Power Factor Controllers
Automatic power factor regulators QC06E and QC12E

Automatic power factor regulator QC06E, QC12E

■ Description

Automatic power factor regulator (APFR) is a device which is designed to maintain the target power factor by regulating lagging or leading current. The APFR is designed to monitor the reactive power within the circuit continuously and to provide ON/OFF signals automatically to control circuit breakers in a capacitor bank. In an electrical network such as an industrial plant using induction motors which produce reactive power, the power factor will drop. This will cause a power loss, a line voltage drop and other disadvantages. In conventional electrical systems the efficiency of transmission and distribution equipment is improved by installing fixed capacitors across the line. However, an over-compensation may arise when there is a light load, such as at night, which would result in an increase in line voltage and excess current. The APFR supervises the power factor in the system, and controls the power factors by switching capacitors ON or OFF as the situation requires in the face of a reactive leading or lagging load.

Low power loss

Correcting the power factor with a power capacitor reduces the line current. This also reduces the power loss caused by the resistances of the power cables and transformer windings.

Effective use of power receiving facility

Correcting the power factor with a power capacitor reduces the line current. Since this produces margins in the transformer capacity and the current-carrying capacity of cables, a heavier load can be carried without adding more facilities.

Stable supply voltage for long equipment service life

A reactive power, especially a leading reactive power at a light load (at night), often produces an overvoltage and shortens the service life of lamps. Use an automatic power factor regulator to suppress a voltage decrease at a heavy load and a voltage increase at a light load.

Laborsaving unmanned operations

This regulator outputs capacitor connection and disconnection commands automatically to maintain an optimum power factor. The simple setup for this output saves labor applied to power factor correction.

■ Features

- **Compact (DIN size) and lightweight**

The DIN-size compact unit permits easy mounting hole on the panel and enhances work efficiency.
The 6-bank and 12-bank models have front panels of the same size (144mm × 144mm). Since in the panel cutout hole sizes are also the same (138mm × 138mm), it is possible to use panel cutout holes of one uniform size.

QC06E

- **220V and 440V power supplies**

The regulator can be connected to a 220V or 440V power supply. Set the voltage input switch on the front panel to the control power supply voltage being used.
Connect control power cables to the correct terminals of the terminal block in accordance with the control power supply voltage being used.

- **Automatic setting of control level by microcomputer**

The mode and data are set simply by using four keys. The microcomputer automatically sets the levels at which capacitors should be connected or disconnected.

- **Three types of capacitor connection and disconnection control by purpose**

1. Cyclic control or optimum control (automatic selection)

Under cyclic control, capacitors of the same capacitance are connected and disconnected in ascending order of capacitor number.
Under optimum control to keep the number of connections and disconnections minimal, a capacitance change is calculated from the measured reactive power and the target power factor and a capacitor of the nearest capacitance is connected or disconnected.
Either control is selected in accordance with the set capacitor capacitance.

2. Unconditional cyclic control

Capacitors are controlled cyclically, irrespective of their capacitances.

3. Multistep control

Capacitors having capacitances incremented in multiples of two (e.g. 1:2:2:2:2:2:, 1:2:4:4:4:4, and 1:2:4:8:8:8) are simultaneously connected or disconnected to optimize the capacitance with a minimal number of steps.

• Useful functions

1. Polarity error diagnosis function
If a polarity error in wiring is detected, the regulator lights the alarm lamp and sounds the buzzer to indicate the miswiring.

2. Forced disconnection function
To protect capacitors from being damaged or reactors from being burnt by excessive harmonics, or to disconnect capacitors unconditionally at night, external time switch signals can be input to the regulator. The signals automatically disconnect the connected capacitors in proper order.

• Automatic capacitor disconnection at light load
When the load of a power line decreases at night, the connected capacitors may increase the leading reactive power and cause an overvoltage.
A voltage increase on the power receiving side will shorten the service life of lamps and other load equipment.
To prevent an excessive leading power factor at a light load, the regulator automatically disconnects capacitors.

QC06E

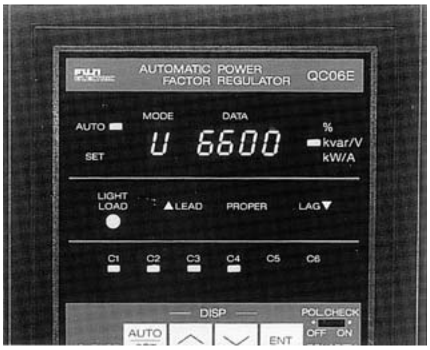
• Abundant regulator status information display

Power factor

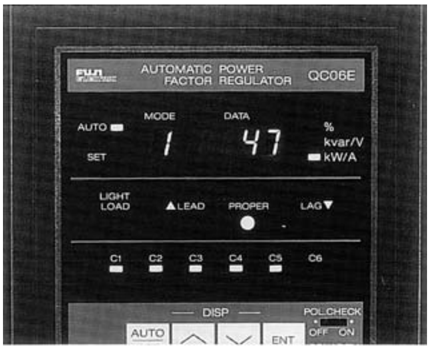
Reactive power

Active power

Voltage



Current



Power Factor Controllers

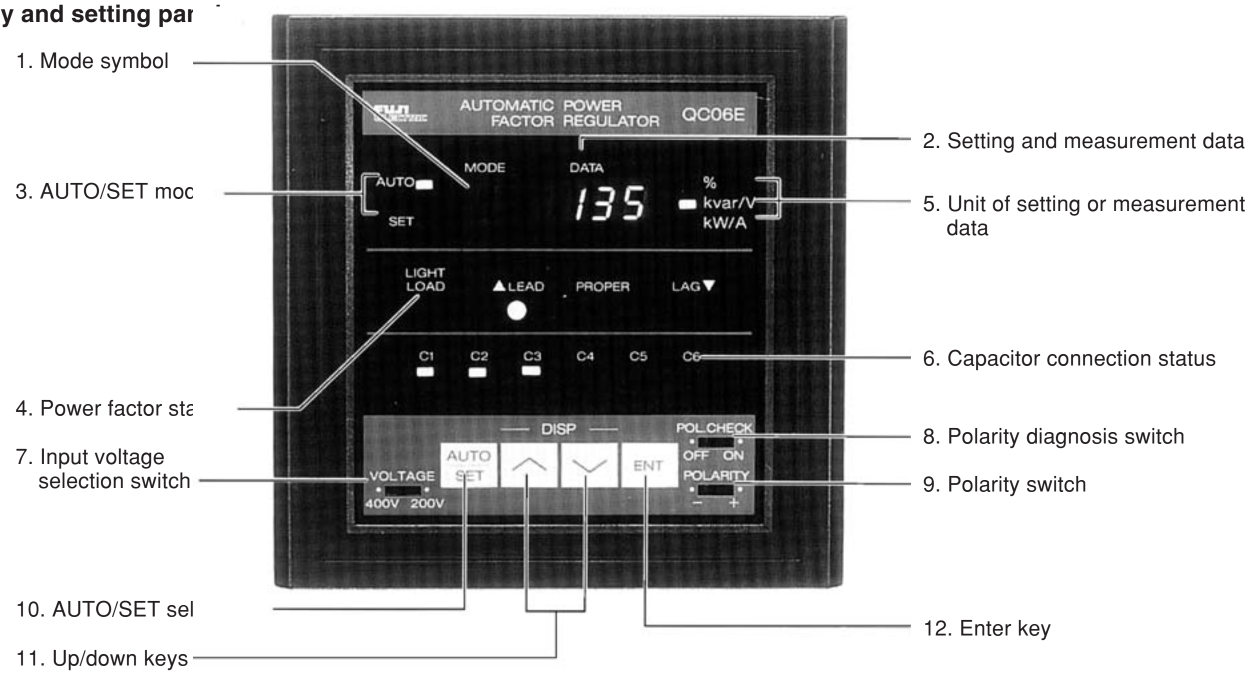
Automatic power factor regulators QC06E and QC12E

