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BR6000-T DYNAMIC POWER FACTOR CONTROLLER — MANUAL

Installation, programming, control principle, MODBUS interface,
troubleshooting and technical data

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< 20 ms

switching time, several steps at once

6 / 12

transistor outputs for TSM-LC modules

30 – 525 V

measuring voltage L-N or L-L

20

pre-programmed control series + editor

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GENERAL, TYPES AND ACCESSORIES

The dynamic power factor controller BR6000-T is the consequent development of the BR6000 series, now in V6. It has been designed to control thyristor modules for dynamic switching of power capacitors (for example TSM-LC). A very fast processor gives extremely short switching cycles; in addition to a switching time under 20 ms, the intelligent control principle tunes the power factor by simultaneous switching of several steps. Operation is menu-guided in plain text with symbols in 10 local languages.

✓ Main features

- Six or 12 switching outputs (depending on the type)
- Measuring voltage 30 ... 525 V (L-N) or (L-L); supply voltage 110 ... 230 V AC

- 20 pre-programmed control series with self-optimised intelligent control response, plus a control-series editor
- Complete menu-guided operation and display (10 languages); illuminated graphic display 2 × 16 characters
- Four-quadrant operation; display of V, I, F, Q, P, S ...; display and monitoring of temperature
- Monitoring of capacitor power values with the accessory MMI6000; storage of maximum line parameters
- Manual / automatic operation; programming of fixed stages and skipping of individual outputs
- No-voltage turn-off; error detection for various states with interference-message output
- Complete 2nd parameter set, programmable / switchable; switchboard-integrated housing 144 × 144 × 55 mm

Type series

TYPE	OUTPUTS	EXTRAS
BR6000-T6	6 transistor outputs	1 alarm relay
BR6000-T12	12 transistor outputs	1 alarm relay
BR6000-T12/S	12 transistor outputs	additional message relay; external input (e.g. for the 2nd parameter set); RS485 interface, controller coupling possible

Accessories

ACCESSORY	PURPOSE
MMI6000 – MultiMeasuringInterface	measurement of the inherent current of the capacitor bank
Interface converter RS485 → USB	PC connection
Interface converter RS485 → RS232	older PCs



Caution

The controller is supplied for an operating voltage of 110 ... 230 V AC (±15 %), a measuring voltage of 30 ... 525 V AC (L-N or L-L) and a measuring current of 5 A or 1 A (programmable). A voltage converter is required for other operating voltages. Voltages which exceed the allowed range can damage the device.

