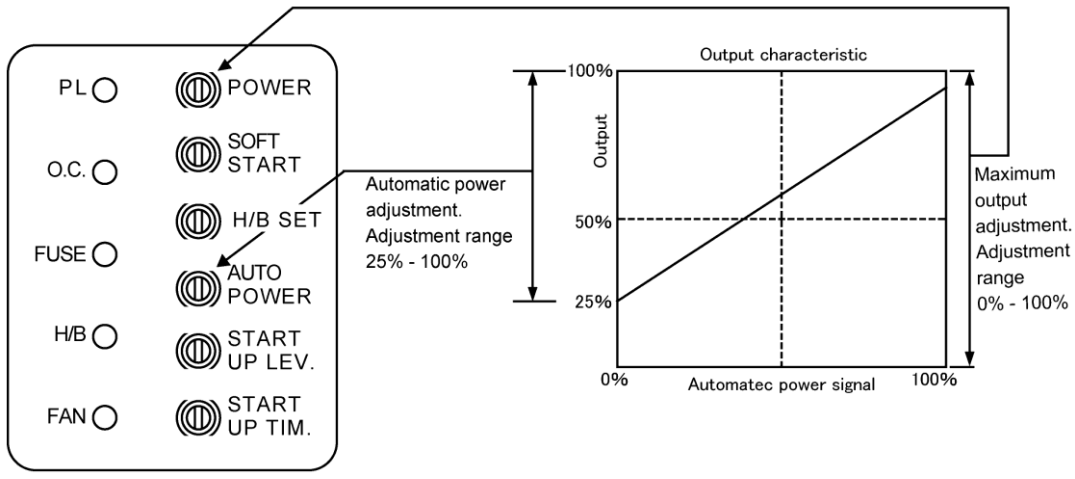
The power adjustment dial is used to control the output power of the PAC46 in the range of 0 to 100%. (Upper-left figure)
For equipment that controls temperature by a heater etc. based on its output, you can use the power adjustment dial (variable resistor) to set the desired temperature.
The time until the temperature is settled depends on the power adjustment dial value. (Upper-right figure)

8-2. Automatic power adjustment (option)

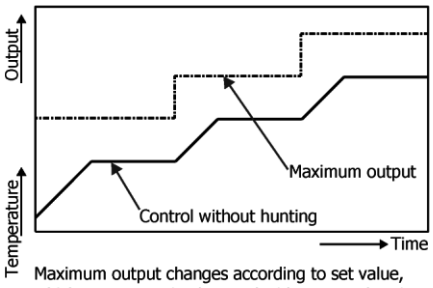


The automatic power adjustment function uses external signals (from a controller, sequencer, etc.) to automatically adjust the maximum output for optimum control.
Transmission signals from the controller are input into terminals AUTO-P+ and AUTO-P-.
Control signals from the controller are input into terminals C (+) and C (-).
Pay attention to the polarity when wiring.

By setting the controller to produce maximum output that is optimal for the set temperature, you can improve control accuracy and prevent the temperature change rate from rising more than necessary.

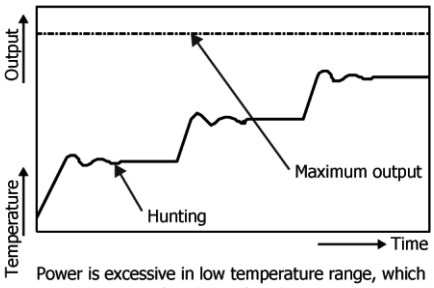


●Output and control result of PAC46 with automatic power adjustment function



Maximum output changes according to set value, which ensures optimal control without overshooting.

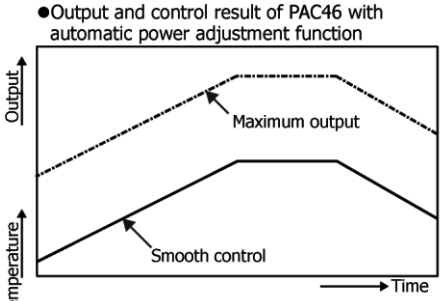
●Output and control result of PAC46 without automatic power adjustment function

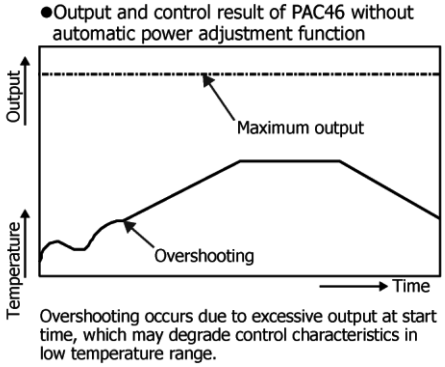


Power is excessive in low temperature range, which may cause overshooting or hunting.

■ Comparison with program control

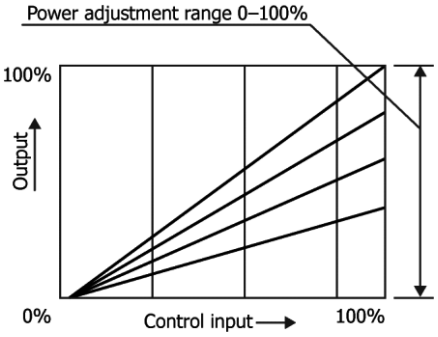
Programmed control has characteristics such that it can prevent overshooting at the start time and handle temperature ramping at extremely low speeds.





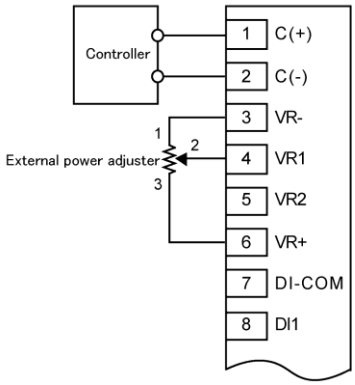
8-3. External power adjustment

External power adjustment is used to adjust the output of the instrument from a remote location. Select the external power adjustment function if you need to operate the instrument away from it.
You can use this adjustment method, after adjusting power to suit the set temperature, to improve control efficiency, adjust the rising ramp, manually correct the load characteristics, and so on.
*When the instrument is combined with a voltage/current input type controller, internal power (available as standard) can be used in the same way as described above.

