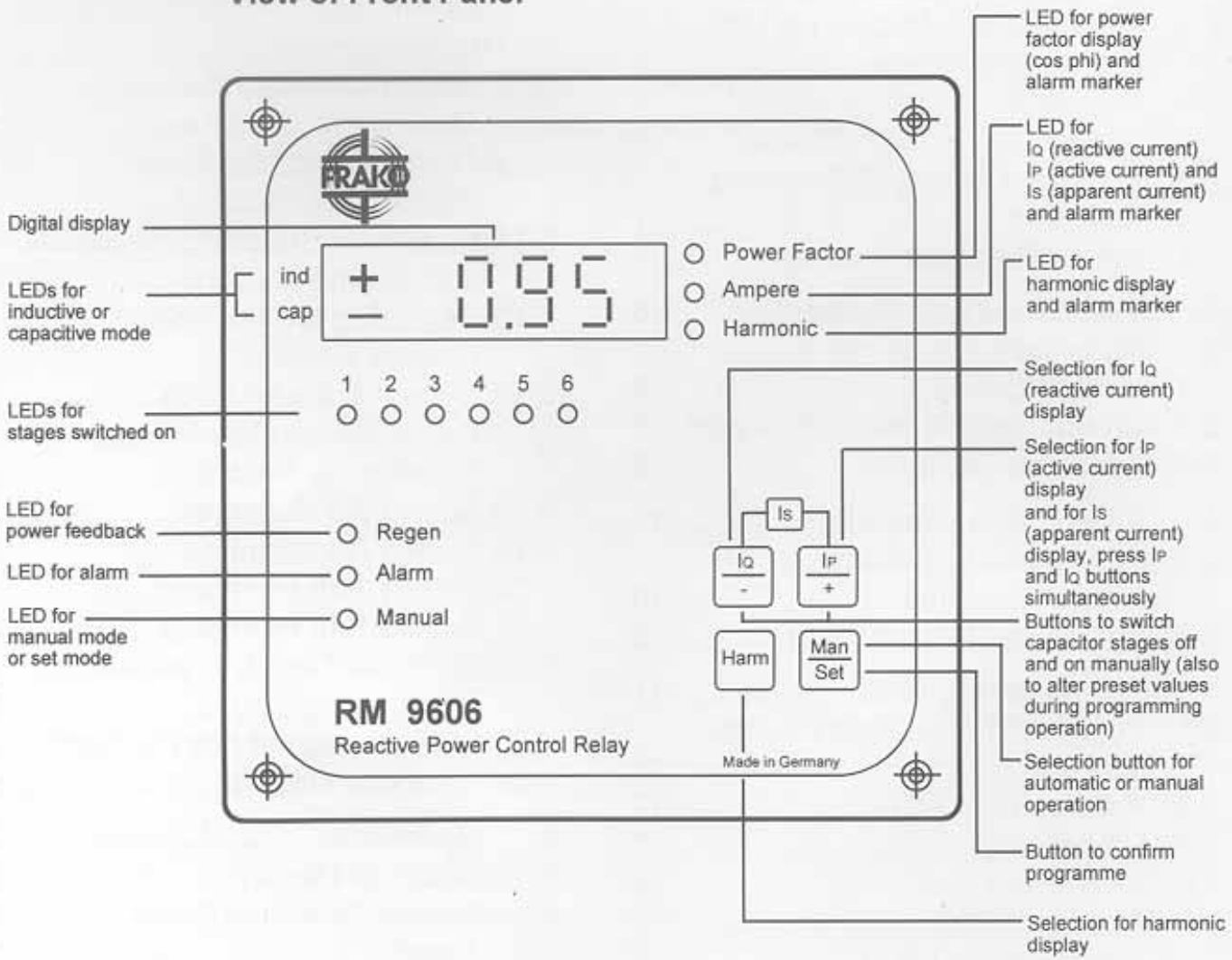
FRAKO Kondensatoren- und Anlagenbau GmbH

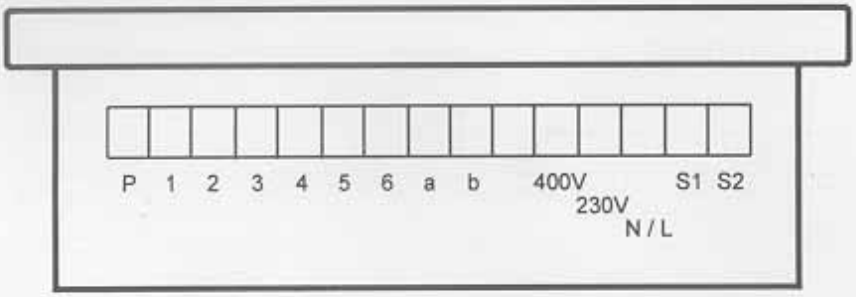
Reactive Power Control Relay Model RM 9606

Operating Instructions

View of Front Panel



View from below



Contents

1. Summary of Instructions

On delivery, the control relay is set to pre-programmed standard values (see Table 1, pages 12-14).
The reactive power control relay RM 9606 is self-regulating (i.e. it detects and adjusts to the voltage phase connection, frequency, and the response current (c/k ratio) automatically.
Before a reactive power control system (capacitor bank) can be put into operation, the target power factor (cos phi rate 1) has to be programmed.

How to programme the control relay:

a) The control relay should be connected as shown in Fig. 1 (see page 9).

b) Apply voltage to the control relay :"---" appears on the digital display. The control relay now identifies the location of the current and voltage source. This process takes at least 2 minutes and a maximum of 15 minutes. If this is not the case, see Pos. 8, page 33. The power factor (cos phi) is displayed.

c) Press the "Set" button for 8 seconds. A "-1-" appears on the digital display and the "manual" LED flashes.

d) By repressing the "Set" button the target power factor (cos phi) is displayed. If necessary, reprogramme to the nearest higher or lower value by pressing either the "+" or "-" button until the required target power factor (cos phi) is displayed.
If no numbers appear on the display then the control relay must be briefly disconnected from the voltage source and then the "Set" button has to be pressed again according to c).

e) To confirm the value press the "Set" button again. A "-2-" will appear on the display.

f) Now press the "-" button twice until "End" appears on the display. Store this value by pressing the "Set" button. The target power factor (cos phi rate 1) is then stored safely in a non-volatile memory.

To prevent unintentional reprogramming, the set mode can only be activated within the first 5 minutes after the operating voltage has been applied. If the set mode has been activated within the first 5 minutes, you have one hour to complete the programming. In order to obtain the set mode again after this period of time the control relay must be briefly disconnected from the voltage source.

Table 1 on pages 12-14 lists all 24 pre-programmed standard values and their programme ranges. The function of the pre-programmed standard values is described in Section 5.

2. Functions

The reactive power and the active power portions of the power source are continuously calculated in the control relay from the measured voltage and the signals of the current transformer. If the reactive power portion exceeds certain threshold values, which the control relay has measured at the time of testing (auto-adaption) or are set as per section 5, a switching action will take place at the switching outputs.

In the case of inductive reactive current (inductive reactive power) one or more control contacts of the reactive power control relay are closed after an adjustable time delay.

This causes the RM 9606 to switch capacitor steps onto the power source supply, as and when required, in order to achieve the programmed target power factor (cos phi). If the inductive reactive current portion of the load is reduced, the excess of reactive current causes the capacitor steps to be switched off line.