2 INSTALLATION AND CONNECTION

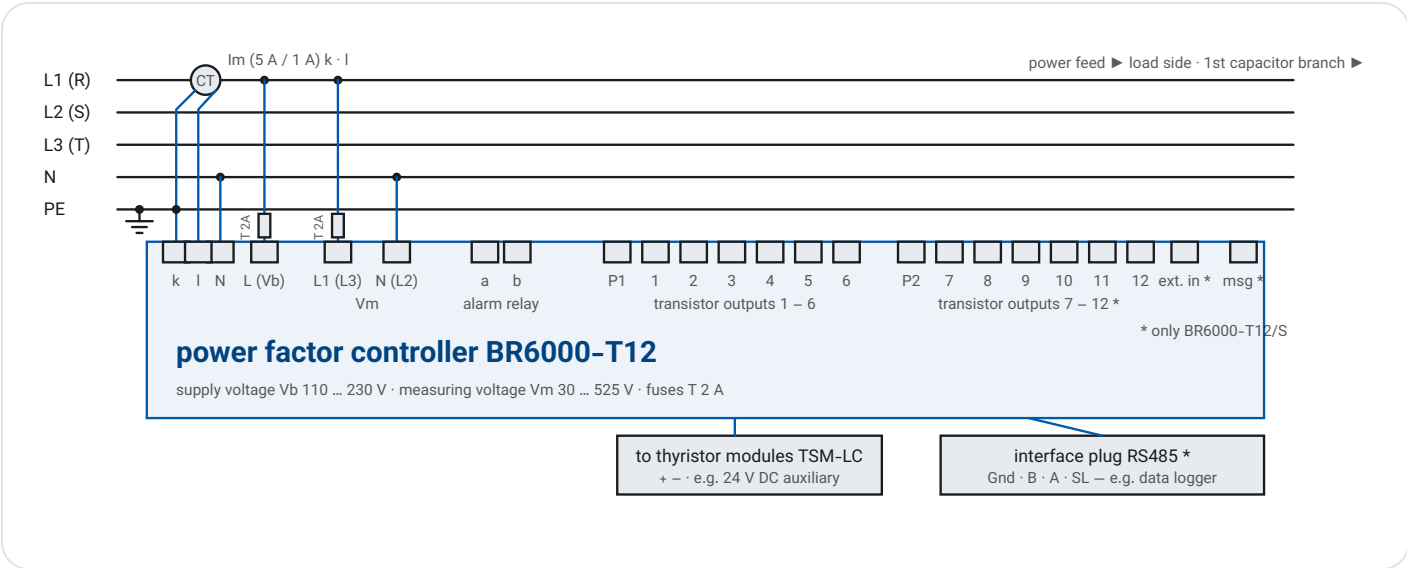
The BR6000 is built into the front panel of a PFC cabinet: it needs a switchboard section of 138×138 mm (DIN 43700 / IEC 61554), is inserted from the front and fixed with the appended clamps. Only qualified technicians may insert it, observing the specified safety regulations. Before connection, check that no current flows through the leads and short-circuit the current converter. Make sure measuring voltage and current are in the correct phase position; wire the measuring-current circuit with 2.5 mm^2 copper leads.

Inside the controller — what sits behind the panel cut-out



The exploded view above is an illustration prepared for this edition, not a manufacturer's service drawing; the numbers belong to the illustration and are not manufacturer part numbers. 1 Front bezel and keypad · 2 LCD display module · 3 Processor and control section (illustrative) · 4 Voltage and current measurement circuitry · 5 Transistor step-output circuitry · 6 Power-supply section · 7 Pluggable terminal connectors · 8 Rear housing and panel mounts. The exterior is taken from a photograph of a BR 6000 whose T6 / T12 suffix is not visible, and the transistor step-output section is drawn generically: the number of outputs actually fitted cannot be read from the front panel. Illustrative exploded view; not to scale. Catalog dimensions and identity limitations are listed separately. Internal geometry and OEM subcomponent part numbers are unverified.

Fig. 3 – BR6000 connection plan



Measuring voltage 30 – 525 V between L – N (default – L1 – N in the figure) or between L – L (the alternative L3 – L2, programming of the phase correction needed). Operating voltage 110 ... 230 V ±15 %, between L – N or L – L depending on the grid; the L of Vb and the L1 of Vm are each taken through a T 2 A fuse.

Current measurement

The load current must flow through the current converter; the outputs of the compensation network are installed behind the converter in the direction of current flow. With sum-current converters the overall conversion ratio is entered – example: converter 1 = 1000/5 A, converter 2 = 1000/5 A, sum converter 5 A + 5 A / 5 A → ratio 2000/5 A.



Current converter clamps should be grounded on one side!

Programming of phase correction

Adjustment of the phase correction between voltage and current is done in expert mode 1. Example: measuring current L1, measuring voltage L3 – L2 → phase U/I = 90°.