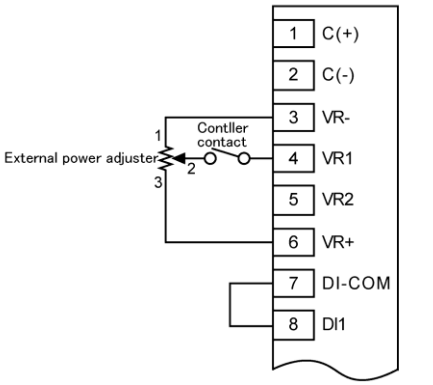


You can add this function even after the instrument is delivered by simply connecting an external power limit setting device (B/10 kΩ) to the appropriate terminals.

■ Combination with voltage / currant output type controller



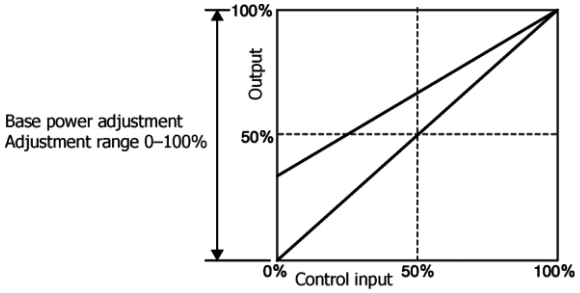
■ Combination with contact signal output type controller

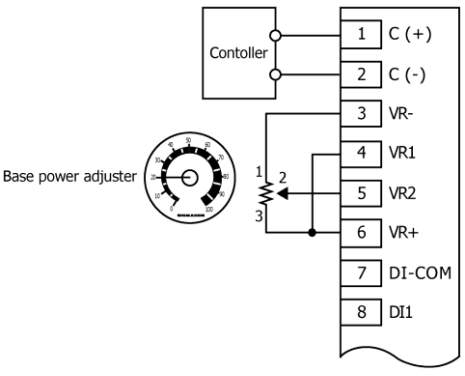


If not using an external power regulator, use the jumper attached to this instrument. please connect 4 (VR1) with 6 (VR +).

8-4. Base power adjustment

Generally, base power adjustment is used to keep output steady even when the control signal is at 0%.

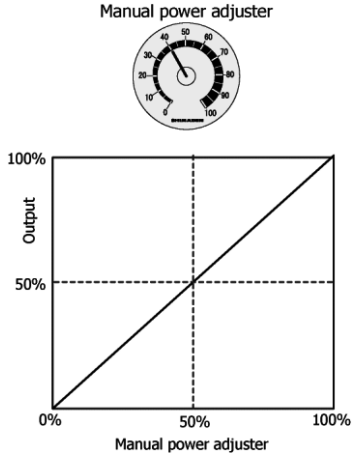




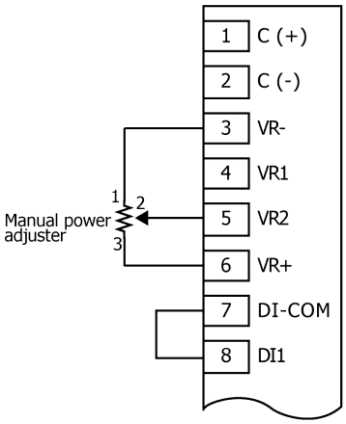
8-5. Manual power adjustment

Manual power adjustment is generally used to adjust output without using control input (automatic mode), to carry out adjustment in a trial run, and to switch to the control input mode in selecting a manually-set output by means of external signals. An example of switching between automatic (control input) and manual modes and methods of adjustment are shown below.

Add external contacts for switching between automatic and manual modes, and perform output adjustment in automatic mode or manual mode.

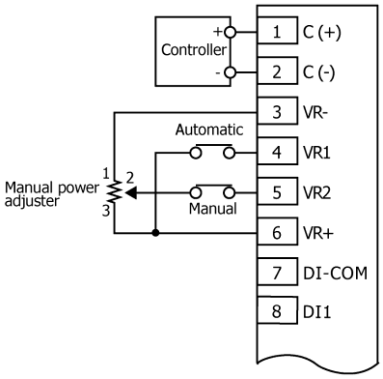


8-5-1 When controller is not connected



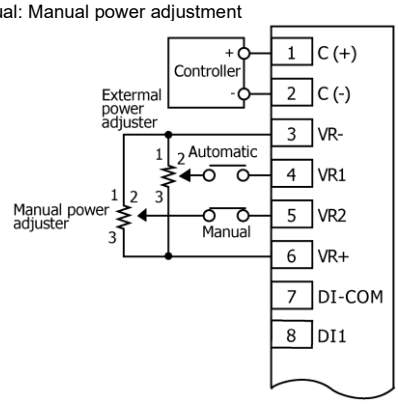
8-5-2 Switching between automatic and manual modes without external power adjuster

Automatic: Controller adjustment
Manual: Manual power adjustment



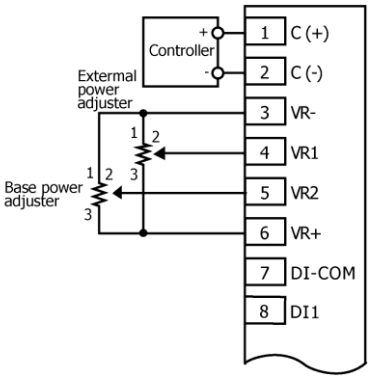
8-5-3 Switching between automatic and manual modes with external power adjuster

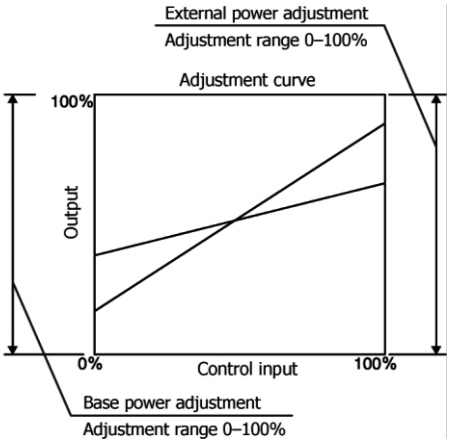
Automatic: Controller adjustment and external power adjustment
Manual: Manual power adjustment



8-6. External power adjustment and base power adjustment

This circuit functions to adjust the maximum output while retaining minimum output in some degree, so as to improve control efficiency and better cope with load characteristics.