The control relay RM 9606 allows a variety of possible settings to meet the conditions on site. The relay's cyclic operation prolongs the life of all connected devices by averaging the length of time that the capacitor stages are switched on.

2.1 Automatic Identification of Voltage and Current Source

When voltage is initially applied to the control relay, it determines the location of the current and voltage sources (automatic phase rotation), i.e. it identifies in which phase and at which phase angle the current path and the voltage path are connected. Should the control relay fail to identify the current and voltage source due to power instabilities, repeat the procedure when the power has stabilized. It is also possible to programme the phasing manually.

> Resetting of the control relay and re-identification of voltage and current sources is initiated by pressing buttons "+", "-" and "Set" simultaneously for at least 8 secs.

2.2 Automatic c/k Identification of Connected Capacitor Stages

Having determined the voltage and current source identification the RM 9606 automatically calculates the c/k identification. During the identification process all the control contacts of the relay are individually switched on and off again. The stage currents ascertained are then stored. These values determine the stage sequence. In this way it can also be determined which switching outputs are in use.

The processes for the automatic identification of voltage and current source and/or the automatic identification of capacitor stages are only carried out when switching on or pressing the combination of buttons for the first time (see section 2.1).

The RM 9606 checks stored stage currents at specific time intervals during normal operation. If it determines that a capacitor stage has failed, this stage (stage without capacitance) will be ignored in future normal operations.

All failed stages are switched on from time to time in order to re-check their capacitance. If a capacitor stage is added later on, or defect fuses are exchanged, the RM 9606 itself identifies this after some time and the stage is then integrated into the normal operation again. However, we recommend that if capacitor stages are added at a later date, the set-up procedure be repeated (see section 2.1).

Important
In case of low voltage networks being fed by several transformers switched in parallel, the capacitor current is distributed to all the transformers. If measurements are not carried out via a summation transformer the current change, measured by the control relay, is too low when switching on the capacitor stages, which can lead to errors during the automatic stage identification process. In such situations we recommend that the stage identification be switched off and the relevant values be programmed manually (see sections 5.5 to 5.8).

2.3 Automatic Setting of Switching Time Delay

In order to keep the wear of the capacitor's contactors down to a minimum the response time of the control relay is lengthened or shortened automatically according to the frequency of the change of the load.

2.4 Power Feedback

The RM 9606 is equipped with a four quadrant control. This means that even when active power is fed back onto the main bus, the control relay ensures compensation for the reactive power which has been drawn from the mains. In this case the LED "Regen" lights up. When power is fed back, no "kinked" characteristic will result (see sections 6.1 to 6.3).

3. Installation and Connection

The reactive power control relay RM 9606 automatically determines the location of the current and voltage sources (automatic phase rotation). It may be connected either to two phases (phase/phase) or to one phase and neutral (phase/neutral).

3.1 Installation

The control relay is inserted through the front of a panel cut-out of 138 mm x 138 mm and screwed tight by fixing screws provided.

Control relays supplied on their own are provided with insulated fixing screws. These can used for installing into switchgear cabinets or cubicles for Protective Class II. Furthermore, a sealing ring is supplied, which must be used when installing in switchgear cabinets or cubicles with Enclosure IP 54.

The pre-mounted terminal connections allow a quick and easy assembly. The control relay is electrically connected by multiple terminal plugs supplied with the relay.

3.2 Voltage Connection

The control relay should preferably be connected to the three-phase system as shown in Fig.1 (page 9).
The supply voltage of the control relay should be connected in the same phase as the contactor voltage.

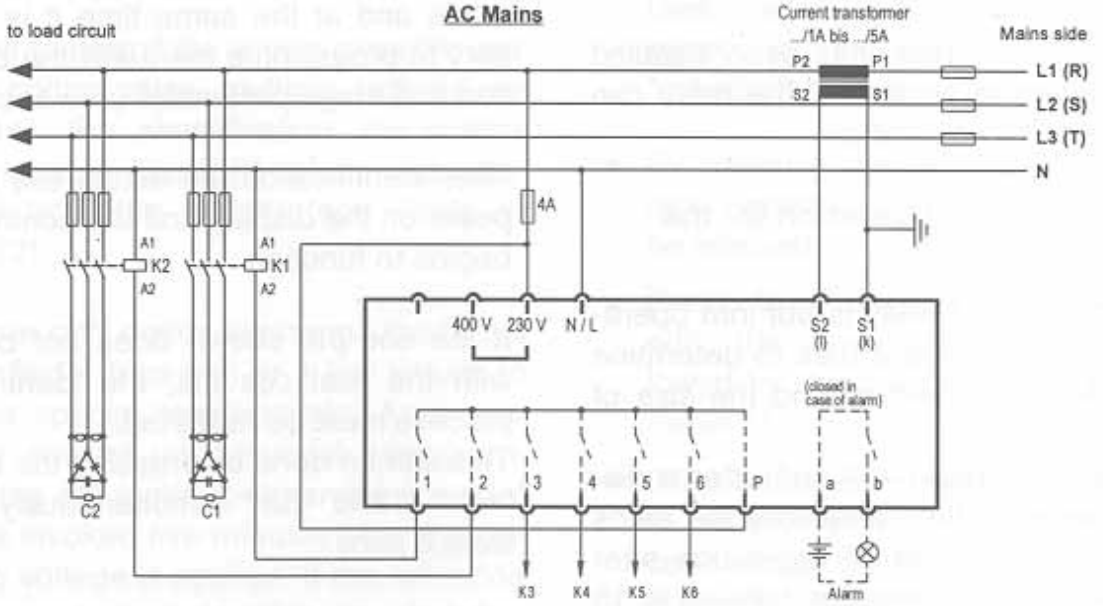
IMPORTANT:
The control relay is designed for a mains voltage supply of 230 VAC and 400 VAC (phase/neutral or phase/phase).
For voltages greater or equal to 400 VAC, a control transformer for the supply of the controller must be used.
It is not allowed to load the switch contacts above 380 VAC max.
Please observe the additional remarks in section 3.4.

3.3 Current Transformer Connection

The outputs S1 and S2 of the current transformer are connected to the terminals S1 and S2 of the control relay. In order to keep the load of the current transformer as low as possible the supply lines should have a cross-section area of 2.5 sq. mm.

Attention:
After connection the short-circuiting bridge must be removed from the current transformer.

Fig 1: Circuit Diagram



3.4 Additional Remarks

The voltage connection of the control relay RM 9606 can also be carried out between phase and phase. In 400 Volt mains supply the connection is carried out at "400 Volt" and "N/L"; in 230 Volt mains supply at "230 Volt" and "N/L" accordingly. In order to maintain the function of the undervoltage monitoring it is absolutely necessary to make sure that the control voltage of the contactors is in the same phase as the control relay supply.

The control relay terminals of the supply voltage and measuring voltage "N/L" and "230 V / 400 V" must be externally protected by fuses. During maintenance work the terminals must be de-energized. The control voltage for the contactors is connected to terminal P. In the control relay this circuit is potential-free.
So as not to overload the control contacts the sum of the holding currents of all the contactor coils connected may not exceed a value of 5 A.

A potential-free alarm signal contact is accessible on the terminals "a" and "b". The contact closes when either there is no mains voltage applied to the control relay or when an alarm is signalled (see section 6.3).