■ Specifications

Item		Specification	
		QC06E	**QC12E**
Voltage input	Frequency	50/60Hz	
	Rated voltage	200 – 220V/400 – 440V selectable	
	Allowable voltage fluctuation range	170 – 264V at 220V 323 – 528V at 440V	
	Power consumption	13VA at 220V, 13VA at 440V	15VA at 220V, 15VA at 440V
Current input	Frequency	50/60Hz	
	Rated current	5A	
	Power consumption	1VA	
Reactive power control range	Connection control level (kvar)	Automatic setting in accordance with the target power factor	
	Disconnection control level (kvar)	Already-connected minimum capacitor capacitance × 1.2 – connection control level (When the calculation result becomes negative, the disconnection control level is automatically set to 0).	
	Correct control range (kvar)	Already-connected minimum capacitor capacitance × 1.2 (Automatic setting)	
	Control error	±0.05 (kvar) × CT ratio (at 220V input)	
Light-load disconnection control value		When the active power level falls below the numeric-input minimum load, the capacitor are disconnected successively from the capacitor banks in descending order of capacitance at disconnecting time intervals. When the minimum load is set to 0, however, no capacitors are disconnected even when the active power level falls below the numeric-input minimum load. [Control error: ±0.05 (kvar) × CT ratio] (at 220V input)	
Capacitor control output	No. of connectable banks	6-circuit (NO contact common on one side)	12-circuit (NO contact common on one side)
	Applicable minimum load	1V DC, 1mA	
	On/Off switching capacity	250V AC, 5A 30V DC, 5A 100V DC, 0.5A	
	Electrical life expectancy	Approx. 100.000 operations at 220V AC, 2A inductive load	
Output control system		A1: Cyclic/optimum control, selectable automatically A2: Uncondentional cyclic control A3: Multistep control, 1:2:2:2:2:2------ A4: Multistep control, 1:2:4:4:4:4------ A5: Multistep control, 1:2:4:8:8:8------ (Control modes A3 to A5 are effective for C1 only 0 to 9999)	
Setting item		1. Bank capacitor capacitance C1 to C6 (0kvar *) (Modes 1 to 6) Output control system A3 to A5 are available only for bank C1.	Bank capacitor capacitance C1 to C12 (0kvar *) (Modes 1 to 9, o, b, c) Output control system A3 to A5 are available only for bank C1.
		2. Target power factor $\cos\theta = 98\%$* Mode F (85 to 100) 3. CT ratio 0* Mode C (1 to 1200) 4. Control mode 1* Mode A (1 to 5) 5. Minimum load 0kW* Mode L (0 to 9999) 6. Delay time 300 sec.* Mode d (30, 60, 120, 300, 600)	
Display	Digital display	Current power factor (%), reactive power (kvar) (no mode symbol: leading, –: lagging), active power (kW), primary voltage (V) and primary current (A) on 7-segment LED panel.	
	Display error: 0.5A or less at CT input Power factor lead (+60%) to lag (–60%)	Power factor: ±5% or less, Reactive/active power: ±0.05kvar/kW × CT ratio or less (at 220V input) Primary current: ±0.1A × CT ratio or less	
	Control status display (LED)	Light load: Active power equal to or lower than the light-load disconnection control level Lagging, leading, optimum: Reactive power lagging, leading, or optimum in the control range	
	Control output display (LED)	Lit: Control output ON, Unlit: Control output OFF	
Operating ambient temperature		–10 to +55°C	
Dielectric strength		2500V AC 1 minute (between all terminals and E terminal)	
Outline dimensions (mm)		Height: 144, Width: 144, Depth: 114.5	Height: 144, Width: 144, Depth: 140
Mass (kg)		Approx. 1.5	Approx. 1.8

Note: * Value at shipment

■ Display and setting par



1. Mode symbol
Displays the set mode (mode symbol) or the kind of measurement data.

2. Setting and measurement data
• Data setting mode
The digital LED display displays the following setting data:

Mode symbol	Setting item	Setting data	Setup at shipment
1 to 9	Capacitance of capacitor C1 to C9 *6	0 to 9999kvar *1	0
o, b, c	Capacitance of capacitor C10, C11, C12 *6	0 to 9999kvar *1	0
A	Capacitor control system	1 to 5 *2	1
C	CT ratio	1 to 1200 *3	0
F	Target power factor	85 to 100%	98
L	Disconnection at light load	0 to 9999kW *4	0
d	Delay time	30, 60, 120, 300, or 600s *5	300

Notes:
*1 When the capacitance is set to 0 or 9999, the control output contact goes ON for 0 or OFF for 9999 during automatic operation.

*2 See the table at right for the meanings of the capacitor control system numbers.

*3 The CT ratio is set to 0 when the regulator is shipped from the factory. Set this value to accommodate the use requirements. The regulator does not operate automatically when the set value is 0 or 1201 or greater.

*4 When the set value is 0, the light-load disconnection function is not activated. To disconnect capacitors when the load becomes light, set the minimum capacitor capacitance.

*5 Select an optimum delay time for the capacitor discharging unit. (Set "300" or "600" if a discharging resistor is used.)

*6 The mode symbols are 1 to 6 (C1 to C6) for type QC06E and 1 to 9, o, b, and c (C1 to C12) for type QC12E.

• Auto operation mode
When the Up (∧) and Down (∨) keys are pressed at the same time, the LED display displays measurement data in the following order:

Model symbol	Display item	Measurement data display
(–) *7	Power factor	–0 to 100 to 0%
(–) *7	Reactive power	–9999 to 0 to 9999kvar *8
A	Active power	0 to 9999kW *8
U	Primary voltage	0 to 9999V *8
I	Primary current	0 to 6000 (5X1200)A
	No display	—

Notes:
*7 No mode symbol is displayed for a lead; a negative sign (–) is displayed for a lag.

*8 The LED display always displays "9999" for any value greater than 9999.

Capacitor control system

Set value	Description
1	Cyclic/optimum control
2	Unconditional cyclic control
3	Multistep control (capacitance ratio: 1:2:2:2:2:2:2:2:2:2:2:2)
4	Multistep control (capacitance ratio: 1:2:4:4:4:4:4:4:4:4:4:4)
5	Multistep control (capacitance ratio: 1:2:4:8:8:8:8:8:8:8:8:8)

3. AUTO/SET mode
The green lamp lights in the auto operation mode and the red one in the data setting mode.

4. Power factor status
Light load: The yellow lamp lights when the active power of the circuit is equal to or lower than the set level for light-load disconnection.
△ Lead:
The red lamp lights when the reactive power of the circuit is leading, compared to the set level for disconnection.
Acceptable:
The green lamp lights when the reactive power of the circuit is within the optimum control range.
Lag ▽:
The red lamp lights when the reactive power of the circuit is lagging, compared to the set level for connection.

