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Application Notes

PQS

# Controlling the Power – PF Controller Series BR604 and BR6000

Power Quality Solutions

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# Application Notes

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## Foreword

Power factor controllers measure the actual power factor and connect or disconnect capacitors to achieve the desired value (cos-φ). With the microprocessor-based series BR604 and BR6000, EPCOS offers a broad range of PF controllers for all kinds of applications and loads. PFC solutions may be customized with versions for conventional and dynamic PFC as well as with a new hybrid version for mixed – conventional and dynamic – applications. All these versions offer user-friendly menu-driven handling, compact dimensions and easy installation.

Use of a PF controller ensures balanced utilization of capacitor stages and minimizes the number of switching operations – thus optimizing the life cycle of the PFC system.

**The Author**

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Dr. Goldstrass is part of the PFC product marketing team at EPCOS HQ/Munich. He is responsible for the definition of the global PFC product range and the product marketing for selected countries.

Professional experience in R&D, marketing and sales as well as his PhD in solid state physics help him to understand the requirements of both, basic development and final application to serve the needs of EPCOS' customers in the optimal way.

**Contents**

Power Factor Correction

# Controlling the Power – PF Controller Series BR604 and BR6000 (V5.0)

It is easy to compensate a sluggish and infrequently changing load caused by a single consumer: a capacitor and contactor will do the job. But these circumstances are as rare as a billion-dollar jackpot in the lottery. In reality, PFC systems have to cope with different kinds of loads, different switching times and behaviors. A power factor controller is needed for this purpose.

## 1. Automatic PFC system

An automatic PFC system consists mainly of capacitors, their contactors and a PF controller. The latter will **measure** the cos-φ value and will automatically **switch** capacitor steps on or off whenever this differs from its pre-set value.

The microprocessor-controlled BR604 and BR6000 series (V5.0) of PF controllers from EPCOS represent a broad **product range** suitable for all kinds of PFC applications.

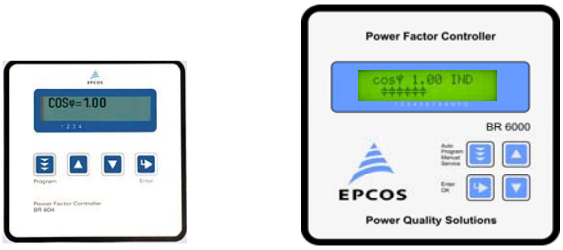


**Fig. 1:** PF controller series BR604 and BR6000 (V5.0)

## 2. Features

- Display:
  - Large and multifunctional LCD
  - 2 x 16 characters
  - Graphic and alphanumeric
  - LCD illumination (BR6000 series)
- Menu-driven handling in
- **two languages for the BR604:**
  - English
  - German
- **nine languages for the BR6000 series:**
  - Czech
  - Dutch
  - German
  - English
  - French
  - Polish
  -.Portuguese
  - Russian
  - Spanish
- Intelligent control behavior
- Automatic initialization (for specific types)
- Self-optimizing control capability
- Recall function of recorded maximum values
- Four-quadrant operation (e.g. stand-by generator)
- Large range of measuring voltage (for the BR6000 series)
- Powerful alarm output (for the BR6000 series)

Display of various grid parameters, storage of various maximum values and a test run option allow easy error analysis and monitoring of the system. Automatic initialization reduces commissioning to a minimum.

## 3. Dimensioning a PFC system

After the required capacitor output has been determined, the **number of steps should be defined**. The BR604 is suited to small PFC systems with four steps. For medium and large systems, the BR6000 series is available with six and twelve steps respectively.[1)]

**Rule of thumb**: The number of steps depends on the number of consumers, i.e. the more small inductive consumers, the higher the number of steps should be. The switching time is also of major importance here: the more frequently a capacitor is switched, the more stress is placed on the capacitor and its contactors.

1) The new series BR7000 offers even 15 outputs: 15 conventional steps, each for one 3-phase capacitor or 3 x 5 steps for 1-phase capacitors. For more information please refer to the product brief BR7000 under www.epcos.com/publications

## 4. Conventional, dynamic or mixed?

The **BR6000 series** not only offers various step sizes but also a choice of conventional or dynamic PFC systems.

The conventional series **B6000-R** features either six or twelve relay outputs for triggering the capacitor contactors.

Types **BR6000-R12/S485** allow messages to be read out on a computer via the RS485 interface. An RS485-USB adapter is available from EPCOS. The RS485 interface is also important for use in conjunction with the MMI6000 Multi-Measuring Interface from EPCOS: together they act as an intelligent link between the measured equipment current and the momentarily active capacitor branches. Monitoring individual capacitor currents offers increased protection for specific components as well as the whole PFC system.