When there is an alarm signal, the LED "alarm" lights up and the relevant LED begins to flash on the control relay.

4. Putting into Operation

After the control relay has been installed as described in section 3, the relay can then be put into operation.

4.1 Putting into Operation for the First Time

When the control relay is put into operation for the first time it tries to determine the mode of connection and the size of the steps.
The display shows "----" and after a discharge time for the capacitors the steps are switched on and off again one after the other. This process can take up to 15 minutes.
If the identification process is not concluded after this time there is probably a fault.
(See section 8, "Trouble Shooting", page 32.)

Note:
In order that the control relay can determine the mode of connection one capacitor stage must be switched on. The control circuit as well as at least one capacitor stage must be fully functional.

It is also possible to discontinue the identification process by switching off the automatic connection and stage current identifications. This takes place in set mode and at the same time it is necessary to programme manually the connection and stage parameter (see section 5).

After identification the actual cos phi appears on the display and the control relay begins to function.

If the cos phi shown does not coincide with the real cos phi, the identification process must be repeated.
This can be done by pressing the buttons "+", "-" and "Set" simultaneously for at least 8 secs.

4.2 Putting into Operation Again

After a mains failure the control relay immediately starts the normal control programme again. The data which were determined whilst being put into operation for the first time are stored in a non-volatile memory.
By pressing the buttons "+", "-" and "Set" simultaneously for at least 8 secs. these data are erased from the memory and the control relay again begins to determine the mode of connection and size of steps.
It is assumed that the automatic connection and stage current identifications are switched on (see section 5).

5. Programming (Set)

In order to permit the widest possible use of the control relay, multiple settings are available. For simplification, the control relay is set to standard values when delivered from the factory (see Table 1, page 12).

The user only needs to change the target power factor (cos phi) or a few values to suit his special requirements. As a protection against unintentional reprogramming, the set mode (programming mode) can be invoked five minutes after the operating voltage is applied. If the set mode has been activated within the first five minutes, it remains available for one hour. In order to reach the set mode again after this period, it is necessary to disconnect the control relay from its source for a short period of time.

The procedure for checking or reprogramming the set values is as follows:

- Press the "man/Set" button for at least eight seconds to switch to the set mode. The display then shows "-1-". This number corresponds to the first variable which is displayed or can be changed in the following sequence (see Table 1). The actual value appears in the display when the "man/Set" button is pressed again.
- By pressing the "+" or "-" button the next higher or next lower setting can be attained.
- Press the "man/Set" button repeatedly; the mode numbers appear followed by the programmed value (see Table 1).
- If the displayed variable does not have to be changed, it is possible to proceed simply by pressing the "man/Set" button or, if the mode number is displayed, by pressing the "+" or "-" button.
- If the "+" button is pressed again after mode number "-24-" appears on the display, or if the "-" button is pressed again after mode number "-1-" appears on the display, then the display will show "End".
- By confirming the display "End" by pressing the "man/Set" button the control relay assumes normal operation; the preset values are then permanently stored in a non-volatile memory.

During the "set mode" none of the capacitor steps are changed and there is no change to the alarm contact.

The significance of the individual variables is described as follows.

Table 1 **Programming of Values**

Programme Mode No.	Description	Pre-programmed standard value	Programme Range
-1-	Target Power Factor Tariff 1	ind 0.92	from cap 0.95 to ind 0.8, in increments of 0.01 steps
-2-	Parallel shift PS Tariff 1	- 1.0 (Target cos phi is lower limit value)	from -2 to +4 in increments of 0.5 steps
-3-	Limitation L Tariff 1	+1.0 (Overcompensation is avoided)	from -2 to +2 in increments of 0.5 steps
-4-	Switching time delay (in secs.) Tariff 1	45	5 to 500 secs. in 1 sec. Steps or at high speed in 5 sec. steps *)
-5-	Automatic c/k identification (ON/OFF)	On	On = automatic mode OFF = manual entry (when"On", the programme switches directly to mode number 13)
-6-	Manual c/k-value setting	2.0	from 0.02 to 2.0 in 0.01 steps or at high speed in 0.05 steps*)
-7-	Switching sequence	1:1:1:1:1	1:1:1:1:1... 1:1:2:4:4... 1:2:3:4:4... 1:1:2:2:2... 1:1:2:4:8... 1:2:3:6:6... 1:1:2:2:4... 1:2:2:2:2... 1:2:4:4:4... 1:1:2:3:3... 1:2:3:3:3... 1:2:4:8:8...

*) By pressing the buttons "+" or "-" for some time, the high-speed mode will be activated.

Table 1 Programming of Values

Programme Mode No.	Description	Pre-programmed standard value	Programme Range
-8-	Number of contactors used	6	from 1 to 6
-9-	Fixed steps	0	0 to 3 0 = no fixed step 1 = Output 1 fixed 2 = Outputs 1 and 2 fixed 3 = Outputs 1 to 3 fixed
-10-	Automatic identification of voltage and current source (ON/OFF)	On	On = automatic OFF = manual When"On", mode 11 can only be read and not changed.
-11-	Enter or read mode of connection	Automatic identification	see Table 2
-12-	Switching-off time (discharge time) in secs.	30	5 to 900 secs. In 1 sec. Steps or at high speed in steps of 5 secs.*)
-13-	Setting cylic/non-cyclic (in series) switching rotation (ON/OFF)	On	ON = cyclic switching OFF = non-cyclic (in series) switching
-14-	Number of switching operations until alarm activates	OFF	from OFF to 1000 The value must be set in thousands of switching operations.
-15-	Cancelling the individual switching operation counters	0	A number from 1 to 6 must be set. When exiting the menu the counter of the corresponding stage number will be erased. „ALL“ erases all counters

*) By pressing the buttons "+" or "-" for some time the high-speed mode will be activated.

Table 1: Programming of Values

Programme Mode No.	Description	Pre-programmed standard value	Programme Range
-16-	Current transformer ratio	1	1 to 6000 in steps of 1 or at high speed in steps of 5 *)
-17-	Primary/Secondary voltage ratio	1	1 to 300 in steps of 1 or at high speed in steps of 5 *)
-18-	5th Harmonic Threshold U5 in %	5	from 1 to 20 % in 0.1 % steps or 0.5 % steps at high speed *)
-19-	7th Harmonic Threshold U7 in %	4	from 1 to 20 % in 0.1 % steps or 0.5 % steps at high speed *)
-20-	11th Harmonic Threshold U11 in %	3	from 1 to 20 % in 0.1 % steps or 0.5 % steps at high speed *)
-21-	13th Harmonic Threshold U13 in %	2.1	from 1 to 20 % in 0.1 % steps or 0.5 % steps at high speed *)
-22-	Switch-off harmonic overcurrent	1.3	from 1,05 to 3.0 times the nominal value in 0.05 steps or 0.1 increments at high speed *)
-23-	cos phi alarm-tripping signal	ON	ON or OFF By setting "OFF" a cos phi alarm can be suppressed.
-24-	Total kvar display	Will only be displayed when in operation.	By pressing "set" button the total applied power in kvar will be displayed.

*) By pressing the buttons "+" or "-" for some time the high-speed mode will be activated.