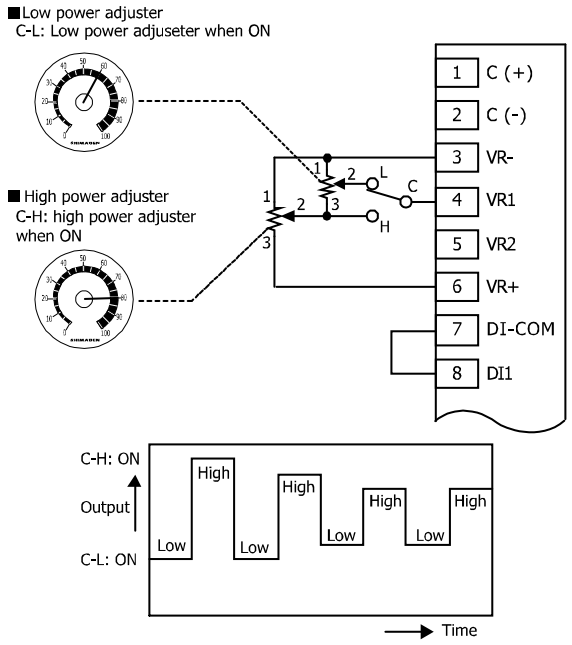




Note 6: If base power adjustment value > external power adjustment value, the instrument delivers output according to the set base power adjustment value regardless of the control input value.

8-7. High-low power adjustment (when combined with contact output type controller)

High-low power adjustment uses contact signals to adjust the power when the contact is short-circuited (high power) and when the contact is open (low power), for the enhancement of control efficiency.
This adjustment method is also used when the heater characteristically requires current at a certain level to be supplied constantly.



■ High power adjustment: The output when C and H are short-circuited can be adjusted in the range of 0 to 100%.

Set the adjuster dial to the optimal output level for the set temperature.

■ Low power adjustment: This adjustment is for residual output when C and L are short-circuited.

The adjuster dial is graduated from 0 to 100%. Use the following equation to determine the residual output level:

Residual output = (High power) x (Low power)

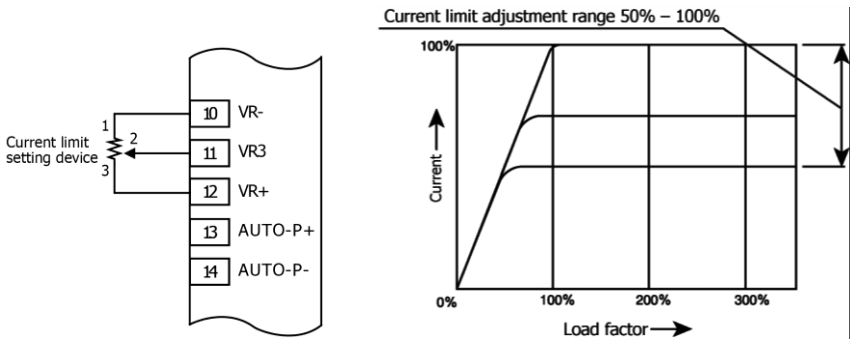
Example:

When high power = 70% and low power = 40%,

the residual output is 70% × 40% = 28%.

8-8. Current limiting (option)

This function is used to limit the current in the range of 50% to 100% of the current capacity.
Connect a current limit setting device with 50% to 100% graduation to terminals 10 (VR-), 11 (VR3), and 12 (VR+), as shown below.



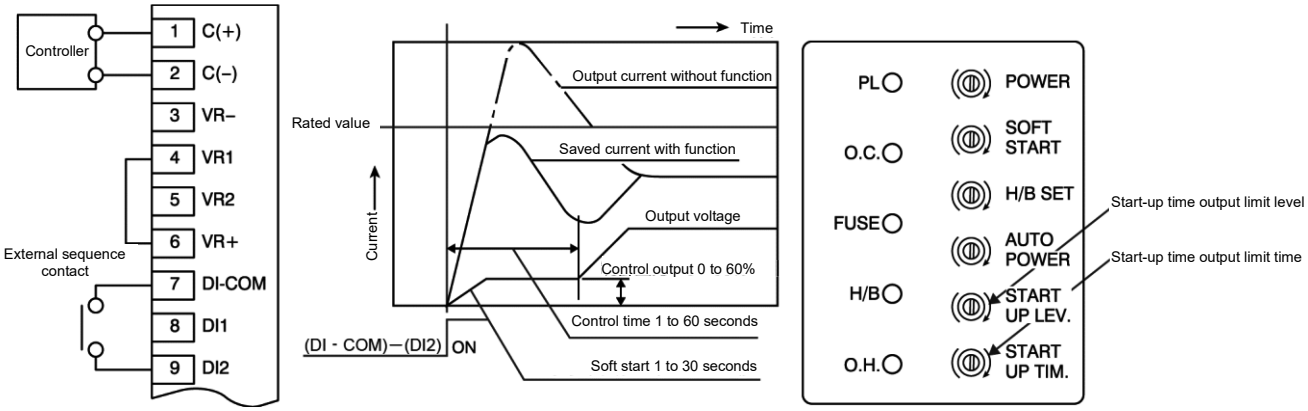
When a current limit setting device is not used, short-circuit terminals 11 (VR3) and 12 (VR+).

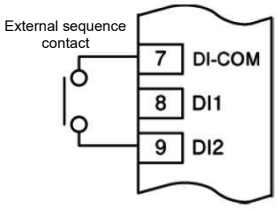
8-9. Start-up time output limiting (option)

This circuit can be used in two ways:

• To limit output when power is supplied
Use it by short-circuiting terminals 7 (DI-COM) and 9 (DI2).
Care should be taken because turning the power on when terminals 7 (DI-COM) and 9 (DI2) are open results in a shortage of output, as the instrument continues to run with limited output.

• To limit output in synchronization with external sequence
In order to change the load without turning off power, it is possible to reduce output by connecting a switching signal (external sequence contact) to terminals 7 (DI-COM) and 9 (DI2), and then short-circuiting the terminals.



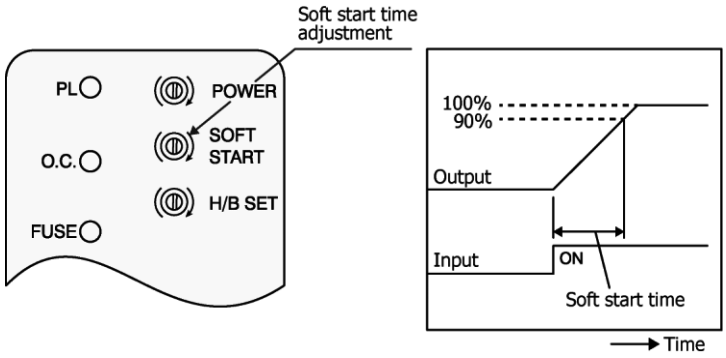


■ To limit output when power is supplied
Leave terminals 7 (DI-COM) and 9 (DI2) short-circuited.

