Installation and
Operating Instructions

Power Factor Regulators
R V Q & R V R

$C\mathcal{E}$

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ABB

1. SAFETY

Installation, maintenance, etc. of the PF regulator should only be performed by qualified electricians.

Do not work under voltage.

Do not open the enclosure. There are no user serviceable parts inside.

Disconnect the voltage before replacing the fuse.

The regulator is connected to a current transformer. Do not un-plug its connections before making sure that the current transformer is short-circuited or is connected to another parallel load of sufficiently low impedance.
FAILURE TO DO SO CAN CREATE DANGEROUS OVERVOLTAGES.

2. ELECTROMAGNETIC COMPATIBILITY

The RVQ and RVR range of PF regulators have been verified for compliance with EU (European Union) directives for EMC (electromagnetic compatibility) for operation at 50Hz and bear the CE mark to this effect.

When an apparatus is used in a system, EU directives may require that the system is verified for EMC compliance.

The following guidelines are helpful in improving the EMC performance of a system :

1)   The use of metallic enclosures generally improves EMC performance.

2)   Run cables away from apertures in the enclosure.

3)   Run cables close to grounded metallic structures.

4)   Use multiple ground straps for doors or other panel parts as required.

5)   Avoid common ground impedances.

3. PRINCIPLE OF OPERATION

The operation principle of the regulator is the monitoring of the network reactive power and the achieving of a required power factor.
The regulator will switch on or switch off capacitor steps in order to reach the preset desired cos Phi.
The regulator reaction sensitivity depends on the preset C/k value. This value is calculated using the actual capacitor step power and the used current transformer ratio (see below).
The sensitivity is normally chosen in such a way that a capacitor step is switched on when two thirds of its power is required to reach the set cos Phi.
The C/k can be set manually or can be automatically calculated by the regulator.

All functions of the regulator are microprocessor based.

The range of active outputs can vary from 1 to 7 for the RVQ, and from 1 to 12 for the RVR.

The regulator switches the capacitor steps according to the programmed sequence (1:1:1..., 1:2:2..., 1:2:4..., 1:2:4:8...).
A delay time between steps is introduced to allow the capacitors to discharge.
This delay has to be set in accordance with the discharge devices of the capacitors (resistors or fast discharge devices) and , in some cases, should take into account other parameters such as the duty cycle of the load.

A power factor meter displays the actual cos Phi. The measurement is not affected by the network harmonics.

Each switched-on capacitor step is indicated by a LED.

The regulator is fitted with a power outage release function which disconnects all capacitors in case of a power outage.

All the programmed parameters are saved in a non-volatile memory even if the regulator has no supply.
After power outage there is a 90s delay before any step is switched on (this delay becomes 10 min if the regulator is configured with long switching delay times).

An auto-adaptable function is provided to simplify the installation. This permits correct operation of the regulator independent of the orientation of the CT and the phase-rotation. After a power outage the non-volatile memory allows the regulator to recall steps which were normally switched and left on.
A programmable alarm function indicates an insufficiency of the capacitor bank to compensate the demand for reactive power.

4. DESCRIPTION OF HANDLING

fig. 1. Front view
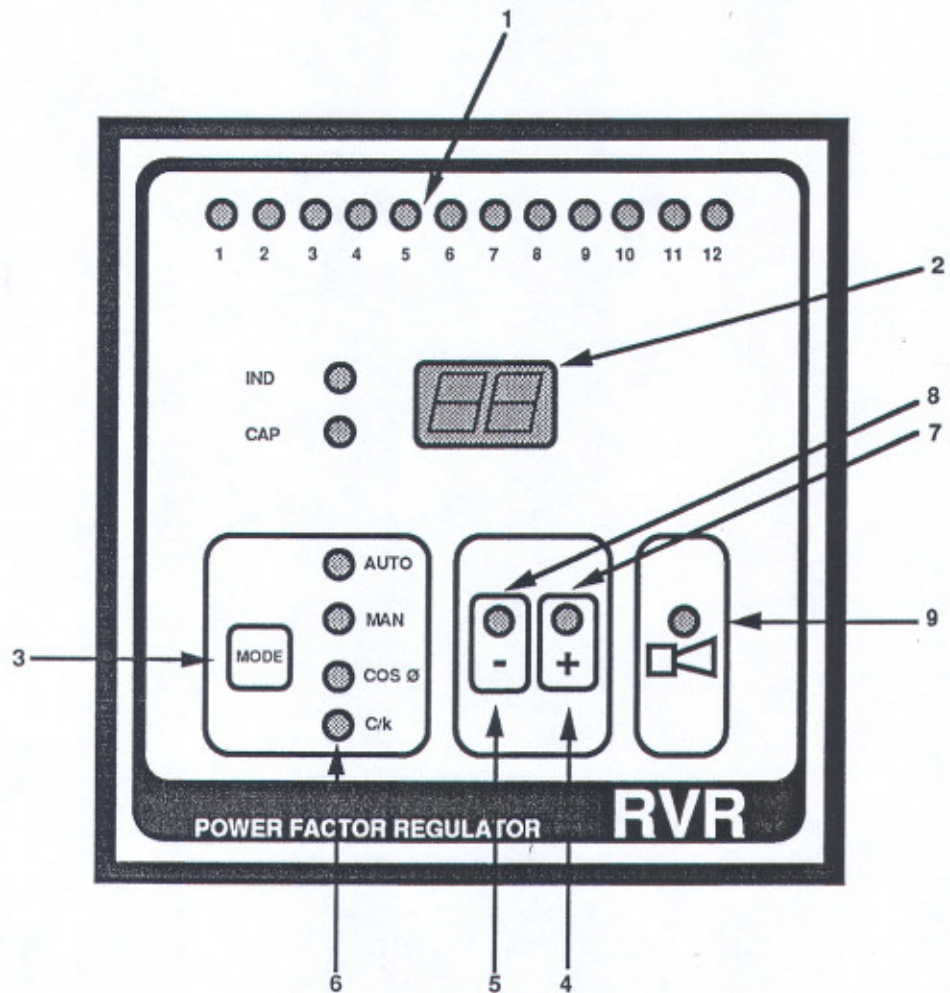
1	LED's light when corresponding output relays are closed.
	RVQ : 7 outputs maximum.
	RVR : 12 outputs maximum.
2	7-segment display used either as a power factor meter or for the setting of the regulator.
3, 4, 5	By pressing selection mode button 3, the regulator goes sequentially from one mode to the following.