Table 2: Connection Mode

Mode	CT Location	Transformer Connection S1	S2	Voltage Path L/N	L
0	L1	l	k	N	and L1
1	L1	k	l	L1	and L3
2	L1	k	l	N	and L3
3	L1	l	k	L3	and L2
4	L1	l	k	N	and L2
5	L1	k	l	L2	and L1
6	L1	k	l	N	and L1
7	L1	l	k	L1	and L3
8	L1	l	k	N	and L3
9	L1	k	l	L3	and L2
10	L1	k	l	N	and L2
11	L1	l	k	L2	and L1

Note:

The mode of connection is identical when the current path lies in phase L2 or L3 and the voltage path is phase shifted in the same direction.

Example of mode of connection "3" :

- Current path in phase L2
- Transformer connection k l
- Voltage path L3 and L1

This is also in case when the transformer connection and the voltage path are in the reverse order.

5.1 Setting of Target Power Factor (cos phi)

The desired target cos phi can be set from cap. 0.9 to ind 0.8 in 0.01 steps.

The mode of operation of this adjustment can be seen in Figs. 2 and 3.
If the control relay operates within the band range shown no switching operations will be activated.

However, if the control relay operates outside the band range, the RM 9606 will try to come within the band range with the minimum of switching

Fig. 2 Control response after setting target cos phi = 1; L = OFF; PS = 0

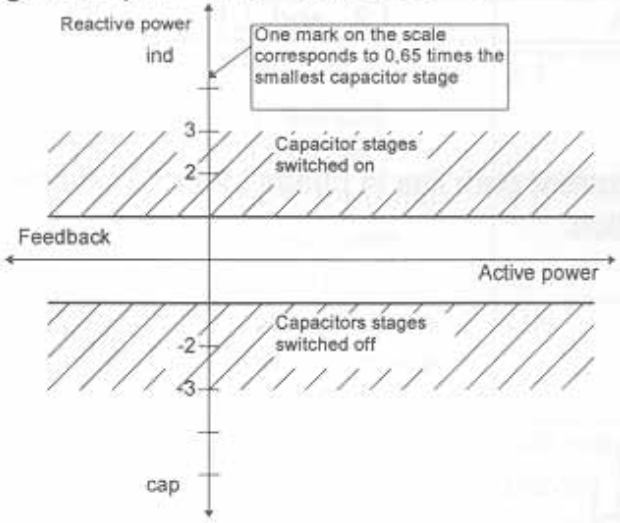
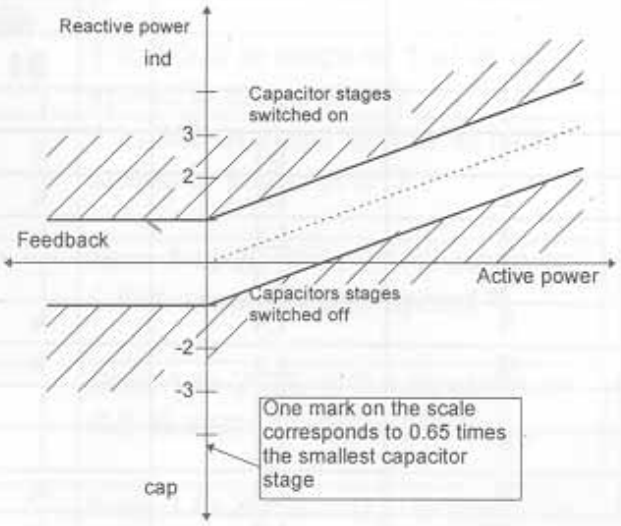


Fig. 3 Control response after setting target cos phi = 0.92 ind; L = OFF; PS = 0



In Fig.3 the behaviour of the control relay during feedback operation can also be seen. The "kink" in the band (characteristic line) is not reflected in the feedback operation but is extended at the point of intersection of the reactive power centre line (axis) with the feedback operation line.

By shifting the band into the capacitive range (see Fig. 5 in section 5.2) the occurrence of an inductive reactive power during the feedback operation can be virtually avoided.

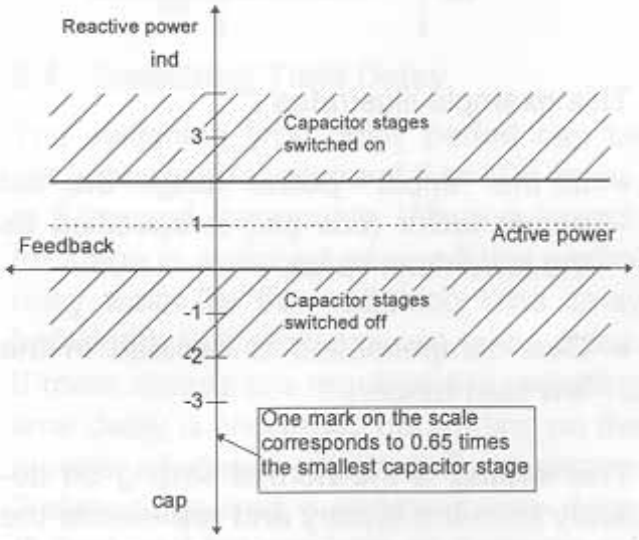
When a capacitive target cos phi mode is set, the control band is reflected on the current side of the feedback side (see Fig. 8).

5.2 Parallel Shift (PS)

This setting causes a parallel displacement (by the value set) of the characteristic shown above and, specifically, in the inductive direction in the case of a positive sign and in the capacitive direction in the case of a negative sign.

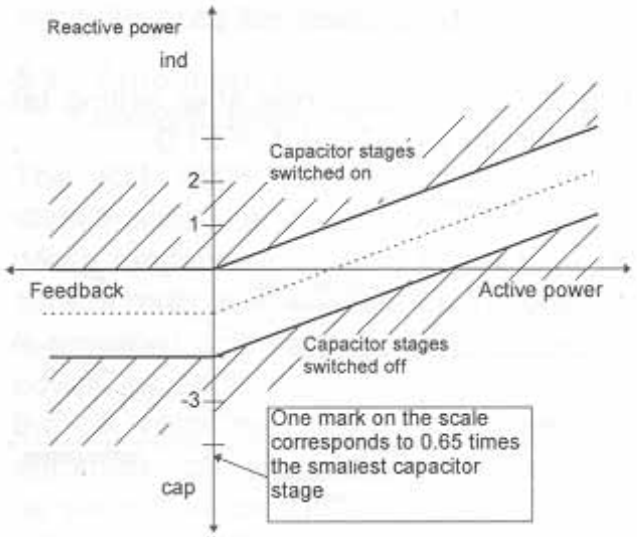
The values -2 to +4 can be set in 0.5 steps. The effects are illustrated by the two examples in Figs. 5 and 6.

Fig. 4 Control response after setting target cos phi = 1; L = OFF; PS = + 1.0



The set target cos phi is therefore the upper limit of the control band.

Fig. 5 Control response after setting target cos phi = 0.92 ind; L = OFF; PS = -1.0



The set target cos phi forms the lower limit of the control band.