■ To limit output in synchronization with external signal
Connect terminals 7 (DI-COM) and 9 (DI2) to external signals.
If terminals 7 (DI-COM) and 9 (DI2) are open, the output continues to be limited.

8-10. Soft start time

The instrument can be adjusted to have the characteristic shown below at the rising edge of the control signal, or at the start of output when power is turned on.
The time until the output changes (to reach 90% from 0) with respect to the rising edge of the control signal (from 0 to 100%) can be adjusted in the range of about 1 to 30 seconds.

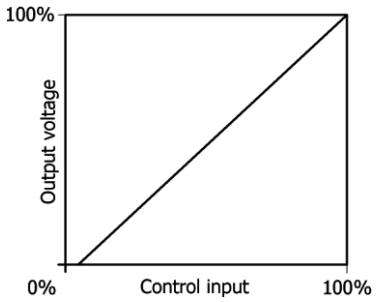


9. Control Mode and Output Limiting Function

This instrument has various (voltage, current, power, and voltage square) feedback control modes.
Feedback control functions to detect the output voltage or output current of the power regulator, and control it to an output value proportional to the control input.

As a result, the instrument can maintain a stable output with a little fluctuation even if the supply voltage or load resistance changes.
As for the output limiting function, current limiting and start-up time output limiting are available.
It should be noted that rectifier type measuring instruments, if used to measure the output voltage or output current of the instrument, cannot display a correct value.
Always use an effective value type measuring instrument.

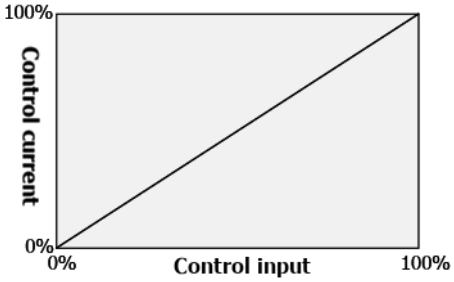
9-1. Phase control and voltage feedback



Voltage feedback control controls output so that the output voltage is proportional to the control input.
When the control input is constant, the output voltage is controlled to a constant level even if the load or power supply fluctuates.
For example, if the supply voltage is 200 V and the control input is 80%, the output voltage is controlled to 160 V.
As shown in the characteristic diagram on the right, voltage feedback has a characteristic that control input and output voltage work in a linear fashion.
Since output is controlled by a voltage controller, even if the primary voltage fluctuates, the secondary voltage fluctuates very little and is 2% or less of the fluctuation width of the primary side (that is, 0.2 V or less in comparison with the fluctuation 10 V on the primary side), which is appropriate for precision control.

Under voltage feedback control, the average of three phase load voltage is controlled.
It is not possible to individually control each phase voltage.

9-2. Phase control and current feedback



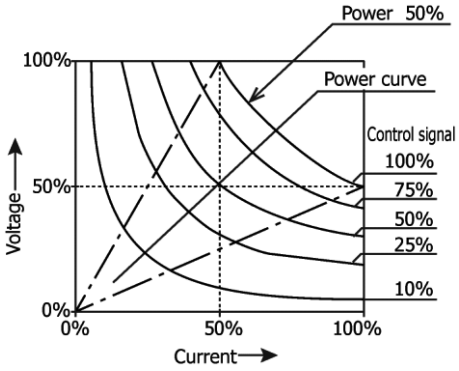
Current feedback control controls output so that the output current is proportional to the control input.
When the control input is constant, the output current is controlled to a constant level even if the load or power supply fluctuates.
For example, if the current capacity is 100 A and the control input is 80%, the output current is controlled to 80 A.
This control characteristic is based on an operation performed using the current setting value given by the control signal and the current signal received from a current transformer (built-in CT) and, assuming that control input is constant, current is controlled at a constant level even if the load and power fluctuate.
Accordingly, this control is suitable for controlling platinum, molybdenum, tungsten, Kanthal Super, and other heating elements.

With this constant current control, the instrument works effectively for the following heaters:

- ☐ Heaters in which rush current flows : Platinum, molybdenum, tungsten, and Kanthal Super
- ☐ Heaters in which current changes significantly : Carbon, salt bath
- ☐ Stability of electrolysis current : Plated

Under current feedback control, the average of three phase load current is controlled.
It is not possible to individually control each phase current.

9-3. Phase control and power feedback

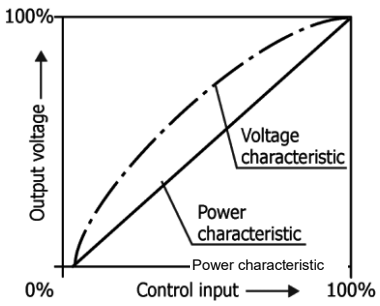


Power feedback control controls output so that the product of the output voltage and output current is proportional to the control input. When the control input is constant, the output power is controlled to a constant level even if the load or power supply fluctuates. For example, if the supply voltage is 200 V, the current capacity is 100 A, and the control input is 80%, the output power is controlled to the following value:

$\sqrt{3}$ x 200V x 100A / 2 x 0.80 ≒ 13.9 (kVA)

In this control mode, power is half of the thyristor rating.
As shown in the diagram on the right, this is represented by curves drawn between the points of 100% voltage x 50% current and 50% voltage x 100% current, which means that power at 50% of the thyristor rating is controlled.
In other words, even a thyristor with a rating of 200 V/100 A can control 17.3 kVA power.
Under power feedback control, the power consumption of load (Total power of three phase: $\sqrt{3}$ x Average of three phase load voltage values x Average of three phase load current values) is controlled. It is not possible to individually control each phase power.

9-4. Phase control and voltage square feedback



Voltage square feedback control controls output so that the square of output voltage is proportional to the control input. For loads with low temperature characteristics such as a nichrome heater, this improves the control efficiency because the control signal is proportional to the output power.

- ☐ The control signal and the output power have a linear relationship for improved control efficiency.
- ☐ In manual adjustment, the power in % can be adjusted according to the graduation of the regulator.
- ☐ Power equation

P = V x I
P = V x V/R ← Constant… (Explanation: P is proportional to V^2.)
$\therefore P \propto V^2$
[P: Power, V: Voltage, I: Current, R: Resistance]

Under voltage square feedback control, the square of the average of three phase load voltage values is controlled. It is not possible to individually control each phase.