5. Unit of setting or measurement data
A green lamp lights at %, kvar, kW, V, or A.

6. Capacitor connection status
The red lamps light at the capacitors for which the capacitor control output contacts are ON (make) and go out at the capacitors for which the contacts are OFF (break).

7. Input voltage selection switch
Set this switch to “200V” for 200/220V input power or “400” for 400/440V input power.

8. Polarity diagnosis switch
The polarity switch must initially be toggled to “+”. Toggle the polarity diagnosis switch to the right to check the voltage or current input polarity. If the polarity is incorrect, “E□□□3” is displayed and the buzzer sounds.

9. Polarity switch
If the voltage or current input polarity is incorrect, toggle this switch to “–” and press the enter key to clear the error display and stop the buzzer. The regulator then operates normally because the input polarity is handled as being reversed.

10. AUTO/SET select key
Press this key to select the auto operation or data setting mode.

11. Up/down keys
Use these keys to select a data setting mode.
Use these keys to increment (+1) or decrement (–1) a numeric value in each setting mode.

12. Enter key
After selecting a data setting mode, start numeric input. The numeric display changes from being continuously lit to blinking.
Press this key to confirm a set value in each data setting mode. The value is stored in the internal memory and the numeric display changes from blinking to being continuously lit.

Press two keys of the four keys, (AUTO SET ∨ ∧ and ENT), at the same time for the following operation or display:

● Data setting mode

∧ ∨

Clears the set value to 0. (This key operation is effective only when the mode symbol is 1 to 9, o, b, c, C, or L and the numeric display is blinking.)

∧ ∨

Resets the set value to the shipping setup. (This key operation is effective only when the mode symbol is 1 to 9, o, b, c, C, or L and the numeric display is blinking.)
(Keep the keys depressed for five seconds or longer.)

● Auto operation mode

∧ ∨

Changes the measurement data display. (Each time the keys are pressed, the display changes in the following order: power factor, reactive power, active power, primary voltage, primary current, and no display. The initial display at power-on is always power factor data.

∧ ENT

Tests a capacitor connection. (Press the keys at the same time for reactive power lag display. Keep the keys depressed to connect the capacitors in the specified order.)

∨ ENT

Tests a capacitor disconnection. (Press the keys at the same time for reactive power lead display. Keep the keys depressed to disconnect the capacitors in the specified order.)

■ Type number nomenclature and ordering code

JD006 – E

Series
E: E series

No. of connectable banks
JD006: QC06, 6 circuits
JD012: QC12, 12 circuits

■ Ordering information

Specify the following:
1. Type number or ordering code
2. Input voltage and current
3. Operating voltage
4. Number of connectable capactor banks

■ Operation of automatic power factor regulator

• Cyclic control

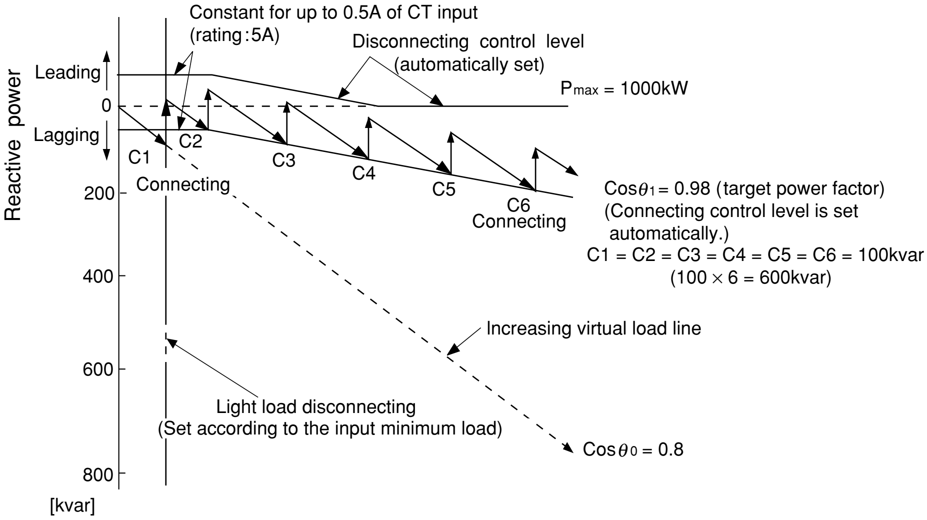
Under cyclic control/optimum control, the regulator connects and disconnects capacitors of the same capacitance cyclically.
Under unconditional cyclic control, the regulator connects and disconnects capacitors of different capacitances cyclically, irrespective of the set capacitance.

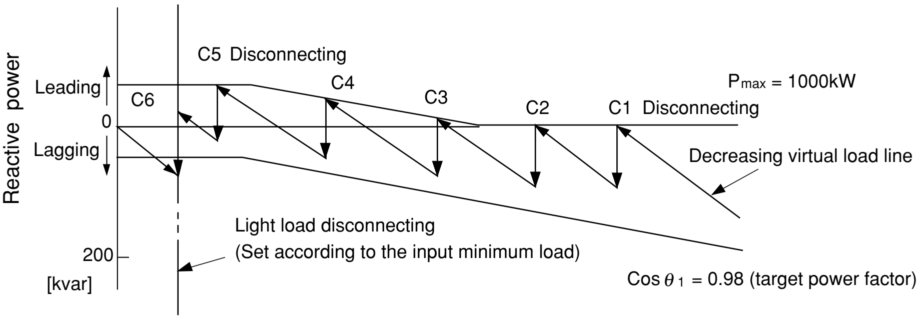
1. Capacitor connection

When the reactive power exceeds the level at which more capacitors should be connected, the red lag lamp lights. If the red lamp remains lit for the set delay time or longer, the corresponding capacitor control output goes ON and the red lamp for the capacitor bank lights.
When the reactive power of the circuit is still over the connection control level and the red lag lamp remains lit, the capacitor control output for the next capacitor goes ON after the delay time. The capacitor control outputs go ON one by one at the delay time intervals until the reactive power level of the circuit falls within the allowable range.

2. Capacitor disconnection

The red lead lamp lights when the circuit load decreases and the connected capacitors increase the leading reactive power of the circuit beyond the level at which a capacitor should be disconnected. When the red lead lamp remains lit for the set delay time or longer, the corresponding capacitor control output goes OFF and the red lamp for the capacitor bank goes OFF.
The capacitors are disconnected in the order of their connection.
The capacitor control output for each capacitor is turned OFF at every delay time interval until the reactive power level falls within the allowable range.





Output operation by the connecting or disconnecting control signals for capacitors

Leading △								○	○	○	○				○		○	○		○	
Acceptable	○																				
Lagging ▽		○	○	○	○	○	○					○	○	○		○			○		○
C1		○ ON	○	○	○	○	○	OFF				○ ON	○	○	○	○	○	OFF			
C2			○ ON	○	○	○	○	○	OFF				○ ON	○	○	○	○	○	○	OFF	
C3				○ ON	○	○	○	○	○	OFF				○ ON	○	○	○	○	○	○	○
C4					○ ON	○	○	○	○	○	OFF					○ ON	○	○	○	○	○
C5						○ ON	○	○	○	○	○	○	○	○	OFF				○ ON	○	○
C6							○ ON	○	○	○	○	○	○	○	○	○	OFF				○ ON

○ : Shows that indicators are lit.