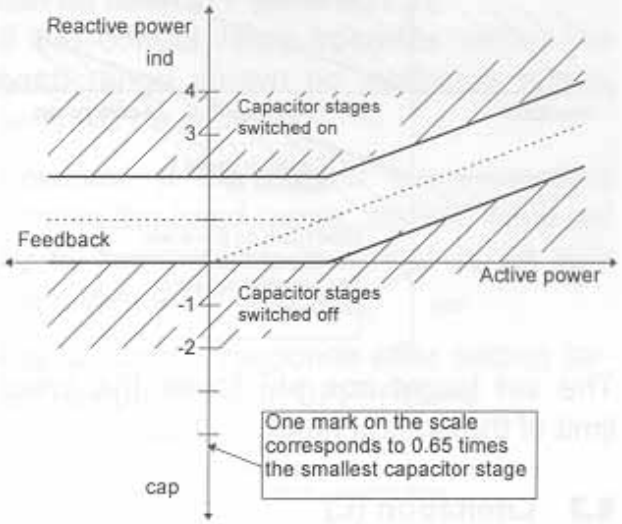
5.3 Limitation (L)

This setting gives new possibilities that could not be attained before due to opposing requirements.

The range of values for L are -2 to +2 in steps of 0.5 and the setting "OFF" and in the case of a target cos phi setting = 1.0 has the same effect as the parallel displacement (paragraph 5.2). For a target cos phi setting other than 1,0 there is a "kinked" characteristic as shown in Fig. 6.

The limitation therefore specifies an absolute reactive power limit, below which the control band does not go.

Fig. 6 Control response after setting target cos phi = 0.92 ind; L = +1.0

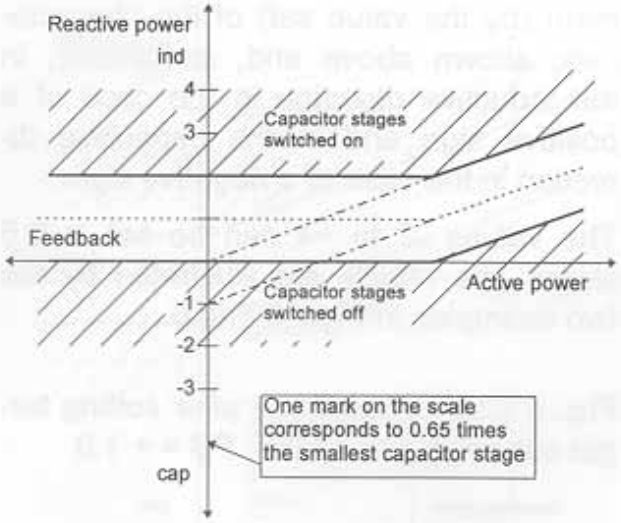


This setting has the following effects:

- The cos phi set is attained, on the average, in the "upper" power range.
- Over-compensation (capacitive load) is avoided in the low load range.

An appropriate combination of "parallel shift" and "limitation" is illustrated in Fig. 7.

Fig. 7 Control response after setting target cos phi = 0.92; PS = - 1,0; L = +1,0



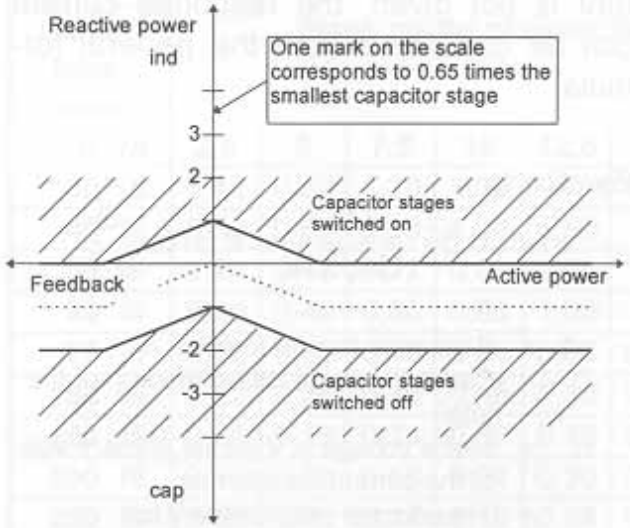
This example illustrates :

- In the "upper" power range the set power factor (cos phi) is specified as the lower limit value.
- Over-compensation is avoided in the low load range.

This setting is the normal setting on delivery from the factory and represents the best possible control characteristic for most applications.

The following Figure shows the characteristic of the control band when set for a capacitive target cos phi.

Fig. 8 Control response after setting target cos phi = 0.95 cap; L = -1,0; PS = 0



5.4 Switching Time Delay

The switching time delay period can be set between the values of 5 to 500 secs. in 5 second increments. When a capacitor stage is switched on or off the control relay waits for the switching time delay before the switching process takes place. If more stages are required the switching time delay is shortened depending on the number of stages required. For example: 2 stages required = switching time delay /2 (reduced by one-half) or 3 stages required = switching time delay /3 (reduced by one-third.)

In order to keep the wear on the contacts to a minimum, the switching delay time should be set to less than 45 secs. in exceptional cases only. The discharge period, which ensures that the capacitors are fully discharged before they are switched on again, overrides the switching delay time (see paragraph 5.12).

5.5 Automatic Stage Current (c/k) Identification On/Off

The RM 9606 has an automatic c/k identification, i.e. it calculates the appropriate response current the first time the control relay is energized. This procedure is repeated until the amount of capacitive power for each stage is determined and the c/k value has been calculated. The automatic c/k identification feature can be set to "On" or "Off".

When set to "On" the RM 9606 operates with the stage currents that the control relay has automatically calculated and when set to "Off", the c/k value can be programmed manually according to Table 3, on page 21.

5.6 Response Current (c/k)

The control relay RM 9606 calculates a control characteristic from the cos phi, the parallel shift and the limitation (in Figs. 2-8 shown as a dotted line) and has a tolerance band of 0.65 times the smallest stage in inductive as well as in capacitive direction (marked with bold line). The relay consistently achieves this control band by switching on and off systematically. It is assumed that the connected capacitor stages are sufficiently dimensioned.

The response current corresponds to half the width of the tolerance band, within which the reactive current can change without capacitor stages being switched on or off.

This is essential to ensure that the system does not oscillate. The total width of the tolerance band is selected in such a way that it corresponds to approx. 1.3 times the reactive current of the smallest capacitor stage.
The response current can be set between 0.02 and 2.0 A in steps of 0.01 A. The correct setting for a 400 V voltage system and a current transformer with 5A secondary current can be taken from Table 3.