10. Heater Break Alarm and Rapid Fuses

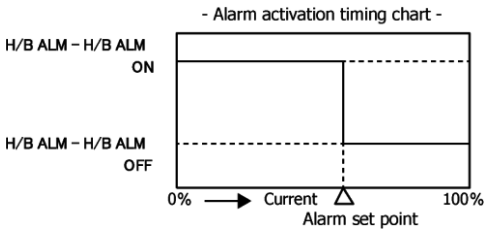
10-1. Heater break alarm

The instrument can be set to generate a heater break alarm by detecting a change in resistance value if it rises abnormally due a heater break or deterioration.
However, this alarm may not function normally for heaters whose resistance value changes due to a temperature rise.

Note 7: This function determines the presence of a heater break by calculating the approximate combined load resistance value between each phase. This means that it does not provide an accurate criterion for direct evaluation of a heater break or deterioration. Use it only as a guide.
Note 8: If a variable resistance heater is used, the function may not be able to determine the presence of heater breaks normally.

Specifications

- Setting range : 10% to 100% (However, accuracy is not guaranteed at 30% or below)
- Setting accuracy : Within ±5% (when set to 30% or above)
- Operation : Alarm signal output
- Output when alarm active : Control output is intact
- Resetting of alarm output : Reset when heater returns to normal
- Allowable range of voltage fluctuation : Within ±10%



10-1-1 Setting of heater break alarm

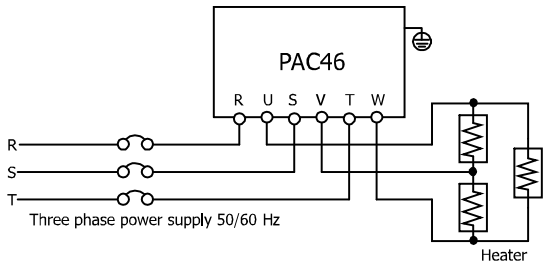
This alarm can be set between Min (10%) and Max (100%). The setting value is a value relative to the current capacity of the power regulator, not the insulated capacity.

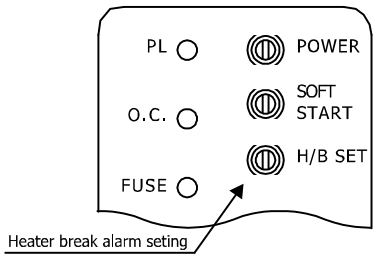
* Example of setting
To output an alarm when one heater breaks in a three phase circuit comprising three heaters:
Conditions:

Thyristor current capacity	20 A
Three phase heater rating	200 V 6 kW (17 A)
Number of heaters	3

Under normal conditions, a current of 17 A flows, which is about 85% of the rated capacity.
It should be noted that, if this alarm is set to 85% or above, a break alarm will be output even under normal conditions.

In a three phase circuit with delta connection, if a heater breaks, the phase current remains at a normal level in one phase, but drops to about 58% in other two phases. Consequently, the total current is reduced to 72% of the normal level.
Accordingly, set this alarm to about 70% to 75%, which is about the midpoint between the normal level (85% of rated value) and the abnormal level (85% of rated value x reduced current 72% = about 61%).
* It should be noted that, if the alarm is set to a value close to the normal level, the instrument tends to malfunction.





Note 9: Check alarm activation at as high output voltage as possible (near 100%).

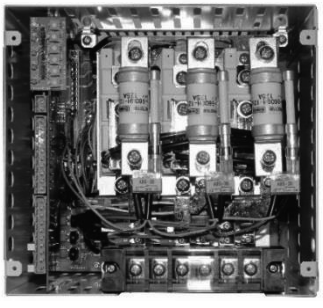
Note 10: If a heavy load that exceeds 100% of the rated load is connected, the alarm will not be activated even when the heater break alarm setting devise is set to the maximum value. In this case, remove a heater to create a heater break state and then check alarm activation.

10-1-2 Resetting (Recovering from alarm)

After output of a heater break alarm, the alarm output will be reset when the heater break state is resolved.
Similarly, even if the instrument is in a heater break state, the alarm output will be reset when the output drops to near 0%.

10-2. Rapid fuse (option)

Opening the cover reveals three fuses attached to the top, as shown in the picture on the right.
To find a blown fuse, check the alarm signal microswitch attached to one side of each fuse. If the switch is pressed on, the fuse has blown.
The number of fuses blown varies from 1 to 3 from time to time, depending on the condition of over-current.



10-3. Current capacity and fuse rating

Current capacity of PAC46	Rated load capacity (200 V to 240 V)	Rated load capacity (380 V to 440 V)	Capacity of attached fuse	Fuse type
20A	6.9 to 8.3 kVA	13.2 to 15.2 kVA	25 A	QSF018
30A	10.4 to 12.5 kVA	19.7 to 22.9 kVA	40 A	QSF009
50A	17.3 to 20.8 kVA	32.9 to 38.1 kVA	63 A	QSF016
75A	26.0 to 31.2 kVA	49.4 to 57.2 kVA	100A	QSF010
100A	34.6 to 41.6 kVA	65.8 to 76.2 kVA	125 A	QSF017
150A	52.0 to 62.4 kVA	98.7 to 114.3 kVA	200A	QSF019
200A	69.3 to 83.1 kVA	131.6 to 152.4 kVA	250 A	QSF012
300A	103.9 to 124.7 kVA	197.4 to 228.6 kVA	350 A	QSF013
500A	173.2 to 207.8 kVA	329.1 to 381.0 kVA	630 A	QSF021
600A	207.8 to 249.4 kVA	394.9 to 457.2 kVA	800 A	QSF022

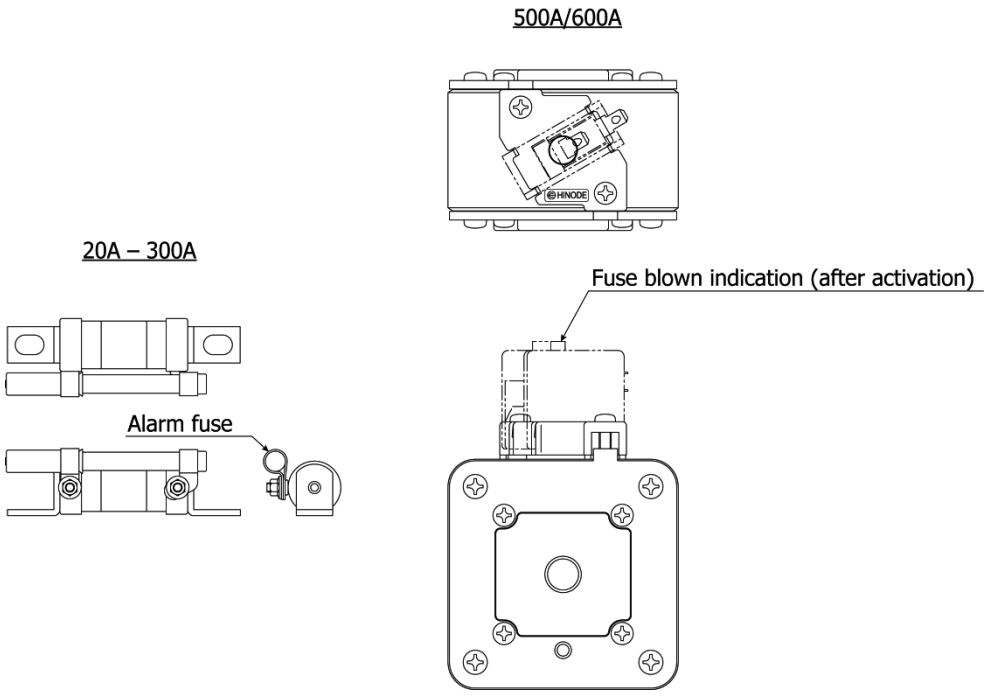
Note 11: The above rated load capacity values are calculated using the following equation: Rated load capacity (three phase) = √3 x Rated input voltage x Output current