MEAS. CURRENT	MEAS. VOLTAGE	PHASE ANGLE
L1	L1 – N	0°
L1	L1 – L2	30°
L1 (k↔l)	L2 – N	60°

MEAS. CURRENT	MEAS. VOLTAGE	PHASE ANGLE
L1	L3 – L2	90°
L1	L3 – N	120°
L1	L3 – L1	150°
L1 (k↔l)	L1 – N	180°
L1 (k↔l)	L1 – L2	210°
L1	L2 – N	240°
L1	L2 – L3	270°
L1 (k↔l)	L3 – N	300°
L1 (k↔l)	L3 – L1	330°

3 ALARM OUTPUT, ERROR MESSAGES AND OPERATING MODES

The alarm contact is closed in normal operation and opens in the event of a fault; the fault is shown on the display in plain text, alternating with the standard display. Messages can be individually suppressed in expert mode 2.

 **UNDER-COMPENSATED**

 **OVER-COMPENSATED**

 **OVERCURRENT**

 **MEASURING VOLTAGE ?**

 **OVERTEMPERATURE**

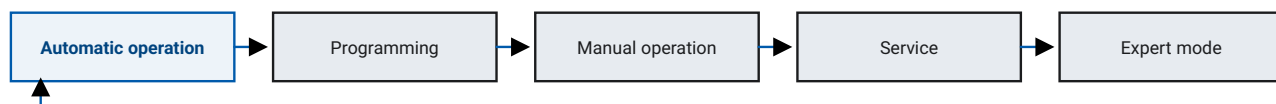
 **OVERVOLTAGE**

 **UNDERVOLTAGE**

 **HARMONICS**

≡ Operating modes

When the operating voltage is switched on, the BR6000 briefly shows its designation and software version and then goes to automatic operation. The active $\cos \phi$ is always in the upper line; the connected capacitors are shown as symbols in the lower line. A closed arrow shows the control direction (connecting-in / connecting-out), an open arrow that the blocking (discharge) time is running, a double arrow the fast switching of several branches.



each press of the "Operating Mode" key moves one step; the loop returns to automatic operation

4 AUTOMATIC OPERATION AND THE TRANSISTOR OUTPUTS

In automatic operation capacitor stages are connected or disconnected to reach the target power factor whenever the required reactive power exceeds the smallest stage. Pressing ENTER repeatedly shows the network parameters; after 60 s without a key the display returns to the operating status.

ENTER	DISPLAY
1	LINE VOLTAGE in V
2	APPARENT CURRENT in A / %
3	REACTIVE POWER in kvar / %
4	ACTIVE POWER in kW / %
5	APPARENT POWER in kVA / %
6	DIFF. kvar TO TARGET COS
7	FREQUENCY in Hz
8	TEMPERATURE in °C / °F
9	HARMONICS (3rd – 19th) V/%, I/%
10	THD-V; THD-I in %
11	Software version, then back to 1



Switching outputs

The outputs are transistor outputs, used with an additional auxiliary voltage (10 – 24 V DC) for direct triggering of thyristor switches (TSM). Max. current for a single output 40 mA; sum current of all 6 outputs 150 mA; X2:P 200 mA.



Warning

Mixing up the outputs and thus applying 230 V AC on the transistor outputs will destroy the internal transistors!