In the case of other voltages or current transformers for which the primary current is not given, the response current can be calculated from the general formula:

Equation 1:

$$c/k = 0{,}65 \cdot \frac{Q}{U \cdot \sqrt{3} \cdot k} \approx 0{,}375 \cdot \frac{Q}{U \cdot k}$$

c/k = Response current to set in A
Q = Capacitor **stage rating** in var (not the total)
U = Mains voltage in V on the primary side of the current transformer
k = Transformer ratio (primary cur rent/secondary current)

Table 3: Response Current at mains voltage 400 VAC - 50 Hz

Current transformer A /A	c/k-adjustment for mains voltage 400 VAC, 50 Hz~ **Stage rating of capacitor bank** (not total rating) in kvar												
	2,5	**5**	**7,5**	**10**	**12,5**	**15**	**20**	**25**	**30**	**40**	**50**	**60**	**100**
30 /5	0,40	0,80	1,20	1,60									
40 /5	0,30	0,60	0,90	1,20	1,50								
50 /5	0,24	0,48	0,72	0,96	1,20	1,44							
60 /5	0,20	0,40	0,60	0,80	1,00	1,20	1,60						
75 /5	0,16	0,32	0,48	0,64	0,80	0,96	1,28	1,60	1,92				
100 /5	0,12	0,24	0,36	0,48	0,60	0,72	0,96	1,20	1,44	1,92			
150 /5	0,08	0,16	0,24	0,32	0,40	0,48	0,64	0,80	0,96	1,28	1,60	1,92	
200 /5	0,06	0,12	0,18	0,24	0,30	0,36	0,48	0,60	0,72	0,96	1,20	1,44	
250 /5	0,05	0,10	0,14	0,19	0,24	0,29	0,38	0,48	0,58	0,77	0,96	1,15	1,92
300 /5	0,04	0,08	0,12	0,16	0,20	0,24	0,32	0,40	0,48	0,64	0,80	0,96	1,60
400 /5	0,03	0,06	0,09	0,12	0,15	0,18	0,24	0,30	0,36	0,48	0,60	0,72	1,20
500 /5	0,02	0,05	0,07	0,10	0,12	0,14	0,19	0,24	0,29	0,38	0,48	0,58	0,96
600 /5		0,04	0,06	0,08	0,10	0,12	0,16	0,20	0,24	0,32	0,40	0,48	0,80
750 /5		0,03	0,05	0,06	0,08	0,10	0,13	0,16	0,19	0,26	0,32	0,38	0,64
1000 /5		0,02	0,04	0,05	0,06	0,07	0,10	0,12	0,14	0,19	0,24	0,29	0,48
1500 /5			0,02	0,03	0,04	0,05	0,06	0,08	0,10	0,13	0,16	0,19	0,32
2000 /5				0,02	0,03	0,04	0,05	0,06	0,07	0,10	0,12	0,14	0,24
2500 /5					0,02	0,03	0,04	0,05	0,06	0,08	0,10	0,12	0,19
3000 /5						0,02	0,03	0,04	0,05	0,06	0,08	0,10	0,16
4000 /5							0,02	0,03	0,04	0,05	0,06	0,07	0,12
5000 /5								0,02	0,03	0,04	0,05	0,06	0,10
6000 /5									0,02	0,03	0,04	0,05	0,08

In case the stage sizes, the current transformer or the rated voltage of the capacitor bank do not coincide with the values in the above table, then the formula on page 20 must be used to calculate the c/k value.

5.7 Switching Sequence

When the automatic c/k identification is switched on every optional switching sequence is possible. Necessary condition: Every multiple of the smallest stage must be possible by switching an optional number of connected stages.

If the automatic c/k identification is switched off, the switching sequence (switching programme) can be reset to the following combinations of capacitor stages:

1:1:1:1:1...	1:1:2:4:4...	1:2:3:4:4...
1:1:2:2:2...	1:1:2:4:8...	1:2:3:6:6...
1:1:2:2:4...	1:2:2:2:2...	1:2:4:4:4...
1:1:2:3:3...	1:2:3:3:3...	1:2:4:8:8...

The smallest capacitor stage is always "1"; the subsequent stages are either the same (1:1:1...) or are larger. In the second line above a more accurate result can be achieved with the same number of switching contactors.
Capacitor steps of the same size are switched cyclically, i.e. a step which has just been switched off will only be switched on again after all the other steps have been switched on. This achieves the most even contact switching.

5.8 Number of Contactors Used

When the automatic c/k identification is switched off, any value between 1 and 6 can be programmed. If, for example, there are five stages in a capacitor bank, these stages are connected to the control outputs "1" to "5" and the number of the control outputs is programmed to "5". This prevents the control relay from activating control outputs which are not connected.
The capacitor switching sequence is of no importance for this setting.

5.9 Specifying Fixed Steps

The control relay RM 9606 allows the first three control outputs to be treated as fixed steps. Fixed steps are steps which are not included in the normal control cycle but are switched on immediately after the control relay is switched on and always remain switched on. The set discharge period is maintained. The target cos phi setting is ignored.
The following settings are possible:

0 = No fixed steps
1 = Control output "1" is fixed
2 = Control outputs "1" and "2" are fixed
3 = Control outputs "1" to "3" are fixed

The switching sequence does not take into account the fixed steps.

5.10 ON/OFF Connection Identification

The control relay has an automatic connection identification feature (refer to section 2.1). The following adjustments are possible:

- Connection identification "ON"
- Connection identification "OFF"

When "ON" is set the connection recognised by the control relay can be read under the mode number 11 in accordance with Table 1 (not variable). When "OFF" is set the connection is manually programmed according to Table 2.

5.11 Connection Mode

Normally the connection mode should be set to automatic operation. If however, the control relay fails to determine the connection mode after 15 minutes due to very high load changes or phase imbalances, it should be entered manually in accordance with Table 2.

5.12 Setting Capacitor Discharge Time

In order to ensure that after switch-off, a capacitor step is not switched on again before the capacitor has been sufficiently discharged, the switch-off time can be set. The switch-off time can be set from between 5 and 900 seconds.

5.13 Setting Cyclic/Non-Cyclic Switching Rotation

In certain cases, for example when there are filtered and non-filtered steps within one system, it is necessary to ensure that the control relay does not operate cyclically. For such applications, this feature can be disconnected. This means:

ON: Cyclic switching is possible when there are at least two switching steps of the same size.

OFF: No cyclic switching; the steps are switched on in series starting with the lowest rating. The lower step ratings are always selected first.

5.14 Number of Switching Processes until Alarm Functions

In order to help when maintaining the capacitor bank the RM 9606 has a counter for each switching process. Whilst in manual operation the actual reading on the counter for each stage can be seen (see paragraph 6.2). By selecting the maximum number of switching processes the control relay itself indicates when maintenance is required. The stage which has exceeded the limits is indicated by flashing (about every 10 secs), on the display (e.g. "St. 4" for the 4th stage). At the same time an alarm signal is given. To cancel the alarm

signal please see description in paragraph 5.15.
Before entering the number of switching processes this number must be divided by 1000. This means for example, for 100,000 switching processes for one stage the number 100 has to be entered before the alarm is triggered.
The fact that an alarm is indicated for a stage has no influence on the behaviour of the RM 9606.

5.15 Cancelling the Switching Process Counter

The switching process counters can be cancelled individually or jointly.
If Programme Number 15 is selected the reading "0" appears on the display. Using the buttons "+" or "-" a stage number between 1 and 6 or "ALL" can be selected. When exiting this programme number by using the button "man"/Set" the last stage number to be shown on the display will be cancelled. The appearance of "ALL" on the display indicates that all counters have been cancelled.

If none of the counters are to be cancelled the display has to be switched back to "0".

5.16 Current Transformer Ratio

In order to display the active current (IP), reactive current (IQ) and apparent current (IS) as actual values, the ratio between the primary current and the secondary current of the current transformer used must be entered. If the current transformer ratio is not entered, the value displayed must be multiplied by the current transformer ratio.
Values between 1 and 7000 can be entered (e.g. 1000/5A → 200).

5.17 Primary/Secondary Voltage Transformer Ratio

If a voltage transformer is used in a measuring circuit the primary/secondary voltage transformer ratio must be entered in order to enable the "missing kvar rating to target cos phi" to function.