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The four modes are :

AUTO : Automatic mode. The regulator switches on or off steps if needed.

MAN : Manual mode. Steps can be added or removed manually by pressing buttons 4 or 5.

COS PHI : In this mode, the desired cos Phi can be set. The display 2 shows the preset cos Phi. By pressing button 4, the preset cos Phi is incremented from 0.7 ind. to 0.9 cap. The button 5 decrements the cos Phi.

C/k : The C/k (sensitivity) is set in this mode. Display 2 shows the preset C/k. Button 4 increments the value of C/k and button 5 decrements this value. By pressing button 4 until C/k = 1.0, and pressing once more, the C/k can be calculated automatically by the regulator (see below).

6	Mode indicator.
7, 8	Lights indicating a demand of adding a step (7) and substracting a step (8).
9	The LED lights for alarm indication.

5. MOUNTING

The regulator is intended for vertical panel mounting. Brackets for door mounting are provided.

6. CONNECTION

The wiring diagrams (figures 2.A and 2.B) show the electrical connections of the relays.

The regulator can recognize the sense of the phase-rotation and adjust itself accordingly.
There is then no requirements for the orientation of the current transformer (k,l) or of the feeding leads (L2, L3).

It is essential that the current transformer is connected on a different phase from the feeding leads (see section 6 for automatic set-up of the phase-rotation).

Before energizing the controller, it is recommended to check the voltage range of the device written on the sticker at the back side of the regulator.

| NOMINAL VOLTAGE	NOMINAL VOLTAGE	NOMINAL VOLTAGE
100 - 120 Vrms	220 - 240 Vrms	380 - 440 Vrms

The working voltage range indicated on the sticker is a nominal voltage. A tolerance of +/- 10 % is allowed.

	Nominal voltage	Allowed tolerance band
Type 3	380 - 440V	342 - 484V (RMS)
Type 2	220 - 240V	198 - 264V (RMS)
Type 1	100 - 120V	90 - 132V (RMS)

Note that the current transformer must be installed on the feeder-side of the capacitor bank. Never open the secondary circuit of an energized current transformer.

The connection arrangements for the various types are shown in figures 3.A and 3.B.