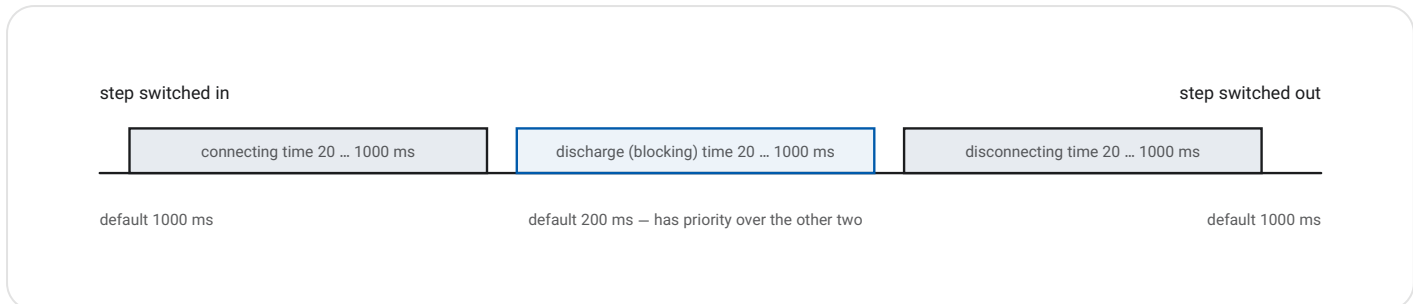
5 PROGRAMMING MENU

Press the “Operating mode” key once to enter programming. The upper line shows the parameter, the lower one the set value; ▲ ▼ change it and ENTER stores it and moves on. Press “Operating mode” to quit at any step.

NO.	PARAMETER	RANGE	NOTES
0	LANGUAGE	G / E / ES / RU / NL / CZ / PL / F / PT / TR	German, English, Spanish, French, Russian, Czech, Dutch, Polish, Portuguese, Turkish
1	I-CONVERTER PRIM	5 ... 13000 A	primary current of the current converter
2	I-CONVERTER SEC	5 or 1 A	
3	END STOPP	1 ... 6 or 1 ... 12	number of active capacitor branches; visible capacitor symbols correspond to the connected outputs
4	CONTROL SERIES	1 ... 20 + E	ratio of the branch powers, first branch = 1; “E” opens the control-series editor (Annex 1)
5	CONTROL PRINCIPLE	SEQUENTIAL · LOOP · INTELLIGENT (default) · COMBINED CHOKE	see Control principle
6	POWER 1. STAGE	0.01 ... 255.99 kvar	smallest capacitor; determines the response sensitivity – a “!” warns when undercut
7	TARGET COS PHI	0.3 ind ... 0.3 cap	
8	MEASURING VOLTAGE	30 ... 525 V	always the voltage at the clamps of the BR6000
9	V-CONVERTER RATIO	NO; 230 V ... 380 kV / Vmeas	for HV measurement enter the primary voltage of the voltage converter
10	CONNECTING TIME	20 ... 1000 ms	default 1000 ms; the real time is also affected by the discharge (locking) time
11	DISCONNECTING TIME	20 ... 1000 ms	default 1000 ms
12	DISCHARGE TIME	20 ... 1000 ms	default 200 ms; blocking time of an output between connecting and disconnecting – has priority; set by the capacitor discharge rating
13	ALARM TEMP	50 ... 85 °C	stages are disconnected step by step; alarm relay after 60 s; automatic reconnection when the temperature drops
14	MESSAGE RELAY (-T12/S)	OFF · External cap. · Fan · Supply · Undercurrent · Harmonics · Remote control R1 / R2	External cap. switches a static stage with 40 s discharge time; fan threshold under 15
15	FAN TEMP	15 ... 70 °C	only with option “Fan”
16	External input (-T12/S)	OFF · 2nd PARAMETER SET · EXTERNAL ERROR · COUPLING	24 V DC signal; External error switches off all stages step by step; coupling per Annex 3
17 – 26	2nd parameter set	as 1, 2, 3, 4, 5, 6, 7, 10, 11, 12	activated by the external input; marked with “2” in the display
27	DELAY-TIME OF ERROR MESSAGES	0 ... 255 s	default 20 s

NO.	PARAMETER	RANGE	NOTES
28	HARMONICS (limit)	0.5 ... 25.5 % THD-V	default 7 %; THD-V = geometric sum of the uneven harmonics over the fundamental
–	BASIC SETTING	YES / NO	resets all parameters to the PFC-system manufacturer's basic setting – all user settings are lost

The three switching times of a dynamic step



A programming lock (activated in expert mode) protects against unauthorised or inadvertent changes: all parameters can be checked but not changed.