The ratio of the primary/secondary voltage should be entered. If there is no voltage transformer the value "1" must be entered. Programmable primary/secondary voltage ratios range from 1 to 300.

5.18 Setting 5th Harmonic Threshold

The control relay RM 9606 has a harmonic monitoring system for the 5th, 7th, 11th and 13th harmonics. If the limiting value is exceeded, there is an alarm signal, i.e. the alarm contact closes and the "Alarm" LED lights up for as long as the limiting value is exceeded. The

"Harmonic" LED flashes until the alarm is switched off. The order and the maximum value of the harmonics which have been exceeded are displayed by pressing the "Set" button several times. The "Set" button must be pressed repeatedly until the flashing "Harmonic" LED goes out.

5.19 Setting 7th Harmonic Threshold

In this case, the limiting value for the 7th harmonic is programmed.

5.20 Setting 11th Harmonic Threshold

In this case, the limiting value for the 11th harmonic is programmed.

5.21 Setting 13th Harmonic Threshold

In this case, the limiting value for the 13th harmonic is programmed.

5.22 Harmonic Over-Current Signal

The control relay RM 9606 is able to determine the ratio between the rms current and the fundamental ripple current (50-60 Hz) in the capacitor. If this ratio is exceeded by the set value for at least one minute, due to harmonics and the resulting amplifications caused by resonances, then the control relay switches off all the stages that are switched on. At the same time the alarm goes off. After about 4 minutes the capacitor stages required are switched on again.

By pressing the "Set" button the maximum value appears on the display.

In the case of filtered stages being used for compensation, set this threshold to the highest value (hence inactive).

5.23 Suppressing the cos phi Alarm

As already mentioned, the control relay tries to attain the prescribed control band. If this is not possible, because insufficient capacitor stages are available, an alarm is indicated after some minutes (depending on the amount of deviation. Also an alarm is indicated if there is a capacitive cos phi outside the control band.
By selecting "OFF" the alarm indication can be suppressed.

5.24 Total kvar Display

Provided the current transformer ratio has been entered, the total kvar will appear in the display, when the "Set" button is pressed according to Mode 24.

6. Operation

6.1 Modes of Display

The choice of displays is independent of the control relay operation and can be reprogrammed at any time. To the right of the digital display there are three LED's indicating which display mode is active, either "Power Factor (cos phi)", "Ampere" or "Harmonic".
Five modes of display can be selected by pressing the appropriate button:

6.1.1 Actual Power Factor (cos phi)

The power factor display (LED "Power Factor" (cos phi) is on) is the standard display. It can be activated from another mode of display by pressing buttons "IQ", "IP" or "Harm".
The symbols "+" for ind. and "-" for cap. show whether the power factor is inductive or capacitive. The LED "Regen" indicates that the power is regenerative. Active and reactive currents are measured separately. The fundamental oscillation portions (50-60 Hz) of both measured variables are filtered out mathematically and used to calculate the cos phi. This ensures accuracy over the entire range down to a cos phi value of 0. The minimum apparent current for a correct power factor (cos phi) display is approx. 0.02 A. When the apparent current falls below 0.02 A for three consecutive measurements one capacitor step is switched off and if there is no change in the measured current, all remaining steps are switched off and "I=0" appears on the display.

6.1.2 Reactive Current (IQ)

The display indicates the reactive current portion in the current transformer circuit. The "+" or "-"LEDs indicate whether the current is inductive or capacitive. The LED "Ampere" lights up.
From this mode of display, the effect of adding or removing capacitor steps manually can be monitored.
If the current transformer ratio (k) is programmed via the set mode the actual reactive current is displayed; otherwise the current portion is displayed and has to be multiplied by the current transformer ratio to obtain the actual value. Press "IQ", "IP" or "Harm" to exit the display.

6.1.3 Active Current (IP)

This display shows the active current on the fundamental oscillation in the current transformer circuit. The LED "Ampere" lights up.

The current direction is also displayed, which is helpful during tests. The LED "Regen" shows that the generative active power is fed back into the mains.
If the current transformer ratio (k) is programmed into the relay, the actual active current is displayed; otherwise the current portion is displayed and must be multiplied by the current transformer ratio to obtain the actual value. Press buttons "IQ", "IP" or "Harm" to exit the display.

6.1.4 Apparent Current (IS)

By pressing the "IQ" and "IP" buttons simultaneously the apparent current of the fundamental oscillation in the current transformer circuit is displayed. The LED "Ampere" lights up.
If the current transformer ratio is programmed via the set mode, the apparent current is displayed; otherwise the current portion is displayed and must be multiplied by the current transformer ratio to obtain the actual value.
Press buttons "IQ", "IP" or "Harm" to exit the display.

6.1.5 Harmonics

This display shows the 5th, 7th, 11th and 13th harmonics on voltage. The previous harmonic reading appears on the display in % and the LED "Harmonic" lights up. By pressing the "+" or "-" buttons several times the display either cycles in ascending or descending order. For example, if "5. 2.9" appears on the display, this means that the 5th harmonic is contained in the voltage to a portion of 2.9% of the fundamental.
Press the button "Harm" to exit the display.

6.2 Manual Operation (man)

When the "man/Set" button is pressed for more than 3 secs. the control relay switches to manual operation and the LED "manual" begins to flash. The capacitor steps can be switched on or off by pressing the "+" or "-" button. By

pressing the button "+" or "-" the steps to be switched can be selected. The stage number (e.g. "1.ON") appears on the display. After about 12 secs. (do not press any buttons during this time) this stage will be switched on. If this stage was already switched on then "1. OFF" will appear in the display. After about 12 secs. this stage will be switched off. Then the display will change to the last displayed value.
During this "waiting time of 12 secs." the switching counter of this stage will be shown. The value is given as factor 0.001 and as far as possible values after the decimal point will be given. This means, for example:
"0.350" corresponds to 350 switching operations.
By pressing the "+" button several times stages 2 - 6 will appear in ascending sequence on the display. They can be switched on/off in the same way. In manual mode the programmed switching off time (discharge time) is taken into consideration, i.e. when switching on a step which was previously switched off the switching-off time is the same as the discharge time. If a stage was identified as a zero stage (without power) the corresponding numbers would indicate this by flashing.
Press "man/Set" button to exit manual mode.

6.3 Alarms

The potential-free alarm contact (a/b) closes whenever the operating voltage is not applied. In the case of the correct operating voltage the contact closes if there is an alarm. The conditions for an alarm can be seen in paragraphs 6.3.1 to 6.3.6.
The LED "Alarm" lights up for as long as a state of alarm exists. When an alarm is signalized, an alarm marker is put into action (LEDs "power factor", "Ampere" or" Harmonic" will flash or there is an indication on the display. The alarm markers remain active after the alarm until they are acknowledged by pressing the "Set" button.
After acknowledgement the flashing alarm marker goes out.
The alarm signals have no influence on the control behaviour or performance of the control relay.

6.3.1 cos phi Alarm

If the threshold values set for "switch-on" and "switch-off" are exceeded and no further change can take place in the output steps, the alarm signal functions. (Exception: when the cos phi alarm is switched off; see mode no. 23, page 14).
By pressing the "Set" button the amount of capacitive or reactive power missing to reach the target power factor is flashed by the display.

Pressing the "Set" button again shows the actual power factor in the display and the alarm marker "cos phi"(Power Factor) no longer flashes.