• Optimum control

Under optimum control, the regulator connects or disconnects the capacitor with the capacitance closest to the change of reactive power among capacitors of different capacitances. If there are two or more capacitors of the same capacitance, the regulator connects or disconnects the capacitors cyclically for optimum control (the number of switchings) match.

1. Capacitor connection

The red lag lamp lights when the reactive power level exceeds the level at which more capacitors should be connected. The regulator calculates the difference between the current reactive power and the level at which more capacitors should be connected, and integrates the calculated value for the set delay time. The average value per unit time is calculated from the integrated total and a capacitor having the capacitance closest to the average value is selected. The capacitor control output for the capacitor is turned ON and the red lamp of the capacitor bank lights.
The regulator continues integrating and averaging the differences between the current reactive power level and the level at which more capacitors should be connected, and selecting optimum capacitors. The capacitor control output is turned ON repeatedly until the reactive power of the circuit falls within the allowable range.

Figure 1 shows an example of a capacitor connection control with a load variation pattern.

2. Capacitor disconnection

When the circuit load decreases, the already-connected capacitors increase the leading reactive power level. If the reactive power level exceeds the level at which capacitors should be disconnected, the red lead lamp lights. The regulator calculates the difference between the current reactive power level and the level at which capacitors should be disconnected, and integrates the calculated value for the set delay time. The average value per unit time is calculated from the integrated total and a capacitor having the capacitance closest to the average value is selected. The capacitor control output for the capacitor is turned OFF and the red lamp of the capacitor bank goes OFF.
The regulator continues integrating and averaging the differences between the current reactive power level and the level at which capacitors should be disconnected, and selecting optimum capacitors. The capacitor control output is turned OFF repeatedly until the reactive power level of the circuit falls within the allowable range.
Figure 2 shows an example of capacitor disconnection control with a load variation pattern.

Fig. 1

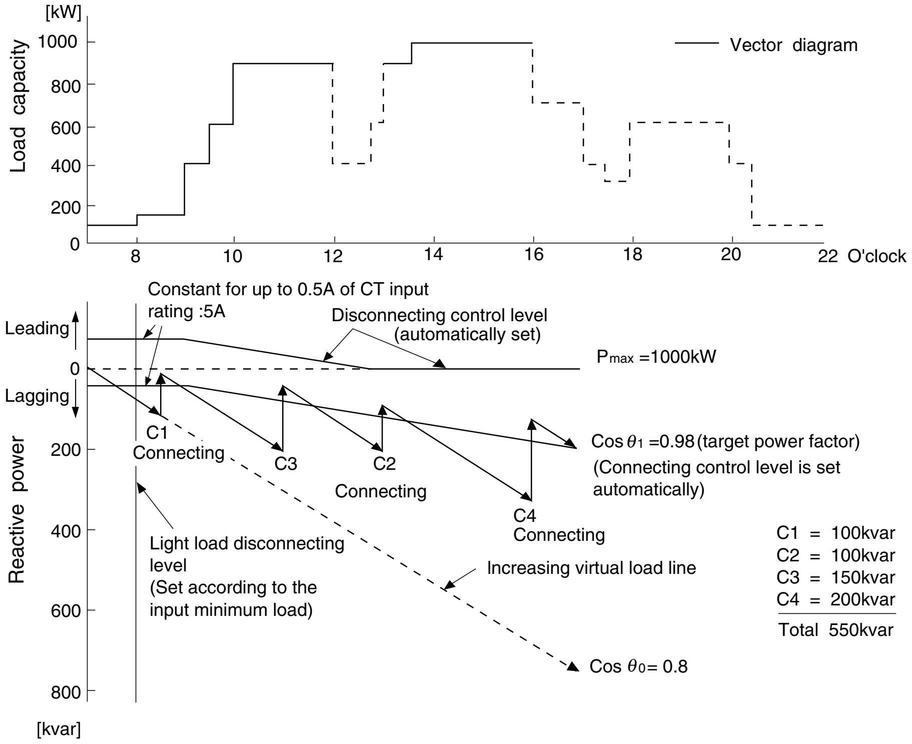
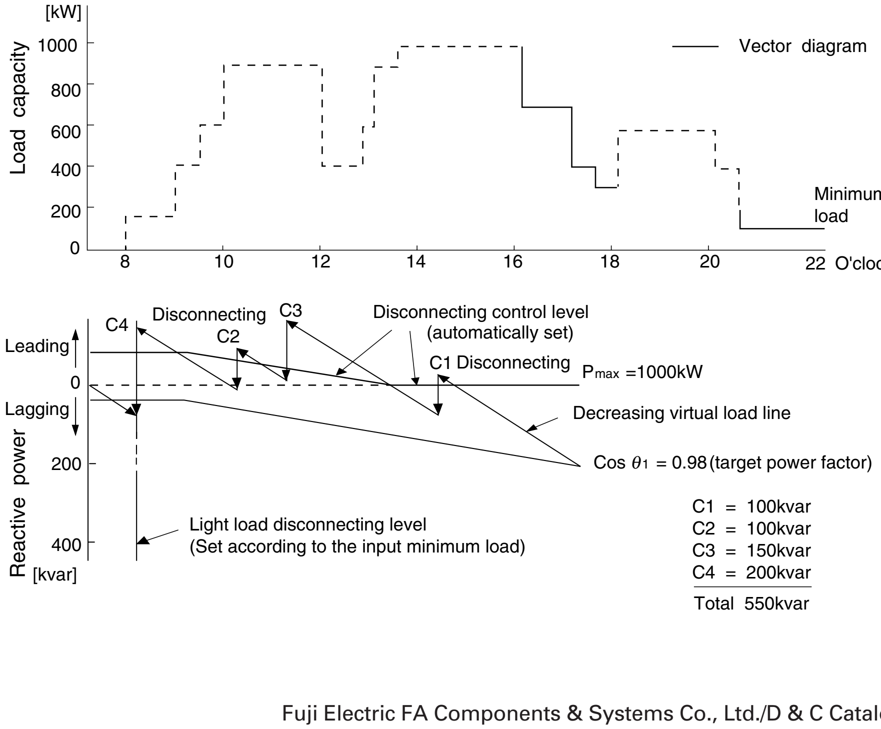


Fig. 2



• Multistep control (step-by-step control)
Under multistep control, the regulator connects or disconnects in units of the minimum capacitance set at C1 in accordance with the changes of the reactive power to approximate the power factor to the target value.
The power factor at a light load can be controlled in the same way.

1. Capacitor connection

When the reactive power level exceeds the level at which more capacitors should be connected, the red lag lamp lights. If the red lamp remains lit for the set delay time or longer, the capacitor control outputs for the next step go ON or OFF and the red lamps of the capacitors light or go OFF. If the reactive power level of the circuit is still over the level at which more capacitors should be connected and the red lag lamp remains lit, the capacitor control outputs for the next capacitor go ON or OFF after the set delay time.
The capacitor control output is turned ON or OFF sequentially at the delay time intervals until the reactive power level of the circuit falls within the allowable range.