6 MANUAL OPERATION, FIXED STAGES, SERVICE AND EXPERT MODES

Manual operation

Branches are connected and disconnected in the set control series and switching time irrespective of the line conditions. Start condition is STOPP; ▲ connects, ▼ leads back to STOPP and then disconnects. ENTER opens “Programming of fixed stages”, where each output C1 – C12 can be set to **OFF** (continuously disconnected, e.g. a defective capacitor), **AUTO, FIXED** (continuously connected, underlined symbol) or **TEST** (short-term switch-on).

Service menu

Shows the stored maximum values (min./max. voltage, max. reactive, active and apparent power, max. temperature), resets them, and holds a fault memory with the last 40 fault states in plain text.

Expert mode 1 (password 6343)

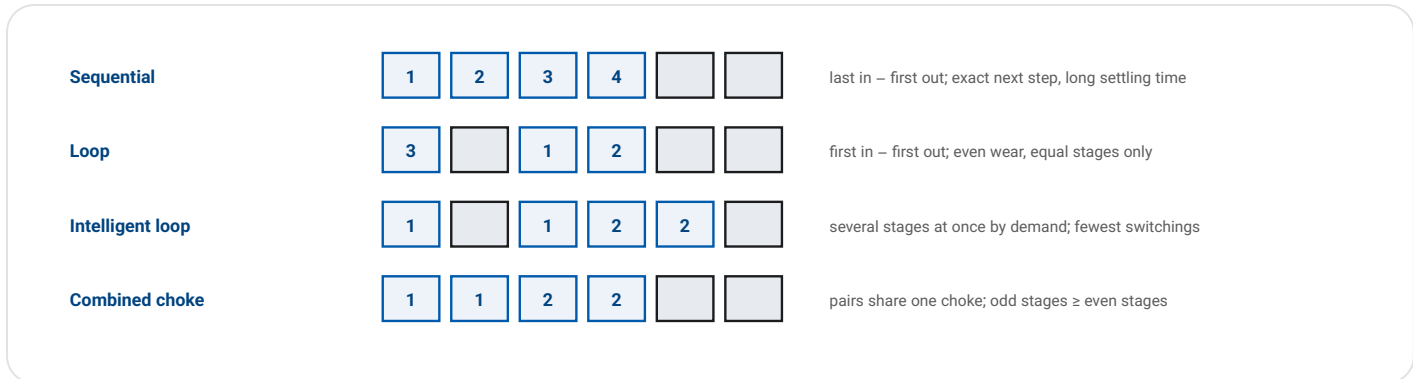
NO.	PARAMETER	DEFAULT / RANGE
2	BASIC SETTING NEW	NO – stores the active programming as the new basic setting (overwrites!)
3	SWITCHING POWER max	100 kvar – max. power in one switching step (multiples of the smallest stage)
4	SWITCH.TRIGGER	66 % (30 ... 100) – do not change normally
5	OPERATING LOCK	NO
6 / 7	PHASE I / PHASE U	0° – phase correction, allows systems without neutral
8	POWER 1. STEP	0 ... 255 (... 2550) – range for HV measuring
9	CONTROL	3 phase (3/1)
10	DISPLAY	cos ϕ / tan ϕ
11	HARMONICS	NO / YES
12	PROTOCOL (-T12/S)	OFF · MODBUS RTU · ASCII OUT · MASTER HYBRID · MASTER MMI
13 – 20	BAUD RATE 38400 · No. of MMI 1 · ADDRESS 1 · UPPER 115 % · LOWER 60 % · TEST ATTEMPT 10 · TEST-TIME 10 · ASCII time 10 s	

Expert mode 2 (password 2244)

NO.	PARAMETER	DEFAULT / RANGE
–	Activation of each of the 20 messages	YES / NO
2	ALARM TIME	120 s (1 ... 255) – time after which the alarm relay responds
3	UNDERVOLTAGE	50 % (20 ... 100) – all stages switched off at once
4	OVERVOLTAGE	115 % (105 ... 140) – stages switched off step by step
5	FREQUENCY	40 ... 80 Hz automatic; fix 50 or 60 Hz in grids with very poor voltage quality

7 CONTROL PRINCIPLE

The four control modes



For a large power-factor requirement the BR6000 switches several stages simultaneously in all modes; the maximum simultaneous power is set in expert mode. Selecting the smallest stage gives the conventional sequential connection.