fig. 2A.RVQ, 7 outputs and RVR, 12 outputs - standard execution
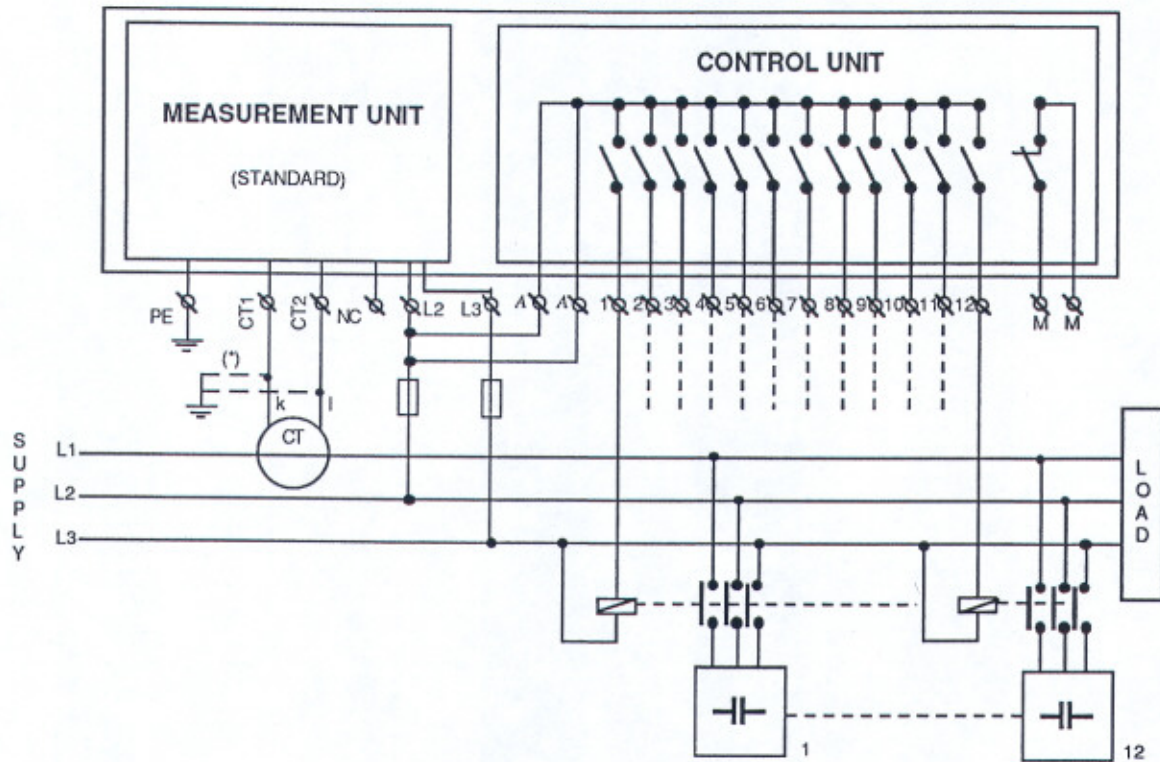
N.B.   Terminals 8 to 12 are inactive for RVQ version.
            Note that RVR (standard) requires two common source leads!
            Check all electrical ratings before making any connection !
(*) Caution : One of the CT terminals (k or l) shall be grounded.

fig. 2B. RVQ, 7 ouputs and RVR, 12 outputs - voltage free contact.
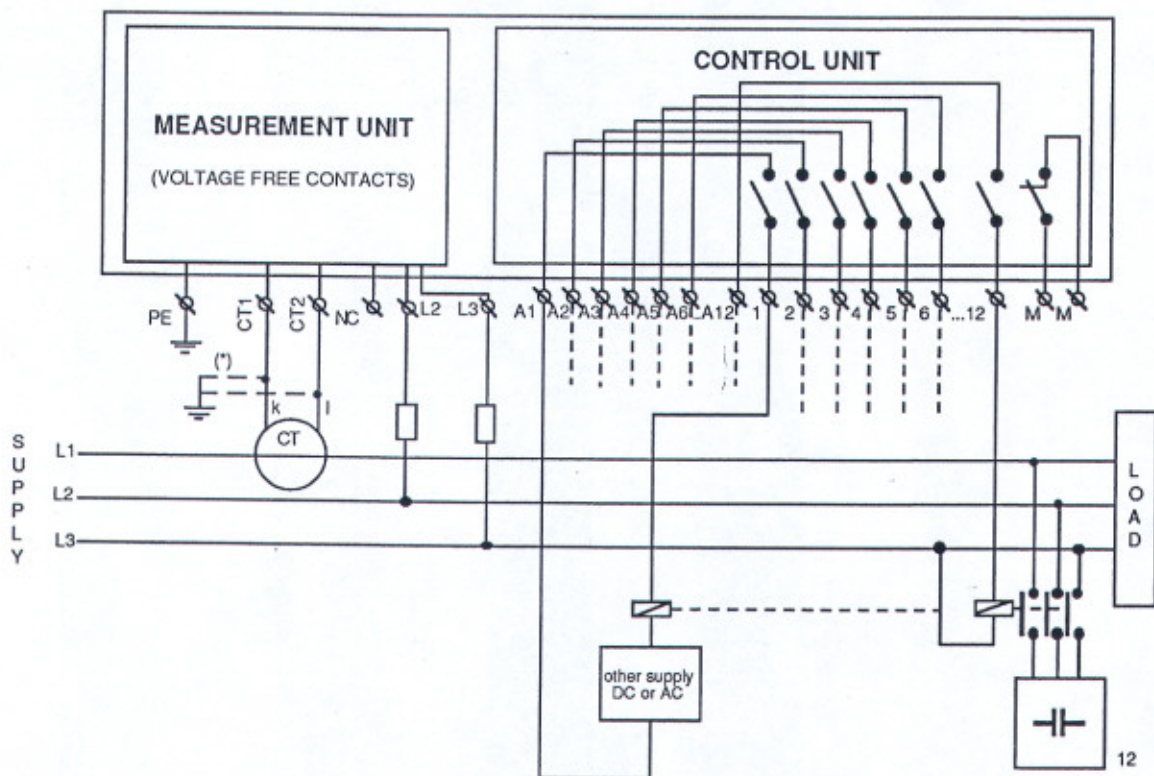
N.B.   Terminals 8 to 12 and A8 to A12 are inactive for RVQ version.
(*) Caution : One of the CT. terminals (k or l) shall be grounded.
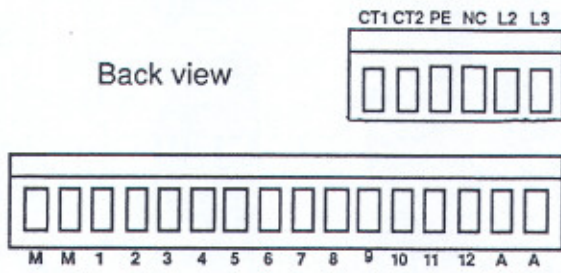
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fig. 3 A.