10-4. Replacement of rapid fuse

- If a rapid fuse has blown, the monitor lamp (FUSE) lights up and an alarm signal is output.
- Check the load side to find the cause of the blown rapid fuse, and replace the blown fuse with a new one.
- The replacement rapid fuse should be of the same rating.
- Spare rapid fuses are not included in the instrument package. They are available from us or a fuse dealer.

Rapid fuse replacement procedure

1. Remove the front cover of the instrument. (For 500A and 600A: After removing the front cover, also remove the top cover.)
2. Remove the alarm signal microswitch from the blown rapid fuse.
   For 20A and 30A, the microswitch may not be removed unless you first remove the fuse body.
   Note 12: The microswitch is connected to the circuit board with leads and a connector. Care should be taken not to pull the leads or apply a load to the microswitch. Doing so may cause connector disconnection or damage.
3. Unscrew the fuse fastening screw, remove the blown fuse, and attach a new rapid fuse.
   (Tighten the screw firmly.)
   Note 13: If using a screwdriver, be careful not to allow it to hit the circuit board and other internal components.
4. Firmly insert the alarm signal microswitch into the rapid fuse. (Insert it all the way to the stopper.)
5. Install the front cover of the instrument. (For 500A and 600A: After installing the top cover, also install the front cover.)



* For the location of the front and top covers of 500A and 600A, refer to the external dimension drawings on page 7.

10-5. Heat generation

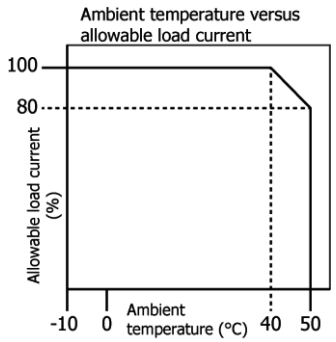
This instrument generates heat as shown in the following table. Temperature rise should be kept to a minimum through proper ventilation.
The heat values are measured at the rated current (100% of the current capacity). The lower the current value, the lower the heat value.

Internal heat value

Rated current (A) / Internal heat value (W)	20A	30A	50A	75A	100A	150A	200A	300A	500A	600A
Without rapid fuse	89	128	179	262	345	517	684	1057	1687	2020
With rapid fuse	97	140	201	297	391	581	775	1208	1847	2208

10-6. Ambient temperature and load current

The rated current of the instrument assumes that the ambient temperature is 50 °C or below.
In locations where the ambient temperature exceeds 40 °C, use the instrument with the load current reduced as shown in the figure.



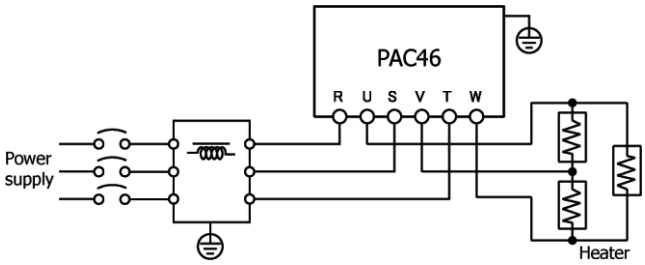
11. Countermeasures to Noise

Thyristors, particularly in phase control, cause power waveform distortion when the impedance of the power supply is high, since they use a partial sinusoidal waveform of the power supply.
In addition, thyristors cause switching noises because they switch the power supply every half cycle.
Such power supply distortion and noise may affect other equipment, so use noise filters as needed.

11-1. Noise filter (sold separately)

Ordinary commercial general-purpose noise filters do not have a sufficient noise attenuation effect on noise generated by thyristors, since the frequency of such noise is distributed in a low range, at a few megahertz (MHz) or below.
Instead, you can use the specified noise filters to attenuate noise.
These noise filters are intended exclusively for our thyristor power regulators.
For details, please contact our nearest sales office.

Current capacity of PAC46	Noise filter model
20A	NF3020C-SXJ
30A	NF3040C-SXK
50A	NF3050C-SXK
75A	NF3100C-SXK
100A	
150A	NF3150C-SXK
200A	NF3200C-SXK
300A	NF3300C-SXK
500A	NF3500C-SXK
600A	NF3600C-SXK



* Keep the wiring between the PAC46 and noise filters as short as possible, at 0.5 m or shorter.

* For wiring to the R, S, T, U, V, and W terminals and loads, use wires corresponding to the current capacity.

12. Notes on Using A Transformer

Purposes of using a transformer
1) To match a different heater voltage with the supply voltage
2) To insulate the heater circuit from the power supply
3) To improve the insulation to earth that decreases as in a vacuum device

12-1. Magnetic flux density of transformer

A transformer allows excess current to flow if magnetic saturation occurs in the iron core, which may cause damage to the instrument.
Since a transformer performs switching in every cycle when operating, its iron core tends to be subject to magnetic saturation under a heavy load.
Therefore, it is necessary to use a transformer with lower magnetic flux density than in ordinary transformers.