- **Sequential connection** – stages are connected and disconnected successively (last in, first out); each step corresponds to the smallest stage. Exact definition of the next capacitor, but long settling time and high switching frequency of the small stages.
- **Loop connection** – first in, first out: the stage disconnected for the longest time is connected next, giving balanced utilisation and longer life of the bank. Only for control series with groups of equal stage power; long settling time.
- **Intelligent loop connection (default)** – combines the network-sparing loop with a much faster settling time even for large load skips, switching several or larger groups as a function of the missing power factor; considers both the real switching frequencies and the turn-on times of the branches.
- **Combined de-tuning** – two adjoining equal steps share one joint choke (series 1:1:1:1, 1:1:2:2, 1:1:2:2:4:4 ...); the number of activated odd steps is always $\geq$ the number of activated even steps.

8 INTERFACE (OPTION)

The BR6000-T12/S has an RS485 interface: full parametrisation via PC, remote read-out of all parameters, display and logging of grid parameters with the Windows software "BR7000-Soft", connection of accessories (remote display, data logger), and MODBUS or ASCII output. Use a shielded cable, make bus connections directly at the device, and activate the terminating resistors (DIP switch ON) for point-to-point connections.

ASCII protocol – permanently refreshed values

VALUE	EXAMPLE
Voltage	230 V
Current	85 A
Power factor	-0.98 (minus = capacitive)
Reactive power	100 kvar
Active power	100 kW
Apparent power	100 kVA
Outputs	XXX----- (3 steps active)

Annex 6 – Register MODBUS protocol: example, function code 3 (read), meas. voltage

BYTE	REQUEST	ANSWER
1	slave address 1	1
2	function code 3	3
3	reg. start "H" 0	no. of bytes 2
4	reg. start "L" 20	data H 0
5	reg. number "H" 0	data L 233
6	reg. number "L" 1	CRC L 121
7	CRC L 196	CRC H 202
8	CRC H 14	



Because the control function has priority over data exchange, at most 12 consecutive values are transferred blockwise per command and parameters should not be retrieved more than once per second. Settings: 8 data bits, 1 stop bit, no parity. Function code 6 (write) example: remote ON = register 40, value 1·3.

9 INITIAL OPERATION, MAINTENANCE AND TROUBLESHOOTING

Install the controller, program all network-specific parameters in sequence as in section 5, then set automatic operation with the operating-mode key. The BR6000 needs no maintenance if the operating conditions are observed; a functional check together with the regular check of the capacitor bank is recommended. Any intervention in the controller during the warranty period voids the warranty.

FAULT	CHECK / SOLUTION
At target $\cos \phi = 1$ and inductive load, switch-off or connection of capacitors in the corrected line; supply / drawing mismatched; wrong line $\cos \phi$ displayed	Check the terminals of the measuring voltage and current (I and k); check the phase position
Display "UNDER CURRENT"	Current in measuring range? Line interruption? Wrong current-converter factor? Current transformer short-circuited?
Display "OVERCURRENT", alarm relay after 1 min	Check the current-converter ratio; go through the measuring current range
Display "UNDERCOMPENSATED", alarm after 1 min	Check connection and phase position; all stages connected but target not reached – is the network sufficiently dimensioned?
Display "OVERCOMPENSATED", alarm after 1 min	Check connection and phase position; capacitive grid although all stages disconnected
Display "MEASUREMENT VOLTAGE ???"	No measurement voltage
Display "OVERTEMPERATURE"	Cabinet temperature too high: outputs are switched off in stages irrespective of the line
Stages disconnected for an inductive line (or connected for a capacitive one)	With a target $\cos \phi \neq 1$ the arrows show the control direction, not the line condition
Not all stages connected, or $\cos \phi$ unchanged at the last stages	Check END STOPP
Individual stages not connected / disconnected	Check whether stages are programmed FIXED or OFF in the fixed-stages menu
Differences between control response and PF measurement in strongly asymmetrical lines	The PF is measured single-phase: choose the most favourable phase and set the current converter accordingly
No operating voltage	No display; the alarm relay is activated (open)