6.3.2 Harmonic Alarm

When the programmed threshold values are exceeded the alarm goes off. By pressing the "Set" button several times the display shows the order and the maximum values of the exceeded harmonics starting with the maximum deviation. The button "Set" must be pressed repeatedly until the "Harmonic" alarm marker no longer flashes.

6.3.3 Over-current Alarm

If the ratio between the rms current value and the fundamental wave current (50-60 Hz) in the capacitor is exceeded by the programmed factor, the alarm goes off. By pressing the "Set" button the display shows the maximum value of the ratio. By pressing the "Set" button again the display shows the actual power factor (cos phi) and the alarm marker "Ampere" no longer flashes.

Attention: The over-current ratio is only a computed value and cannot be applied to systems with filter circuits.

6.3.4 "U=0" Alarm

The voltage applied during automatic identification is stored by the control relay as rated voltage.
In order to use the control relay again at 230 VAC after it has been in operation at 400 VAC it is necessary to wait until "U=0" appears on the display. By pressing the buttons "+", "-" and "man/Set" simultaneously for about 5 secs. the new voltage (in this case 230 VAC) can be accepted as rated voltage.

6.3.5 "C=0" Alarm

If the control relay does not recognise a capacitor stage during the processes for the automatic identification and recognition of connected capacitor stages this is shown by the "C=0" indicator and an alarm.
The attempts to recognize are carried out inspite of the indication.

6.3.6 "I=0" Signal

If there is an interruption in the current path for at least 3 secs. the control relay immediately switches off a capacitor step. If no change in the current results, the steps which are still on are then switched off.
No alarm is triggered off.

7. Technical Data

Mode of Connection:
Phase/Phase connection or Phase/Neutral connection. Current via current transformer in optional phase (see Fig. 1, page 9).

Operating Voltage:

Supply Voltage	Mains Connection Voltage	Absolute permissible/threshold values
230 - 400 V	220 to 400 V	198 ... 462 V

Attention: The terminals for 230 V and 400 V are internally bridged.

Frequency:
50 Hz / 60 Hz (48 to 62 Hz).

Consumption of Supply Voltage:
Approx. 9 / 11 VA at 0 / 6 switched-on control contacts.

Current path:
For current transformer ... / 1 A to ... / 5 A.

Consumption in Current Path:
Max. 1,8 VA at 5 A transformer rated current.

Control Contacts:
6 potential-free contacts.

Loading Capacity of the Control Contacts:

Switching voltage	
acc. to VDE 0110 Group B	380 VAC
acc. to VDE 0110 Group C	250 VAC
Total switching current	5 A max.
Switching load	1800 VA max

Fault Signal Contacts:
Loading capacity as control contacts.

No-Voltage Trip (Undervoltage Monitoring):
For a voltage loss of longer than 15 ms all capacitor stages connected are switched off. After voltage is restored the control relay switches the required steps on.

Zero Current Trip:
For a current loss of longer than 3 secs. capacitor stages connected are switched off. After current is restored the control relay switches the required steps on.

Operating Elements:
Foil keyboard with 4 buttons.

LED Indicators:
12 LEDs
4 1/2 character digital display

Temperature Range:
-25^0 C to $+60^0$ C according to DIN VDE 0660, Part 500, para. 6.1.1.1.

Casing:
Black synthetic plastic.
Flame-resistant to UL-94, Class VO.

Fastening:
Through the front panel by means of a screwdriver.

Front Panel:
144 x 144 mm (to DIN 43 700)

Panel Cut Out:
138 x 138 mm (to DIN 43 700)

Mounting Depth:
40 mm

Weight:
approx. 0,9 kg

Mounting Position:
as desired

Terminals:
Plug-in connector blocks
(supplied with the control relay).

Enclosure:
Terminals IP 20
Casing IP 54
(when using sealing ring)

Design:
to VDE 0160, Protective Class II,
Insulation Group B
(when using insulated fastening screws).

Fusing:
External required.

8. Trouble Shooting

Pos.	Faults	Possible Causes	Necessary Action
1	Control relay does not function, digital display remains blank.	There is either no voltage or the wrong voltage has been applied to the control relay.	Check whether the correct operating voltage is applied to the control relay.
2	"U=0" flashes on the display for some time.	The operating voltage applied to the relay is too low.	Check the operating voltage. If the voltage is correct press the buttons "+", "-" and "Set" to recognise this voltage as rated voltage.
3	Relay does not respond to manual operation, in spite of having voltage and digital display is operational.	End of delay time of approx. 10 secs. was not observed.	For example, if "1.ON" appears on the display wait until the control relay has switched on the first step.
		Relay was not in manual mode.	"Man" button must be pressed until the LED "manual" flashes.
4	Step display (LED 1-6) lights up but capacitor contactors are not activated.	Control circuit is not connected properly or there is no control voltage.	Check the control circuit according to the circuit diagram and check fuses.
		There is no neutral on the contactors.	
5	Control relay does not complete the automatic identification process.	Unstable power supply (power factor fluctuation).	Wait for power supply to stabilize and set c/k factor and mode of connection manually.
6	"C=0" appears on the display during the automatic identification process.	Fault in control circuit (Contactors do not switch on.)	Check the control circuit according to the circuit diagram and check fuses.
		Capacitor stage fuses are missing or are defect.	Check whether voltage is applied to the capacitors after the switching process.
		Current transformer is mounted on the wrong place.	Check whether the position of the current transformer corresponds with that on the circuit diagram.
7	"I=0" flashes on the display.	Current transformer wire is disconnected.	Use ammeter to check current in current path (1 min ≥0,02A).

Pos.	Faults	Possible Causes	Necessary Action
8	Despite inductive load no steps are switched on when relay is in automatic mode.	When programming the c/k factor of the control relay, the switching time delay or discharge time have been set too high.	Check programming of control relay and change if necessary.
		In automatic operation the circuit c/k factor was not correctly identified.	Check the control according to the circuit diagram and repeat the automatic test procedure.
		Another current measuring meter (e.g. ammeter) was connected in parallel with the control relay's current path.	The current paths of the various measuring instruments must be connected in series.
9	In automatic mode one stage is continually switched on or off (hunting).	The c/k factor was set too low.	Correctly set c/k factor according to the table.
		High load change; The delay time was set too low.	Set higher delay time.
10	The cos phi display is less than the target cos phi, although the control relay has switched on all stages.	Mode of connection incorrectly programmed.	Reset mode of connection.
		Fault in control circuit.	Check whether the capacitor contactors have been energized.
		Fault in capacitor circuit.	Check the fuses and contacts of the capacitor contactors. Measure the current of each capacitor stage with a clamp-on current meter.
		System undersized.	Press "Set" button and read the missing power from the display.
		Failure in identification process.	Repeat identification process.
11	Control relay does not switch off all stages during times of low load or facility shut-down.	c/k factor set too high.	Set c/k factor according to the table.
		Control relay is in manual mode.	Press "Man" button.

FRAKO Kondensatoren- und Anlagenbau GmbH

Reactive Power Control Relay Model RM 9606

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Power factor correction capacitors
Capacitors for power electronics
Reactive VA control systems
Reactive power control relays
Filter circuits
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Network analyzers
Energy management systems
Capacitors for discharge lamps

Quality is our Motto
Quality has a Name
We are certified for DIN ISO 9001
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