2. Capacitor disconnection

The red lead lamp lights when the load decreases and the connected capacitors increase the leading reactive power level of the circuit beyond the level at which capacitors should be disconnected. When the red lamp remains lit for the set delay time or longer, the capacitor control outputs for the next step go OFF or ON and the red lamps of the capacitor banks go OFF or light.
The capacitor control output is turned OFF or ON sequentially at the delay time intervals until the reactive power level of the circuit falls within the allowable range.

**Capacitor connection and disconnection signal output operation
Signal output in multistep control mode/QC06E**

Example 1

Lag/Lead	Step	C1=10kvar C2=20kvar C3=20kvar C4=20kvar C5=20kvar C6=20kvar Control system [3] Capacitance ratio C1:C2:C3:C4:C5:C6=1:2:2:2:2:2							Lag/Lead	C1=10kvar C2=20kvar C3=20kvar C4=20kvar C5=20kvar C6=20kvar Control system [3] Capacitance ratio C1:C2:C3:C4:C5:C6=1:2:2:2:2:2						
		C1	C2	C3	C4	C5	C6	Total capacitance		C1	C2	C3	C4	C5	C6	Total capacitance
Lag ▽	1	○						10kvar	Lead △	○	○	○	○	○	○	110kvar
	2		○					20			○	○	○	○	○	100
	3	○	○					30		○		○	○	○	○	90
	4		○	○				40				○	○	○	○	80
	5	○	○	○				50		○			○	○	○	70
	6		○	○	○			60					○	○	○	60
	7	○	○	○	○			70		○				○	○	50
	8		○	○	○	○		80						○	○	40
	9	○	○	○	○	○		90		○					○	30
	10		○	○	○	○	○	100							○	20
	11	○	○	○	○	○	○	110		○						10

Example 2

Lag/Lead	Step	C1=10kvar C2=20kvar C3=40kvar C4=40kvar C5=40kvar C6=40kvar Control system [4] Capacitance ratio C1:C2:C3:C4:C5:C6=1:2:4:4:4:4							Lag/Lead	C1=10kvar C2=20kvar C3=40kvar C4=40kvar C5=40kvar C6=40kvar Control system [4] Capacitance ratio C1:C2:C3:C4:C5:C6=1:2:4:4:4:4						
		C1	C2	C3	C4	C5	C6	Total capacitance		C1	C2	C3	C4	C5	C6	Total capacitance
Lag ▽	1	○						10kvar	Lead △	○	○	○	○	○	○	190kvar
	2		○					20			○	○	○	○	○	180
	3	○	○					30		○		○	○	○	○	170
	4			○				40				○	○	○	○	160
	5	○		○				50		○	○		○	○	○	150
	6		○	○				60			○		○	○	○	140
	7	○	○	○				70		○			○	○	○	130
	8			○	○			80					○	○	○	120
	9	○		○	○			90		○	○			○	○	110
	10		○	○	○			100			○			○	○	100
	11	○	○	○	○			110		○				○	○	90
	12			○	○	○		120						○	○	80
	13	○		○	○	○		130		○	○				○	70
	14		○	○	○	○		140			○				○	60
	15	○	○	○	○	○		150		○					○	50
	16			○	○	○	○	160							○	40
	17	○		○	○	○	○	170		○	○					30
	18		○	○	○	○	○	180			○					20
	19	○	○	○	○	○	○	190		○						10

Automatic power factor regulators
QC06E and QC12E

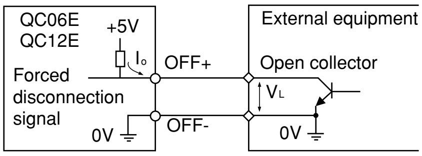
Example 3

Lag/Lead	Step	C1=10kvar C2=20kvar C3=40kvar C4=80kvar C5=80kvar C6=80kvar Control system [5] Capacitance ratio C1:C2:C3:C4:C5:C6=1:2:4:8:8:8							Lag/Lead	C1=10kvar C2=20kvar C3=40kvar C4=80kvar C5=80kvar C6=80kvar Control system [5] Capacitance ratio C1:C2:C3:C4:C5:C6=1:2:4:8:8:8						
		C1	C2	C3	C4	C5	C6	Total capacitance		C1	C2	C3	C4	C5	C6	Total capacitance
Lag ▽	1	○						10kvar	Lead △	○	○	○	○	○	○	310kvar
	2		○					20			○	○	○	○	○	300
	3	○	○					30		○		○	○	○	○	290
	4			○				40				○	○	○	○	280
	5	○		○				50		○	○		○	○	○	270
	6		○	○				60			○		○	○	○	260
	7	○	○	○				70		○			○	○	○	250
	8				○			80					○	○	○	240
	9	○			○			90		○	○	○		○	○	230
	10		○		○			100			○	○		○	○	220
	11	○	○		○			110		○		○		○	○	210
	12			○	○			120				○		○	○	200
	13	○		○	○			130		○	○			○	○	190
	14		○	○	○			140			○			○	○	180
	15	○	○	○	○			150		○				○	○	170
	16				○	○		160						○	○	160
	17	○			○	○		170		○	○	○			○	150
	18		○		○	○		180			○	○			○	140
	19	○	○		○	○		190		○		○			○	130
	20			○	○	○		200				○			○	120
	21	○		○	○	○		210		○	○				○	110
	22		○	○	○	○		220			○				○	100
	23	○	○	○	○	○		230		○					○	90
	24				○	○	○	240							○	80
	25	○			○	○	○	250		○	○	○				70
	26		○		○	○	○	260			○	○				60
	27	○	○		○	○	○	270		○		○				50
	28			○	○	○	○	280				○				40
	29	○		○	○	○	○	290		○	○					30
	30		○	○	○	○	○	300			○					20
	31	○	○	○	○	○	○	310		○						10

■ Terminals

Used for	Terminal symbol	Terminal name	Description
Input	P2 (at 220V) P3	Voltage input (220V)	Connect this terminal directly to a 220V power line. Note: The current for the internal control power supply flows between terminal P2 and P3.
	P2 (at 440V) P3	Voltage input (440V)	Connect this terminal directly to a 440V power line. Note: The current for the internal control power supply flows between terminal P2 and P3.
	1S, 1L	Current input	Connect these terminals to the secondary side of a CT.
	E	Ground	Grounding resistance: 100Ω or less
Contact output	COM	Capacitor control output common	Connect the common cable for capacitor connection and disconnection signals. Be sure to connect the upper and middle COM terminals (QC12E)
	C 1 to C12	Control output terminal for C 1 to C12	This terminal output control signals to the capacitor control section (Ex. VMC*1) connected to the terminal.
External forced disconnection signal input *2	OFF +	Forced disconnection signal input (positive)	Connect this terminal to one side of a contact for a contact signal input. Connect this terminal to a collector for NPN transistor open-collector signal input.
	OFF –	Forced disconnection signal input (negative)	Connect this terminal to opposing side of a contact for a contact signal input. Connect this terminal to 0V for NPN transistor open-collector signal input.