RVQ/RVR - standard execution

fig. 3 B.

RVQ/RVR - voltage free contacts
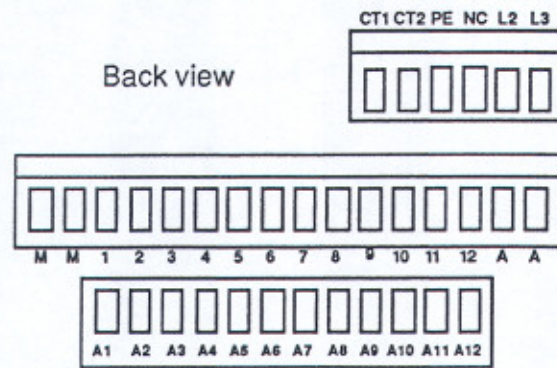
CT1,CT2 :   leads of the current transformer.
PE :   protective earth.
NC :   non connected.
L2, L3 :   two of the three phases (those which are not monitored by the current transformer).
M :   leads of the normally closed contact of the alarm relay.
A :   output relay common source (inactive for voltage free contact execution).
1-12 :   outputs.
A1-A12 :   voltage free contacts for each output of the voltage free contact execution of RVQ/RVR regulators.

N.B.   Terminals 8 to 12 are not connected for RVQ - standard execution.
       Terminals 8 to 12 and A8 to A12 are not connected for RVQ - voltage free contacts execution.

fig. 3 C.

Leads connection
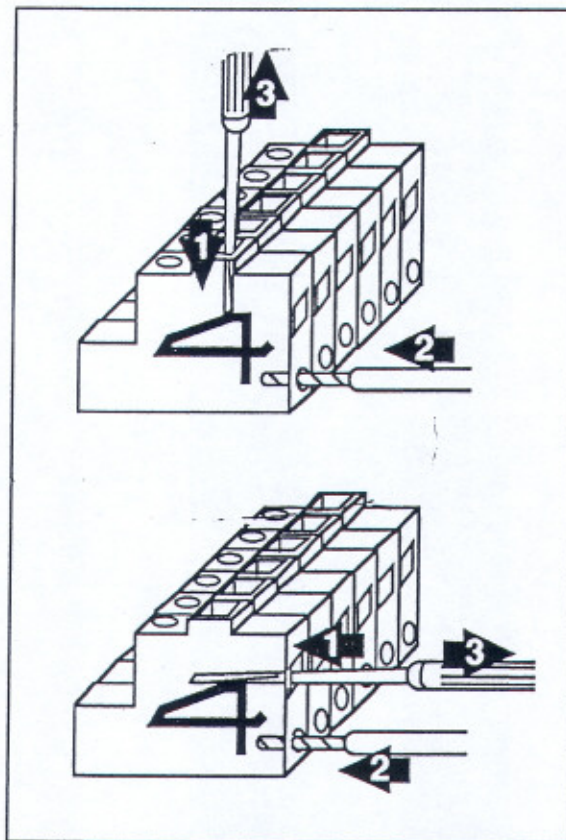
7. PROGRAMMING

Caution : Before using the regulator, programming of the following parameters has to be performed :
- sequence
- number of outputs
- three or single-phase network
- switching delay time
- alarm delay time

This is performed by the capacitor bank manufacturer.

These parameters are :

7.1. Type of sequence :

7.1. a.1:1:1:1:1:.... linear.

Demand

↗ demand of adding a step.

↘ demand of removing a step.

Result   ▼ : output closed
0 : output open

Example :

Demand	1	1	1	1	....	1	1	Steps
	▼	0	0	0	......	0	0	1
↗	▼	▼	0	0	......	0	0	2
↗	▼	▼	▼	0	......	0	0	3
↘	▼	▼	0	0	......	0	0	2
↘	▼	0	0	0	......	0	0	1

7.1.b. 1:1:1:1:1..... circular.

Example :

Demand	1	1	1	1	....	1	1	Steps
	▼	0	0	0	......	0	▼	2
↗	▼	▼	0	0	......	0	▼	3
↗	▼	▼	▼	0	......	0	▼	4
↘	▼	▼	▼	0	......	0	0	3
↘	0	▼	▼	0	......	0	0	2

7.1.c. 1:2:2:2:2.....

Example :

Demand	1	2	2	2	....	2	2	Steps
	▼	0	0	0	......	0	0	1
↗	0	▼	0	0	......	0	0	2
↗	▼	▼	0	0	......	0	0	3
↗	0	▼	▼	0	......	0	0	4
↘	▼	▼	0	0	......	0	0	3
↘	0	▼	0	0	......	0	0	2

7.1.d. 1:2:4:4:4:.....