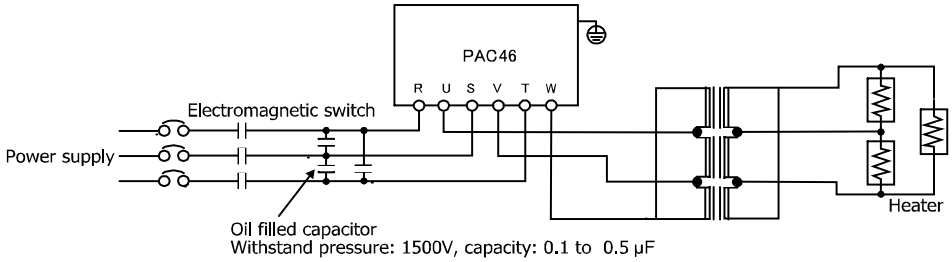
Example: To use an ordinary transformer with this instrument, we recommend using a load factor of 70% or below of the rated transformer capacity.
If the transformer is used on the load side (phase control) of the instrument, we recommended using as low a magnetic flux density as possible.

12-2. Use of isolation transformer

If the heater structurally tends to cause earth fault, and the withstand voltage to earth decreases as in a vacuum device, an isolation transformer should be used so that the thyristor and power source can be protected.

12-3. Note on use of electromagnetic switch

If an electromagnetic switch is used in a circuit connected to a transformer, noise may occur when the contact is opened or closed, which may cause a malfunction.
If such is the case, a capacitor should be connected on the power supply side of the instrument to absorb noise, as shown below.



12-4. Use of transformer with rapid fuse

To protect the thyristor element from excess current caused by high-frequency noise or a load problem, a transformer with rapid fuses should be used.

12-5. Prohibition of opening secondary side of transformer

If a load cannot be connected, for example, in a trial run, disconnect the transformer wiring and operate the instrument connected with a dummy load such as an electric heater or a light bulb so as not to open the secondary side of the transformer. Do not switch the load, either.

12-6. Dummy resistor

If the secondary side of the transformer is opened while the instrument is operating, not only the instrument, but also peripheral equipment may be damaged.
To prevent such damage, connect a dummy resistor between each phase on the primary side of the transformer.
The resistance value of the dummy resistors should be selected so that the load current between each phase is 0.5 A or above.
For example, if the supply voltage is 200 V, the resistance value should be 400 Ω.
As for the rated power of the resistors, allow for a margin of about three times the power consumption.
In addition, depending on the heating performance of the resistors, take measures such as installing a cooling fan.
It should be noted that dummy resistors generate heat and may cause burn injury.

13. External Equipment

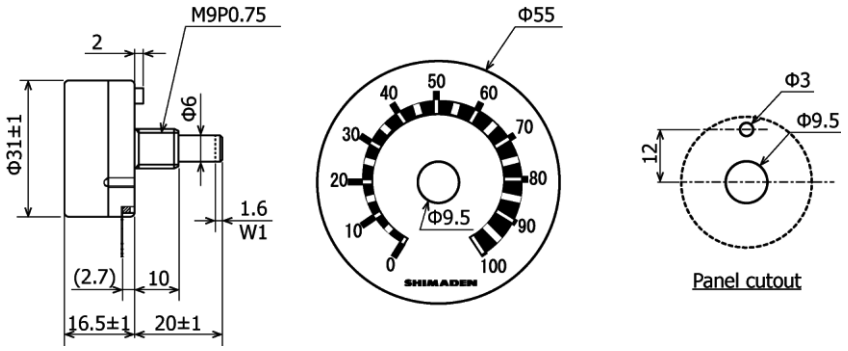
13-1. External power adjuster (sold separately)

- Model : QSV005/QSV006
- Specifications : Characteristic/resistance: B/10 kΩ
  : Lead: Vinyl lead 1 m included
  Wire end treatment: Half-stripped
  : Scale plate and knob, one each

·Name and graduation

External power	(QSV005)	0 to 100%
Manual power	(QSV005)	0 to 100%
Base power	(QSV005)	0 to 100%
High-low power	(QSV005)	0 to 100%
Current limit setting device	(QSV006)	50 to 100%

- External dimensions and mounting dimensions



14. Inspection

14-1. Inspection and remedial measures when alarm is generated

Monitor lamp	Alarm Indication	Inspection and Remedial Measures
Red PL lights.	Open phase/phase sequence abnormal/ frequency abnormal	Phase sequence of power supply is incorrect. Check wiring. Operation is normal when green lamp is lit.
O.C. lights.	Over-current alarm detected	Turn off power. Check and find cause of over-current and take appropriate measures. Then, resupply power. Over-current detection is not reset unless power supply to the instrument is turned off. If over-current occurs, never resupply power without checking and taking remedial measures on load side. Otherwise, thyristor element may be destroyed.
FUSE lights.	Rapid fuse blown	Check load side, find cause of blown fuse, and take remedial measures. Then, replace it with new rapid fuse. For the fuse replacement procedure, refer to 10-4 'Replacement of rapid fuse.'
H/B lights.	Heater break alarm	Check heater for heater break.
O.H. lights.	Internal temperature abnormal	Check instrument body for overheating. If current is 50 A or above, check fan for stoppage or slow rotation.

14-2. Troubleshooting

Symptom	Possible Cause	Remedy
Output is not produced.	Is voltage across power supply terminals (R, S, T) normal? Is alarm active? (Is Monitor lamp lit?) Is control input signal normal? Is internal power or external power setting normal?	Control board or thyristor element may have problem.
Output remains on.	Is control input signal normal? Is internal power or external power setting normal?	Control board or thyristor element may have problem.
Alarm is output frequently.	Is load short-circuited?	Check and repair load.
	Has load insulation failed?	Check and repair load.
	Is load capacity rating exceeded?	Replace the PAC46 with one having sufficient load capacity.
	Is phase sequence of power supply adjusted correctly?	Check power supply for phase sequence.
Output is out of balance.	Is voltage across power supply terminals (R, S, T) normal? Is phase sequence of power supply correct? Is one phase of load side broken?	Control board or thyristor element may have problem.