10 TECHNICAL DATA

Type series	BR6000-T ...; outputs 6 or 12; languages G / E / ES / RU / NL / CZ / PL / F / PT / TR
Switching power of outputs	24 V DC, approx. 40 mA for triggering TSM-LC; number of active outputs programmable
Operation and display	illuminated graphic display 2 × 16 characters; 20 control series + 1 user-defined; sequential, loop or self-optimised switching; four-quadrant operation

Operating voltage	110 ... 230 V AC $\pm 15\%$, 50/60 Hz; measuring voltage 30 ... 525 V AC (L-N or L-L); measuring current X:5 / 1 A; power drawn < 5 VA; sensitivity 50 mA / 10 mA
Target cos ϕ	0.3 inductive to 0.3 capacitive
Connecting / disconnecting / discharge time	each selectable 20 ms – 1 s
Displays and memory	power factor, voltage, apparent current, frequency, reactive, active and apparent power, missing kvar, temperature, harmonics; maximum values stored; error memory of the last 40 states; temperature range $-30 \dots 100\text{ }^{\circ}\text{C}$
Accuracy	current, voltage 1 %; reactive, active, apparent power 2 %
Housing	switchboard-integrated, DIN 43700, 144 × 144 × 53 mm; 1 kg
Ambient / protection	-20 to $+60\text{ }^{\circ}\text{C}$; front IP54, rear IP20 (DIN 40050)
Safety / EMC	IEC 61010-1:2001, EN 61010-1:2001; EN 50082-1:1995; IEC 61000-4-2: 8 kV; IEC 61000-4-4: 4 kV
Option -T12/S	additional external input, user-programmable message relay, RS485 interface

11 ANNEXES

≡ Annex 1 – control series (loop connection possible for all)

NO.	SERIES
1	1:1:1:1:1:1:1:1:1:1:1
2	1:2:2:2:2:2:2:2:2:2:2
3	1:2:3:3:3:3:3:3:3:3:3
4	1:2:3:4:4:4:4:4:4:4:4
5	1:2:4:4:4:4:4:4:4:4:4
6	1:2:3:6:6:6:6:6:6:6:6
7	1:2:4:8:8:8:8:8:8:8:8
8	1:1:1:1:2:2:2:2:2:2:2
9	1:1:1:1:1:6:6:6:6:6:6
10	1:1:2:2:2:2:2:2:2:2:2
11	1:1:2:2:2:4:4:4:4:4:4
12	1:1:2:2:4:4:4:4:4:4:4
13	1:1:1:2:2:2:2:2:2:2:2
14	1:1:2:3:3:3:3:3:3:3:3
15	1:1:2:4:4:4:4:4:4:4:4
16	1:1:2:4:8:8:8:8:8:8:8
17	1:2:2:3:3:3:3:3:3:3:3
18	1:2:3:4:4:8:8:8:8:8:8
19	1:2:2:4:4:4:4:4:4:4:4

NO.	SERIES
20	1:2:2:2:4:4:4:4:4:4:4
E	control-series editor – any series up to a rating of 30 (10 = A ... 30 = U)

Annex 2 – default settings (ex works)