Example :

	1	2	4	4	....	4	4	Steps
	0	0	▼	0	......	0	0	4
↗	▼	0	▼	0	......	0	0	5
↗	0	▼	▼	0	......	0	0	6
↗	▼	▼	▼	0	......	0	0	7
↗	0	0	▼	▼	......	0	0	8
↘	▼	▼	▼	0	......	0	0	7
↘	0	▼	▼	0	......	0	0	6

7.1.e. 1:2:4:8:8:.....

Example :

	1	2	4	8	....	8	8	Steps
	▼	0	▼	▼	......	0	0	13
↗	0	▼	▼	▼	......	0	0	14
↗	▼	▼	▼	▼	......	0	0	15
↘	0	▼	▼	▼	......	0	0	14
↘	▼	0	▼	▼	......	0	0	13
↘	0	0	▼	▼	......	0	0	12
↘	▼	▼	0	▼	......	0	0	11

Note : Types of sequence available :

    RVQ :1:1:1:1:1:..... linear
          1:1:1:1:1:..... circular
          1:2:2:2:2:..... linear
          1:2:2:2:2:..... circular on outputs of value "2"
          1:2:4:4:4:..... linear
          1:2:4:4:4:..... circular on outputs of value "4"
          1:2:4:8:8:..... linear
          1:2:4:8:8:..... circular on outputs of value "8"
    RVR :1:1:1:1:1:..... linear
          1:1:1:1:1:..... circular
          1:2:2:2:2:..... linear
          1:2:2:2:2:..... circular on outputs of value "2"
          1:2:4:4:4:..... linear
          1:2:4:4:4:..... circular on outputs of value "4"

7.2. Number of active outputs (programmable)

RVQ : 1 to 7
RVR : 1 to 12

7.3. Three or single-phase system

The RVQ-RVR can be connected either to a three-phase balanced network or to a single-phase network as shown in figures 4.A. and 4.B. The regulator must be programmed as a three-phase or a single-phase measuring device.

Note : a single-phase configuration of the regulator can only be done with single-phase loads.
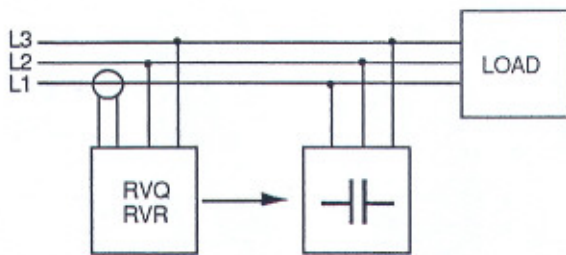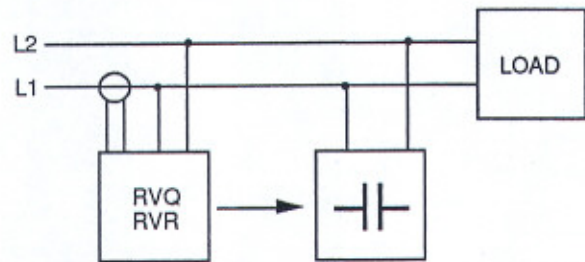
fig.4.A.

fig.4.B.
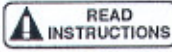

7.4. Switching delay time between steps

The switching delay time can be set in the range 1s to 99s or 1 min to 99 min. The switching-on and the switching-off delay times are separately programmable.

7.5. Alarm function

A normally closed relay is open when the regulator is energized and no fault conditions are present (alarm OFF). This relay is released (alarm ON) when all steps are switched on and the bank is insufficient to compensate the required amount of reactive power during the programmed delay time (1 min to 99 min). The alarm function resets when this condition disappears.

7.6. Programming procedure

The parameters are programmed as follows :

1. To enter the programming procedure, the red and white sticker ⚠ READ INSTRUCTIONS located on the back side of the regulator must be removed and the switch placed on the "PROG" position.

2. The display indicates P1. This is the first parameter, the type of sequence. Pressing buttons + or - gives access to the desired type of sequence :

    E1 : 1:1:1:1:1:.....
    E2 : 1:2:2:2:2:.....
    E3 : 1:2:4:4:4:.....
    E4 : 1:2:4:8:8:.....

3. Press button MODE and the display indicates P2. This is the second parameter : linear or circular switching. By pressing button + the linear operation is selected (Ln). The circular (Cr) operation is selected by button -.

4. By pressing the button MODE, the third parameter (the number of active outputs) can be entered : P3. Buttons + and - increment and decrement the displayed value.

5. By pressing the button MODE the parameter P4 is displayed. If the regulator is wired in a three-phase network, press button + (tr = tri). Otherwise, if it is wired as a single-phase device, press button - (mo = mono).

6. Parameter P5 selects the units of the switching delay times : seconds (Sc) or minutes (Mn).
    N.B. After a power outage the delay before any step is switched on is 90 s. if P5 = Sc and 10 min. if P5 = Mn.

7. P6 is the switch-on delay time, from 1 to 99 (see P5 for seconds or minutes).

8. P7 is the switch-off delay time, from 1 to 99 (see P5 for seconds or minutes).

9. The parameter P8 (the alarm delay time) can be adjusted by button + and -, from 1 to 99 minutes.

10. To end the process, press button mode. The display indicates "--". The parameters are automatically saved and the regulator programming is completed. The programmed inputs can be checked by repetition of steps 1 to 11.