15. Specifications

■ Model	PAC46 Thyristor three phase power regulator				
■ Control Input and Ratings					
• Current input	: 4 to 20 mA DC/Receiving resistance: 100 Ω				
• Voltage input	: 1 to 5 V DC/Input resistance: About 300 kΩ or above 0 to 10 V DC/Input resistance: About 220 kΩ or above				
■ Supply Voltage and Ratings					
• 200 V type	: 200 to 240V AC ±10% 50/60Hz				
• 400 V type	380 to 440 V AC ±10% 50/60 Hz, TBD*				
■ Current Capacity	: 20A, 30A, 50A, 75A, 100A, 150A, 200A, 300A, 500A, 600A				
■ Control Mode	: Phase angle control				
■ Soft-start Function	: About 1 to 30 seconds, adjustable (time to reach 90% output from 0)				
■ Possible Loads	: Resistive load, inductive load (transformer primary side control)				
■ Minimum Load	: 20A:0.5A 30A:0.5A 50A:0.5A 75A:0.5A 100A: 1.0A 150A: 1.0A 200A: 2.0A 300A: 2.0A 500A: 2.0A 600A: 2.0A				
■ Output Voltage Control Range	: 0 to above 98% of input voltage				
■ Output Stability	: Input fluctuation ±2% or less when input fluctuation is ±10% (Output voltage 95% or less)				
■ Output Accuracy	: Output accuracy of various feedback controls Control output accuracy ±3.0%FS possible (Output within 10 to 90% range, average of three phases)				
■ Control Element Composition	: SCR x6, parallel/anti-parallel connection (six arms)				
■ Over-current Protection System					
• Electronic gate signal shutoff function	: About 110% of rated current (when crest factor is 2 or less)				
• Rapid fuse (option)	: About 117 to 133% of rated current				
■ Cooling System					
• Self-cooling system	: 20A, 30A				
• Forced air cooling system	: 50A to 600A				
■ Alarm Monitors					
• Over-current	: [O.C]	LED lights.	Continuity established between terminals (ALM-C) and (ALM-N.O.)	···	When over-current protection is active
• Rapid fuse blown	: [FUSE]	LED lights.	Continuity established between terminals (ALM-C) and (ALM-N.O.)	···	When rapid fuse is blown
• Internal temperature abnormal	: [O.H.]	LED lights.	Continuity established between terminals (ALM-C) and (ALM-N.O.)	···	When abnormal temperature is detected in radiator
• Heater break	: [H/B]	LED lights.	Continuity established between (H/B-ALM) terminals	···	When heater break alarm is active
• Output contact rating	: 240V AC 1A		Resistive load		
■ Power Lamp					
• When power supply is normal	: Green LED lights.				
• When open phase/phase sequence abnormal /frequency abnormal occurs	: Red LED lights. Open phase/phase sequence abnormal, abnormal frequency (when power supply frequency is about 44 Hz or below or about 65 Hz or above)				
■ Standard Functions					
• Control Mode	: Select one of the following: • Phase control and voltage feedback • Phase control and current feedback (Possible loads: Pure metal, Kanthal Super heater, and other heaters) • Phase control and power feedback (Possible loads: Silicon carbide, carbon, and other heaters) • Phase control and voltage square feedback (Possible loads: Nickel chrome and other heaters) • Communication function (Factory-set to voltage feedback control mode, Can be set to desired feedback mode via RS-485 communication) * Output increases at control input of 3% or above				
• Output adjustment function	: Internal power 0 to 100%				
• Digital control input (DI)	: Two-point input Non-voltage contact, or open-collector connection possible, 5 V 0.88 mA max. DI-1: Base power/manual power selection DI-2: Start-up time output limit time synchronization signal				
• Alarm output (ALM)	: One point (1C contact), 240 V AC 1 A, insulated from system Over-current, internal temperature abnormal				
• Heater break alarm function	: Heater break detection and H/B alarm output (H/B ALM) Setting range 10 to 100% (Accuracy is not guaranteed at less than 30%) Accuracy Within ±5% (When set to 30% or above)				

■ Additional Functions (option)

- Output limiting function
  - Current limit : 50 to 100% of rated current (External current limit setting device VR3)
  - Start-up time output limit : 0 to 60% output for 1 to 60 seconds
- Output adjustment function
  - * When combined with voltage/current output type controller
    - : External power 0 to 100% (at 100% input)
    - Manual power 0 to 100%
    - Base power 0 to 100% (at 0% input)
    - External power + Manual power 0 to 100%
    - External power + Base power 0 to 100%
  - * When combined with contact output type controller
    - : External power 0 to 100% (when contact is on)
    - High-low power 0 to 100%
- Rapid fuse : Alarm output (ALM) when fuse is blown
- Automatic power adjustment function : 25 to 100%, not insulated from control input
- Communication (When communication function is selected in control mode) : RS-485 specification, insulated from system
  - Communication protocol : Modbus RTU
  - Communication speed : 9600 or 19200 bps selectable
  - Parity : EVEN, NON, or ODD selectable
  - Stop bit : 1 bit
  - Parameters that can be read : Control mode, output voltage value*/current value*/power value*, heater resistance value*, phase-to-phase output voltage values, phase-to-phase output current values, alarm status, control signal input value, trimer adjustment values, VR input values, DI input values, control input scale lower limit value, automatic power control input value (when corresponding option is added)
    * Average value in each phase
  - Parameters that can be set : Control mode, control signal input value, trimer adjustment values, VR input values, DI input values, control input scale lower limit value, automatic power control input value (when corresponding option is added)

Refer to the separate PAC46 SERIES COMMUNICATION INTERFACE INSTRUCTION MANUAL.

■ Operating Environment

- Ambient temperature range : -10 to 50°C (Current reduction required at 40°C or above)
- Ambient humidity range : 90%RH or below, no condensation allowed

■ Insulation Resistance : Between power supply terminal and earth terminal 500V DC, 20 MΩ or higher
Between power supply terminal and control input terminal 500V DC, 20 MΩ or higher

■ Withstand voltage : Between power supply terminal and earth terminal 200 to 240 V: 2000 VAC, 1 min; 380 to 440 V: 2500 VAC, 1 min
: Between power supply terminal and control input terminal 200 to 240 V: 2000 VAC, 1 min; 380 to 440 V: 2500 VAC, 1 min

■ Power consumption :

	• 200 to 240 V	• 380 to 440 V
20A,30 A	: 18 VA max. (at 200 V)	: 11 VA max.(at 380 V)
50A, 75A, 100A	: 33 VA max. (at 200 V)	: 22 VA max.(at 380 V)
150A, 200A, 300A	: 40 VA max. (at 200 V)	: 30 VA max.(at 380 V)
500A, 600A	: 80 VA max. (at 200 V)	: 55 VA max.(at 380 V)

■ Material /Finish : Ordinary steel plate/paint coating (equivalent to Munsell N8.5)

■ External Dimensions : See external dimension drawings.

■ Weight :

	• 200 to 240 V	• 380 to 440 V
20A, 30A	: Approx. 5.0 kg	: Approx. 7.5 kg
50A, 75A, 100A	: Approx. 6.0 kg	: Approx. 10.0 kg
150A, 200A, 300A	: Approx. 15.0 kg	: Approx. 20.0 kg
500A, 600A	: Approx. 42.0 kg	: Approx. 50.0 kg

Temperature and Humidity Control Specialists

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Printed in Japan