Notes:
*1 VMC: Vacuum magnetic contactor
*2 Signal input circuits
ON voltage VL < 1. 0V
Drain current Io = Approx. 10mA



QC06E and QC12E

Upper terminal arrangement

Main circuit

C6	C5	C4	C3	C2	C1	COM	OFF–	OFF+

Lower terminal arrangement

Control circuit

* NC	* NC	1S	1L	* NC	P3	P2 (220V)	P2 (440V)	E

*NC: No connection

QC12E only

Middle terminal arrangement

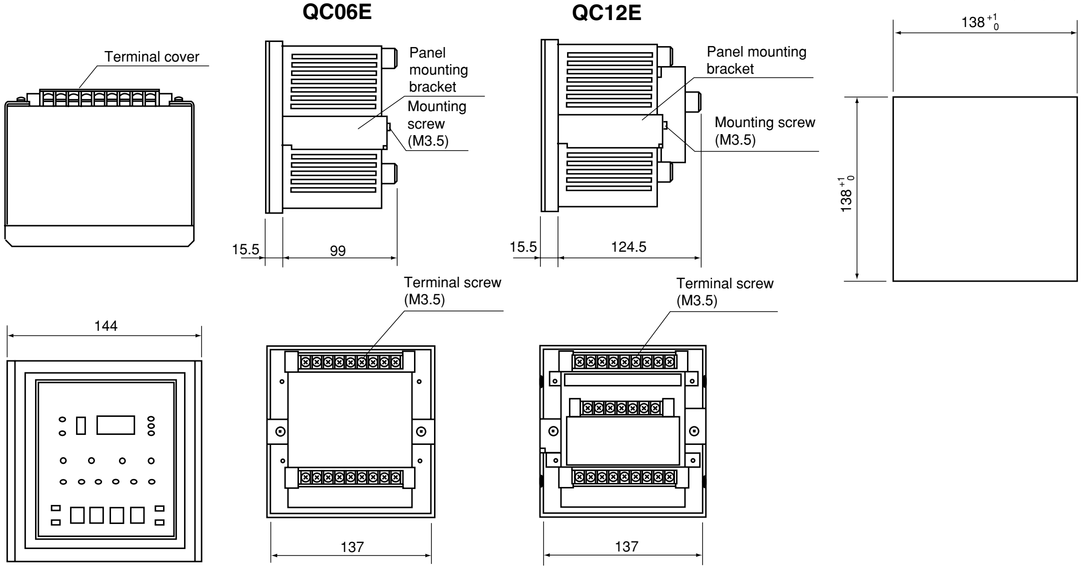
Main circuit

C12	C11	C10	C9	C8	C7	COM

Note: For QC12E, the upper and middle COM terminals are not connected internally. Be sure to connect these terminals.

Automatic power factor regulators QC06E and QC12E

■ Dimensions, mm



■ Key operations

● Data setting mode

Operation	Key operation	Remarks
Selecting a setting item	∧ or ∨	
Setting a value	∧ ∨ ENT	
Incrementing the data value (+1)	∧	Control mode (Mode A): 1 to 5 Target power factor (Mode F): 85 to 100 Delay time (Mode d): 30, 60, 120, 300, or 600 For other modes, be sure to enter a four-digit numeric value. The input order is thousands, hundreds, tens, then ones. Change the set value if a high-order digit is not required, skip the digit by pressing the ENT key, then enter a numeric value (1 to 9) to the next digit. (The skipped digit is not displayed.)
Decrementing the data value (–1)	∨	
Shifting the digit up	ENT	
Enter capacitance 0 value	ENT	When the value “0” is blinking, press the ENT key four times to set the value.
Determining the set value	ENT	
Clearing the set value to 0	∧ + ∨ Press at the same time.	This key operation is effective only when the mode symbol is 1 to 9, o, b, c, C, or L and numeric display is blinking.
Resetting all set value	∧ + ∨ Press for five seconds or longer at the same time.	This key operation is effective only when the mode symbol is 1 to 9, o, b, c, C, or L and numeric display is blinking. (All the set items are reset to the shipping setup.)
Stopping the buzzer giving error notification during diagnosis	AUTO SET ∧ ∨ ENT	Any key may be pressed.
Changing mode to auto operation	AUTO SET	

● Auto operation mode

Operation	Key operation	Remarks
Changing measurement display	∧ + ∨ Press at the same time.	The measurement data display changes cyclically in the following order: Power factor, reactive power, active power, primary voltage, primary current, and no display. The initial display at power-on is power factor data.
Testing capacitor connection	∧ + ENT Press continually at the same time.	For the operation sequence, operation time, and other details, refer to the instruction manual.
Testing capacitor disconnection	∨ + ENT Press continually at the same time.	
Stopping the buzzer giving error notification during diagnosis	AUTO SET ∧ ∨ ENT	Any key may be pressed.
Changing mode to data setting	AUTO SET	

■ Data setting procedure

• Set the following items

1. Capacitor capacitance: Capacitor 1 (150kvar) to 3 (150kvar)
2. Capacitor control mode (example): 2
3. CT ratio (example): 20 (current transformation ratio: 100/50)
4. Target power factor: 100(%)
5. Minimum load: 100(kW)
6. Delay time: 120(s)

• Data setting and change procedure

Data setting flow	Key operation	Display status		Explanation
		Mode	Data	
Power-on *1 Mode-1 initial value display	Press AUTO SET key to change already-input data.	1	0	"0" is set at shipping from the factory.
Capacitor-1 capacitance input awaited	1 ENT	1	0000	"0" starts blinking to wait for capacitor-1 capacitance input. An entry in the thousands place is awaited.
Enter 0 in the thousands place	2 ENT	1	0000	The display value dose not change but "0" is set at the thousand place. An entry in the hundreds place is awaited.
Enter 1 in the hundreds place	3 ∧	1	0100	Enter 1 in the hundreds place.
	4 ENT	1	0100	"1" is set at the hundreds place. An entry in the tens place is awaited.
Enter 5 in the tens place	5 Press ∧ key five times	1	0150	Enter 5 in the tens place.
Enter 0 in the ones place	6 ENT	1	150	"5" is set at the tens place. An entry in the ones place is awaited.
	7 ENT	1	0150	Capacitor-1 capacitance input has been completed.
Mode-2 initial value display	∧	2	0	"0" is set at shipping from the factory.
Capacitor-2 capacitance input awaited	ENT	2	0000	"0" starts blinking to wait for capacitor-2 capacitance input. An entry in the thousands place is awaited.
Set each place following the above order	2 to 7			Capacitor-2 capacitance input has been completed.
Mode-3 initial value display	∧	3	0	"0" is set at shipping from the factory.
Enter capacitor-3 capacitance	1 to 7			Capacitor-3 capacitance input has been completed.
Enter 0 for capacitance of capacitor 4 to 12	∧	4 c	0	The confirmation of capacitance setup (0) has been completed.
To correct an input error or change a set value	ENT	Each mode	0000	Data can be entered in a blinking field.
Control-mode initial value display	∧	A	1	Capacitor control mode: 1 is set at shipment from the factory.
Control-mode input awaited	ENT	A	1	Capacitor control mode: An entry in the control mode is awaited.
Enter 2 in control mode	∧ or ∨	A	2	Capacitor control mode input is in progress.
	ENT	A	2	The input in capacitor control mode has been completed.
CT ratio initial display	∧	C	0	CT ratio setting mode: "0" is set at shipping from the factory.
CT ratio input awaited	ENT	C	0000	"0" starts blinking to wait for CT ratio input. An entry in the thousand place is awaited.
Enter 0 in the thousands place	ENT	C	0000	"0" is set at the thousands place. An entry in the hundreds place is awaited.
Enter 0 in the hundreds place	ENT	C	0000	"0" is set at the hundreds place. An entry in the tens place is awaited.
Enter 2 in the tens place	∧ two times	C	0020	Enter 2 in the tens place.