11. Place the switch on the "RUN" position and put the sticker back to its proper place.

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8. SETTING OF COS PHI , C/k and PHASE-ROTATION

These settings must be performed at least once when the regulator is installed in the field.

The self-correcting set-up of the phase-rotation is required when one of the connections L2-L3 or CT1-CT2 are mistakenly inverted. This operation is carried out in the MANUAL MODE by pushing simultaneously the buttons "+" and "-". The regulator displays the message "Ct" when entering the phase-rotation set-up.

Caution :   inverting physical connections (L2-L3 or CT1-CT2) without doing again the set-up causes the regulator to work erroneously.
Important : make sure the load is passive during the set-up of the phase-rotation. Common loads meet this requirement but some may temporarily "supply" the network and then become active for short times.

Checking the regulator phase-rotation is strongly recommended. The manual switching-on of capacitor steps must lead the currently displayed cos Phi to become more capacitive or less inductive depending on the actual power factor of the network at the time of the test.
The controller works with all kinds of loads provided the set-up of the phase-rotation has been properly completed.

First set the regulator in the desired mode by pressing the MODE button (figure 1, point 3).

The target cos Phi is set in the cos Phi mode by pressing buttons + and - (figure 1). The range of adjustment is 0.70 inductive (lag) to 0.90 capacitive (lead).
The sensitivity, C/k value, is set in the C/k mode by pressing buttons + and - (figure 1). The range of adjustment is 0.07 A to 1.0A (reactive current).
The recommended setting of C/k can be calculated by the following formula or read directly in table 1.

Three-phase network:

$$C/k = 0.62 \times \frac{Q \times 1000}{\sqrt{3} \times U \times k}$$

Q : reactive 3-phase power of one step (kvar)

U : system voltage (V)

k : current transformer ratio.

Single-phase network:

$$C/k = 0.62 \times \frac{Q \times 1000}{U \times k}$$

Q : reactive power of one step (kvar)

U : system voltage (V)

k : current transformer ratio.

table 1

C/k values for 400 V supply (three-phase network)

N.B.   The " 5 A input" regulator can be set with a C/k in the range (0.07 - 1).
The "1 A input" regulator can be set with a C/k in the range (0.014 - 0.200).

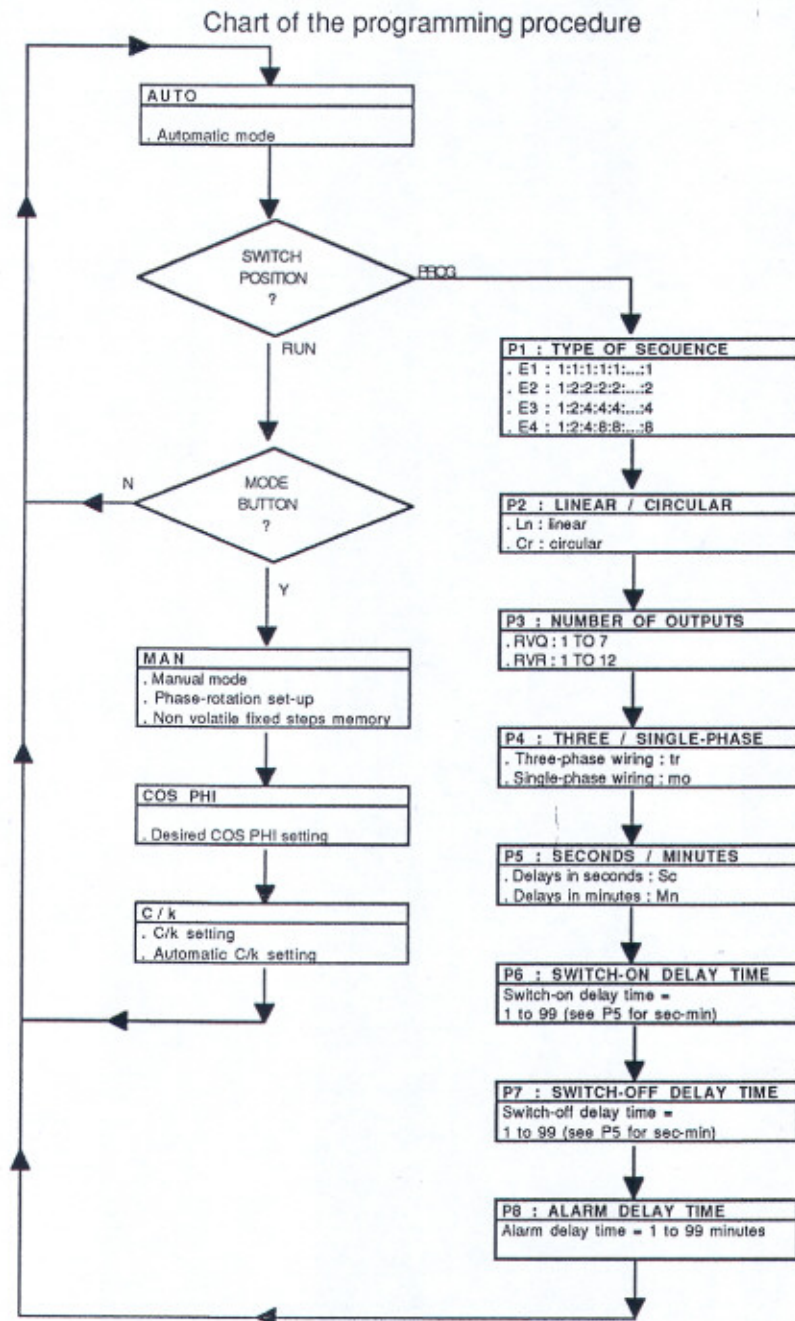| CT Ratio		k	Capacitor step rating (kvar)											
			5	10	15	20	30	40	50	60	70	90	100	120
10/1	50/5	10	.45	.90										
20/1	100/5	20	.23	.45	.68	.90								
30/1	150/5	30	.15	.30	.45	.60	.90							
40/1	200/5	40	.11	.23	.34	.45	.68	.90						
60/1	300/5	60	.07	.15	.23	.30	.45	.60	.75	.90				
80/1	400/5	80	.056	.11	.17	.23	.34	.45	.56	.68	.79	.90		
100/1	500/5	100	.045	.09	.14	.18	.27	.36	.45	.54	.63	.81	.90	
120/1	600/5	120	.037	.07	.11	.15	.23	.30	.38	.45	.53	.68	.75	.90
160/1	800/5	160	.028	.056	.08	.11	.17	.23	.28	.34	.40	.50	.56	.68
200/1	1000/5	200	.022	.045	.067	.09	.13	.18	.23	.27	.31	.40	.45	.54
300/1	1500/5	300	.015	.030	.045	.060	.09	.12	.15	.18	.21	.27	.30	.36
400/1	2000/5	400		.022	.034	.045	.067	.09	.11	.14	.16	.20	.23	.27
600/1	3000/5	600		.015	.022	.030	.045	.06	.07	.09	.11	.14	.15	.18