NO.	PARAMETER	DEFAULT
0	LANGUAGE	ENGLISH
1	I CONVERTER prim.	1000 A
2	I CONVERTER sec.	5 A
3	END STOPP	12 (6)
4	CONTROL SERIES	1
5	CONTROL PRINCIPLE	INTELLIGENT
6	POWER 1. STAGE	25.00 kvar
7	TARGET COS-PHI	0.98 IND
8	MEASURING VOLTAGE	230 V L-N
9	V-CONVERTER RATIO	NO
10 / 11	SWITCH-IN / OFF TIME	1 s
12	DISCHARGE TIME	0.2 s
13	ALARM TEMP	55 °C
14	MESSAGE RELAY	OFF
15	TEMP. FAN ON	30 °C
16	EXTERNAL INPUT	OFF
27	DELAY ERROR MESSAGE	20 s
–	Trigger value 66 %; max. simultaneous switching power 4 × smallest stage; phase shift U/I 0°; control 3-phase; protocol MODBUS-RTU 38400, address 1	

Annex 3 – coupling of two PFC systems

Two PFC systems at two transformers can be coupled without a sum current transformer: connect the two controllers via their system interface with a standard LAN cable (CAT5) and feed the “coupler switch closed” signal (24 V DC) to the external input of the master. Coupler open: both systems work independently; coupler closed: the two systems operate in parallel, avoiding mutual interaction (oscillation) on a common busbar. Programming – master: PROGRAM MODE 16 EXTERNAL INPUT: COUPLING; second controller: EXPERT MODE 19 PROTOCOL: MODBUS RTU, 20 BAUDRATE 38400, 21 ADDRESS 1.

Annex 4 – capacitor current monitoring with MMI6000

The MMI6000 measures the sum current of the PFC system with a current transformer at its power input. At each switching operation the current change is compared with the rated current of the switched capacitor; in between, the current of the complete system is monitored. If the current of a step is too low (default 60 %) it is switched off, the BR6000 shows “E” and the alarm relay operates (re-activation in manual mode); if too high (default 115 %) it is switched off and checked periodically; if the sum current is too high, stages are switched off one after another. Settings – MMI6000: coupling MMI-BR6000-T, 3-phase, 38400 baud; BR6000-T (expert mode): protocol Master-MMI, 38400, number of MMI, upper / lower limits. Smallest switching time in this mode: 200 ms.

Annex 5 – mixed dynamic compensation

Fast-changing loads are compensated dynamically and basic loads conventionally. The BR6000-T6R6 supports 6 transistor outputs plus 6 relay outputs; for more stages a hybrid system with one dynamic and one or two standard controllers is used: BR6000-T12/S as [Master Hybrid], BR6000-R12/S as [Slave Hybrid] with addresses 1 and 2, 38400 baud, connected with LAN cables and the adapter CV-1xRJ45-BR6000.

Annex 6 – Register MODBUS protocol

The register example of the MODBUS protocol is given with the interface in section 8. A detailed description of the MODBUS-protocol parameters (last version) is available on the software CD, which is included in delivery with each BR6000 device with interface (BR6000-T12/S485).

Annex 7 – Windows software BR7000-Soft and accessories

The software (CD included with BR6000-T12/S485) offers a display mode, configuration manager, grid parameter table, analysis tool and harmonics diagram. Accessories: multi measuring devices MMI6000 and MMI7000, USB-to-RS485 converter, RJ45 adapter connectors and terminal-to-RJ45 converters, and the thyristor switches TSM-LC / TSM-HV for 10 ... 200 kvar, 400 ... 690 V.



SABA KHAZEN MANUFACTURING & INDUSTRIAL CO.

Saba Khazen Industrial Company, established in 1994, is the first and only manufacturer of gas capacitors MKK and resin capacitors MKP under Siemens Germany license in Iran. With the slogan of superior quality and customer satisfaction, the company provides regular after-sales services. It is also the official representative of EPCOS and BELUK Germany, offering a wide range of power factor correction equipment and harmonic elimination solutions to industries.

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