Note:

[1] The initial value setup in mode 1 is always displayed at the first power-on after the unit is delivered from the factory, or displayed if all data have been reset to the factory setup.

[2] Although 0 is set at shipping from the factory, check the setup by incrementing the capacitor numbers with this key.

Data setting flow	Key operation	Display status		Explanation
		Mode	Data	
Enter 0 in the ones place	ENT	C	0020	"2" is set at the tens place. An entry in the ones place is awaited.
	ENT	C	0020	CT ratio input has been completed.
Target power factor initial display	∧	F	98	Target power factor: "98" is set at shipping from the factory.
Target power factor input awaited	ENT	F	98	An entry of target power factor is awaited.
Enter target power factor "100"	∧ or ∨	F	100	Target power factor input is in progress.
	ENT	F	100	Target power factor input has been completed.
Minimum load initial display	∧	L	0	Minimum load: "0" is set at shipping from the factory.
Minimum load input awaited	ENT	L	0000	"0" is set at the thousands place. An entry in the thousand place is awaited.
Enter 0 in the thousands place	ENT	L	0000	"0" is set at the thousands place. An entry in the hundreds place is awaited.
Enter 1 in the hundreds place	∧	L	0100	Enter "1" in the hundreds place.
Enter 0 in the tens place	ENT	L	0100	"1" is set at the hundreds place. An entry in the tens place is awaited.
Enter 0 in the ones place	ENT	L	0100	"0" is set at the tens place. An entry in the ones place is awaited.
	ENT	L	100	Minimum load input has been completed.
Delay time initial display	∧	d	300	Delay time: "300" is set at shipping from the factory.
Delay time input awaited	ENT	d	300	An entry of delay time is awaited.
Enter delay time 120	∧ or ∨	d	120	Delay time input is in progress.
	ENT	d	120	Delay time input has been completed.
Data setting completed	AUTO SET	Display item	Measured data	Measured data is displayed.

• Supplemental explanations

1. Mode symbols 1 to 9 and o, b, c.

- The capacitor bank is never connected when the capacitance is set to 0.
- The capacitor bank is never disconnected when the capacitance is set to 9999.
- When multistep control is selected, only the capacitance of mode symbol 1 becomes valid. No data needs to be set for mode symbols 2 to 9 and o, b, c.

2. Capacitor connection and disconnection

Mode symbol	Set value	Description
A	1	Cyclic/optimum control
	2	Uncondentional cyclic control
	3	Multistep control, capacitance ratio 1:2:2:2:2:2:2:2:2:2:2:2
	4	Multistep control, capacitance ratio 1:2:4:4:4:4:4:4:4:4:4:4
	5	Multistep control, capacitance ratio 1:2:4:8:8:8:8:8:8:8:8:8

A capacitor discharger recommended for multistep control of A3, A4, or A5 is a discharging coil which reduces the residual voltage of the capacitor to 50 volts or less within five seconds.

3. If “100%” is set as the target power factor of mode symbol F, a control of leading reactive power is performed.

4. Set the minimum load value to one slightly higher than the actual minimum load of the equipment to ensure an accurate light-load disconnection even when the measuring error or circuit constant fluctuates slightly.

Example: When the actual minimum load of the equipment is 100kW, set the value to 120kW (100 × 1.2).

Note:
Select a delay time suitable for the capacitor discharger. When using a discharging resistor, set the delay time to 300s (5min) or 600s (10min). An inappropriate delay time may damage capacitors or reduce their service lives.

Automatic power factor regulators QC06E and QC12E

■ Calculating CT ratios

• CT ratio

Example: When the primary current is 400A and secondary current is 5A.
$400 \div 5 = 80$ CT ratio = 80

■ Determining capacitances and number of capacitor banks to improve the power factor by switching-on capacitors

The capacitances and the number of capacitor banks are determined as follows:

● For capacitors having the same capacitances

When load variation (increase and decrease of load) is frequent.

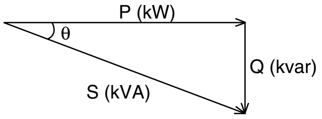
1. Determining the target power factor

Consider how far the power factor can be improved from the current value by automatic control.

Example

Current power factor (before improvement): 0.8
Target power factor (after improvement): 0.98
Maximum demand power: 1000kW

Power factor: Cosθ
P: Active power
Q: Reactive power
S: Max. demand power



2. Calculating the capacitances needed to improve the power factor

See the capacitor selection chart (*Page 09/101*) to calculate the necessary capacitance.

Example

To improve the power factor from 0.8 to 0.98, the factor K_1 should be 0.54. Therefore, the necessary capacitance (Cm) is obtained as follows:

Cm = Maximum demand power $\times$ K_1 = 1000kW $\times$ 0.54 = 540kvar

The necessary capacitance is 540kvar.

3. Calculating the target reactive power

Calculate the target reactive power from the target power factor (after improvement) and the maximum demand power.

Example

The target value is calculated using the factor K_2 selection table. (*Page 09/101*)
Target power factor: 0.98
K_2=0.2
The target reactive power (Q_1):
Q_1 =Maximum demand power $\times$ K_2
=1000kW $\times$ 0.2
=200kvar

4. Determining the number of capacitor banks

Determine the number of capacitor banks from the necessary capacitance for power factor improvement and target reactive power.

Example

Determine the number of capacitor banks as follows:

$$n = \frac{\text{Necessary capacitance for power factor improvement (Cm)}}{\text{Target reactive power } (Q_1)}$$

(1) If n 6, the number of banks should be six.
(2) If n < 6, the number of banks should be n.
(Round up any fraction)
In this example,

$$n = \frac{540\text{kvar}}{200\text{kvar}} = 2.7 < 6$$

If the fraction is rounded up, the number of necessary banks is 3.

Note: The necessary capacitance for power factor improvement (Cm) means the total capacitance to be controlled by this unit.

5. Calculating the capacitance per capacitor bank

If each bank should have the same capacitance, the capacitance needed to improve the power factor must be divided by the number of banks calculated at step 4.

Example

Capacitance per capacitor bank:

$$Co = \frac{\text{Capacitance needed to improve the power factor (Cm)}}{\text{Number of capacitor banks (n)}}$$

In this example,

$$Co = \frac{Cm}{n} = \frac{540\text{kvar}}{3\text{ (banks)}} = 180\text{kvar}$$

Since there are no 180kvar capacitors, a 200kvar-capacitor can be used.

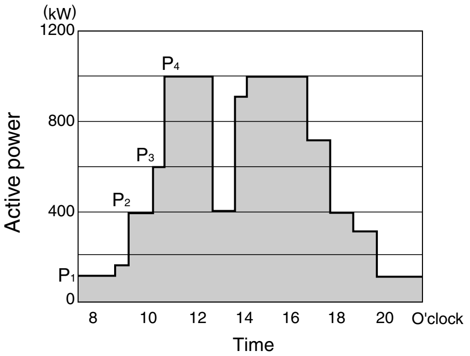
● For capacitors having unequal-capacitances

When load variation is a slight and stable all the year round. Target power factor and the necessary capacitance for power factor improvement are calculated using step 1 and 2.