Caution :   For a single-phase network the C/k values given in the table 1 must be multiplied by 1.732.

The regulator can automaticaly set the C/k of the installation by itself. To enter the automatic C/k setting function, please follow this sequence:

Caution :   The type of sequence, the number of outputs, and the delay times have to be programmed previously (see Chapter 5).

1. Enter the C/k mode by pressing button MODE. The display indicates the present value of C/k.

2. By pressing button +, the C/k is incremented until 0.99, 1.0, and then AU appears. This is the automatic C/k setting function.

3. Start the automatic process of C/k by pressing button MODE. The indication AU is then flashing.
4. The regulator will switch on or switch off one step automatically to measure the variation of reactive current due to this step and to calculate the C/k value :

   1 step ON
   1 step OFF
   1 step ON
   1 step OFF

5. If another load is switched on during the automatic C/k measuring, the C/k value is false. The display indicates Er and the sequence comes back to step 4. This loop is executed until the correct C/k value is found. It is recommended to start the automatic C/k setting function when there is no great variation of reactive current on the network.

6. It is possible to stop the automatic C/k setting function by pressing button MODE. "AU" stops flashing on the display and the regulator returns to step 3.

7. When the automatic process is successfully done, the C/k value is indicated on the display. The regulator then comes back by itself into automatic mode.

fig. 5.

Chart of the programming procedure

AUTO
. Automatic mode

SWITCH POSITION ?

PROG

RUN

P1 : TYPE OF SEQUENCE
. E1 : 1:1:1:1:1:...:1
. E2 : 1:2:2:2:2:...:2
. E3 : 1:2:4:4:4:...:4
. E4 : 1:2:4:8:8:...:8

MODE BUTTON ?   N

Y

P2 : LINEAR / CIRCULAR
. Ln : linear
. Cr : circular

MAN
. Manual mode
. Phase-rotation set-up
. Non volatile fixed steps memory

P3 : NUMBER OF OUTPUTS
. RVQ : 1 TO 7
. RVR : 1 TO 12

COS PHI
. Desired COS PHI setting

P4 : THREE / SINGLE-PHASE
. Three-phase wiring : tr
. Single-phase wiring : mo

C / k
. C/k setting
. Automatic C/k setting

P5 : SECONDS / MINUTES
. Delays in seconds : Sc
. Delays in minutes : Mn

P6 : SWITCH-ON DELAY TIME
Switch-on delay time =
1 to 99 (see P5 for sec-min)

P7 : SWITCH-OFF DELAY TIME
Switch-off delay time =
1 to 99 (see P5 for sec-min)

P8 : ALARM DELAY TIME
Alarm delay time = 1 to 99 minutes

9. TESTING

After installation of the automatic capacitor bank and programming of the switching parameters (see Chapter 5), the following tests can be performed depending on load situation.

1) No load or cos Phi = 1 or capacitive load (set desired cos Phi = 0.95 ind.).

      a) Select manual mode.
      b) Add two or more steps by pressing button +
      c) Select automatic mode.

All capacitor steps must be switched off with the programmed delay time between each switching operation.