Current power factor (before improvement): 0.8
Target power factor (after inprovement): 0.98
Necessary capacitance for power factor improvement (Cm): 540kvar
For load variation as shown below, calculate the reactive power variation using K_1.

Example

- When P_1 is 150kW, $Q_1 = P_1 \times K_1 = 150 \times 0.54 = 81$kvar
  Capacitor C_1 = 100kvar
- When P_2 is 400kW, Q_2 = 216kvar
  Capacitor $C_2 = Q_2 - C_1$ = 116kvar, C_2 = 150kvar
- When P_3 is 600kW, Q_3 = 324kvar
  Capacitor $C_3 = Q_3 - (C_1 + C_2)$ = 74kvar, C_3 = 100kvar
- When P_4 is 1000kW, Q_4 = 540kvar
  Capacitor $C_4 = Q_4 - (C_1 + C_2 + C_3)$ = 190kvar, C_4 = 200kvar



■ Capacitor selection / Factor K_1

Obtain the value of the capacitor required for improving the power factor by referring to the following list:

		Power factor after being improved = $\cos\theta_1$																													
		1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91	0.9	0.875	0.85	0.825	0.8	0.775	0.75	0.725	0.7	0.675	0.65	0.625	0.6	0.575	0.55	0.525	0.5	0.475	0.45	0.425
Power factor before being improved = $\cos\theta_0$	0.4	2.30	2.16	2.10	2.05	2.01	1.97	1.94	1.90	1.87	1.84	1.82	1.75	1.68	1.61	1.55	1.49	1.42	1.35	1.28	1.21	1.13	1.05	0.96	0.88	0.78	0.68	0.57	0.45	0.32	0.17
	0.425	2.13	1.98	1.92	1.88	1.84	1.80	1.76	1.73	1.70	1.67	1.64	1.57	1.51	1.44	1.38	1.31	1.24	1.18	1.11	1.04	0.96	0.88	0.79	0.71	0.61	0.51	0.40	0.27	0.15	
	0.45	1.98	1.83	1.77	1.73	1.68	1.65	1.61	1.58	1.55	1.52	1.49	1.42	1.36	1.29	1.23	1.16	1.10	1.03	0.96	0.89	0.81	0.73	0.64	0.56	0.46	0.36	0.24	0.12		
	0.475	1.85	1.71	1.65	1.61	1.56	1.53	1.49	1.46	1.43	1.40	1.37	1.30	1.23	1.16	1.10	1.04	0.98	0.91	0.84	0.76	0.68	0.60	0.52	0.44	0.33	0.23	0.12			
	0.5	1.73	1.59	1.53	1.48	1.44	1.40	1.37	1.34	1.30	1.28	1.25	1.18	1.11	1.04	0.98	0.92	0.85	0.78	0.71	0.64	0.56	0.48	0.40	0.31	0.21	0.11				
	0.525	1.62	1.48	1.42	1.37	1.33	1.29	1.26	1.22	1.19	1.17	1.14	1.07	1.00	0.93	0.87	0.81	0.74	0.67	0.60	0.53	0.45	0.37	0.29	0.20	0.10					
	0.55	1.52	1.38	1.32	1.27	1.23	1.19	1.16	1.12	1.09	1.06	1.04	0.97	0.90	0.83	0.77	0.71	0.64	0.57	0.50	0.43	0.35	0.27	0.19	0.10						
	0.575	1.42	1.28	1.22	1.17	1.14	1.10	1.06	1.03	0.99	0.96	0.94	0.87	0.80	0.74	0.67	0.60	0.54	0.47	0.40	0.33	0.25	0.17	0.08							
	0.6	1.33	1.19	1.13	1.08	1.04	1.01	0.97	0.94	0.91	0.88	0.85	0.78	0.71	0.65	0.58	0.52	0.46	0.39	0.32	0.24	0.16	0.085								
	0.625	1.25	1.11	1.05	1.90	0.96	0.92	0.89	0.85	0.82	0.79	0.77	0.70	0.63	0.56	0.50	0.44	0.37	0.30	0.23	0.16	0.08									
	0.65	1.17	1.03	0.97	0.82	0.88	0.84	0.81	0.77	0.74	0.71	0.69	0.62	0.55	0.48	0.42	0.36	0.29	0.22	0.15	0.08										
	0.675	1.09	0.95	0.89	0.84	0.80	0.76	0.73	0.70	0.66	0.64	0.61	0.54	0.47	0.40	0.34	0.28	0.21	0.14	0.07											
	0.7	1.02	0.88	0.81	0.77	0.73	0.69	0.66	0.62	0.59	0.56	0.54	0.46	0.40	0.33	0.27	0.20	0.14	0.07												
	0.725	0.95	0.81	0.75	0.70	0.66	0.62	0.59	0.55	0.52	0.49	0.46	0.39	0.33	0.26	0.20	0.13	0.07													
	0.75	0.88	0.74	0.67	0.63	0.58	0.55	0.52	0.49	0.45	0.43	0.40	0.33	0.26	0.19	0.13	0.065														
	0.775	0.81	0.67	0.61	0.57	0.52	0.49	0.45	0.42	0.39	0.36	0.33	0.26	0.19	0.12	0.065															
	0.8	0.75	0.61	0.54	0.50	0.46	0.42	0.39	0.35	0.32	0.29	0.27	0.19	0.13	0.06																
	0.825	0.69	0.54	0.48	0.44	0.40	0.36	0.33	0.29	0.26	0.23	0.21	0.14	0.07																	
	0.85	0.62	0.48	0.42	0.37	0.33	0.29	0.26	0.22	0.19	0.16	0.14	0.07																		
	0.875	0.55	0.41	0.35	0.30	0.26	0.23	0.19	0.16	0.13	0.10	0.07																			
	0.9	0.48	0.34	0.28	0.23	0.19	0.16	0.12	0.09	0.06	0.028																				
	0.91	0.45	0.31	0.25	0.21	0.16	0.13	0.09	0.06	0.028																					
	0.92	0.43	0.28	0.22	0.18	0.13	0.10	0.06	0.031																						
	0.93	0.40	0.25	0.19	0.15	0.10	0.07	0.033																							
	0.94	0.36	0.22	0.16	0.11	0.07	0.036																								
	0.95	0.33	0.18	0.12	0.08	0.035																									
	0.96	0.29	0.15	0.09	0.04																										
	0.97	0.25	0.11	0.05																											
	0.98	0.20	0.06																												
	0.99	0.14																													

k: Figures obtained by $\cos\theta_0$ and $\cos\theta_1$

■ Factor K_2 selection

Power factor ($\cos\theta_2$)	0.7	0.75	0.8	0.85	0.875	0.9	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99
$K_2=\sqrt{\frac{1}{\mathrm{COS}^2\theta_2}-1}$	1.02	0.88	0.75	0.62	0.55	0.48	0.45	0.43	0.40	0.36	0.33	0.29	0.25	0.20	0.14

K_2: Figures obtained by $\cos\theta_2$