If all steps are not switched off, check the following :

      - If an inductive load has been switched in.

      - If an incorrect setting of C/k ratio has been set (it is recommended to set the value slightly higher than the calculated value).

2) Inductive load.

      a) Set desired cos Phi = 1
      b) Select automatic mode.

Capacitor steps will now be automatically switched on to compensate the inductive load. (The relay will not react if the inductive current is lower than the preset C/k value. In such a case, test according to 1 above).

If all steps are switched on and there is still a demand for additional steps, then check the setting of C/k. If it is correct, then the bank is too small to compensate to cos Phi = 1. Select a lower value for cos Phi.

When one stage repeatedly switches on and off, it means the C/k is set too low (unless the load actually fluctuates periodically with a time period equal to the switching delay time).

10. TROUBLE SHOOTING

A) The regulator does not switch on or off steps although there is a considerable variable inductive load.

- Check that the relay is in automatic mode.
- Check the CT - connection (i.e. "R" phase) and the voltage connections (i.e. "S-T" phases) are connected to different phases.
- Check setting of C/k.

B) The regulator does not seem to activate any steps.

- Wait for the delay time between switching or a power outage delay time.

C) The preset power factor is not achieved.

- At low or no load, a low power factor can correspond to a very small inductive current. The corresponding capacitor steps are too large for a compensation.
- If the average cos Phi over a period of time is too low, the preset cos Phi may be increased.

D) The + or - lights flash.

- Normal situation when the actual inductive current varies around the set sensitivity (C/k).

E) The regulator indicates capacitor steps switched on, but the contactors are not activated.

- Check the wiring diagram of the power contactors and the regulator outputs.

F) The alarm function is activated although everything seems normal.

- A very high demand of reactive power during a few minutes may make the bank insufficient to compensate the required amount of reactive power. It shall therefore indicate alarm.

G) All capacitors are switched on, although the required reactive power is relatively low.

- The CT has been placed on the load side of the capacitors.

H) The regulator is connected but does not work (no flashing led)

- Check the voltage setting and the fuse (0.125A/250V) located on the back side of the regulator.

11. TECHNICAL DATA

Electronic measuring system for balanced three-phase networks or single-phase networks.

Voltage supply V(L2 - L3) : nominal voltage between 100 and 120V, between 220V and 240V, between 380V and 440V, following types.

Voltage tolerance : +/- 10 % on indicated nominal voltages.

N.B. A regulator may work with a voltage supply out of the above mentioned specified range. Should it be the case, ABB does not give any guarantee that technical specifications will be respected.

Frequency range : RVQ and RVR regulators can work equally with 50 or 60Hz.

Current input : 5A (RMS) (1A on request)

Current input impedance : < 0.1 Ohm.

Fuse rating :125 mA / 250Vmin. (T-type).

Primary transformer fuse : a primary transformer fuse is included (for UL approval). This fuse is a safety device in the "A" range. An external fuse`(rated 500V) shall be added for a safe "B" range operation.

Consumption : 12 VA max.
Switching sequences : RVQ :1:1:1:1:.... 1 linear
                  1:1:1:1:.... 1 circular
                  1:2:2:2:.... 2 linear
                  1:2:2:2:.....2 circular on outputs of value "2"
                  1:2:4:4:.... 4 linear
                  1:2:4:4:.... 4 circular on outputs of value "4"
                  1:2:4:8..... 8 linear
                  1:2:4:8..... 8 circular on outputs of value "8"

            RVR :1:1:1:1:.... 1 linear
                  1:1:1:1:.... 1 circular
                  1:2:2:2:.... 2 linear
                  1:2:2:2:.... 2 circular on outputs of value "4"
                  1:2:4:4:.... 4 linear
                  1:2:4:4:.... 4 circular on outputs of value "4"

Output contact rating : Max. continuous current : 1.5A.
                  Max. peak current : 5A.
                  Max. voltage : 440V.

Terminal A-A are rated for a continuous current of 18 A (9 A/terminal).

Power factor setting : 0.7 inductive to 0.9 capacitive.

Starting current setting : - 0.07 to 1A (0.014 to 0.2 for a "1 A input" regulator).
                  - Automatic measurement of C/k.

Variable number of active outputs : -RVQ : 1 to 7.
                       -RVR : 1 to 12.

Switching time between steps : 1s - 99s or 1 min - 99 min. (Independent of reactive load).

Customer programmable.

Saving-function of all programmed parameters in case of power outage longer than 40 ms.

Power outage release : automatic disconnection of all capacitors in case of power outage.

Power outage delay time : 90s or 10 min.

Recognition and autocorrection of the phase-rotation of the network and of the CT-terminals.

Insensibility to harmonics.

Ambient temperature : - 10° C to 70 ° C.

Mounting position : vertical panel mounting.

12. OPTIONS

1) Voltage free contact.

2) Door : a fully transparent door is available to protect the front panel. A security key locks the regulator so that it cannot be opened by unauthorised persons.

3) 1 A (RMS) current input for current transformer ratio X/1 (refer to chapter 6 for C/k setting).

4) 24 V supply.

ABB

ABB
Capacitors

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