The **BR6000-T** dynamic types may be used to trigger electronically controlled thyristor switches (e.g. the TSM series) via transistor outputs. Such a dynamic PFC solution should be chosen whenever 5,000 switching operations are exceeded per year.

The mixed dynamic power factor controller **BR6000-T6R6** is a follow-up development of the BR6000 series. Designed especially for triggering up to six thyristor modules and simultaneously up to six standard capacitor contactors, it is the ideal device for combined conventional-dynamic PFC systems. This cost-effective solution is the ideal way to have all the advantages of a dynamic PF system only part of whose load is "dynamic".

## 5. Zero voltage release

A very important feature of a PF controller is zero voltage release – a standard for BR604 and BR6000-series. **Basics:** Short-term voltage interruptions can cause major stress to power capacitors and it is mandatory to handle such network situations appropriately in order to protect PFC systems.

In electronic signaling, the phase defines the position of a point in time (instant) on a **waveform cycle**. A complete cycle is defined as 360 degrees of phase as shown in the following illustration. Phase can also be an expression of relative displacement between waves having the same frequency.

**The phase difference**, also called the phase angle (in degrees) is conventionally defined as a number greater than -180 and less than or equal to +180. Leading phase refers to a wave located "ahead" of another wave of the same frequency. Lagging phase refers to a wave located "behind" another wave of the same frequency. When two waves differ in phase by 180 (-180 is technically the same as +180), the waves are said to be in phase opposition.

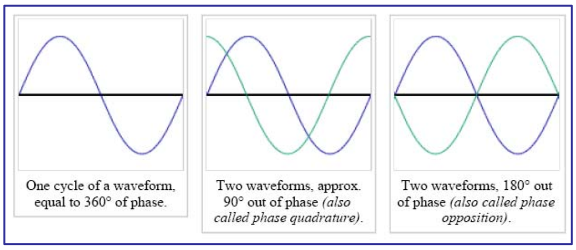


**Fig. 2:** Waveform cycles

The most critical situation would be when the capacitor is fully charged to a positive **peak voltage**. An interruption occurs and the voltage returns at the same negative peak value. The capacitors will then be over-stressed with a peak value of 2 * $V_R$ *1.41, leading to a high voltage and consequently to a very high inrush current as shown in Fig. 3.

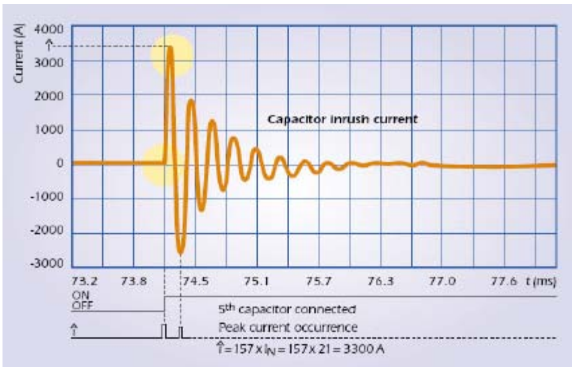


**Fig. 3:** Excessive stress causing high inrush currents

These short interruptions are extremely hazardous for PFC systems because the contactors briefly disconnect from and then switch back to the charged capacitors as soon as the voltage returns. The phase opposition leads to very **high inrush currents** that may cause the contactors to melt. Disturbances may occur more often in rural areas with overhead power supply lines than in cable grids: e.g. during a storm when fallen trees may lead to a temporary phase interruption or by birds triggering a short-circuit to ground. In both cases, the closest power switch will activate a short interruption of 200 to 300 ms and then energize the line again. This applies in cases of a temporary disturbance only, e.g. the grid is restored to its proper condition when the tree or bird no longer cause the interruption. Only during a continuous short-circuit will the power switch definitely activate and leave the line sector at zero-voltage until final elimination of the interruption.

Due to its **zero-voltage release function**, the PF controller will normally create an interruption of between 20 and 50 ms and then separate the charged capacitors from the grid. It is mandatory to observe a minimum capacitor discharge time – also called the idle period – of 60 seconds. Only after this period may the controller resume its operation.

For **optimum protection** of the PF controller, we recommend programming the BR6000 controller to a minimum reconnection time. This should be at least the time needed to discharge the remaining capacitor voltage.

The appropriate reconnection time should be chosen depending on the kind of discharge device used.

## 6. Controller coupling

Some applications may require coupling (**cascading**) of two controllers. This is possible with PF controllers with software version 4.0 or higher.

1. BR6000-R12/F
2. BR6000-R12/S
3. BR6000-T12/S485

### a) Application: Extending a PFC system to more than 12 steps

In this case, the number of switching outputs of a PFC system will be extended (e.g. up to 24 steps instead of 12 – see Fig. 4).

The current path of both PF controllers has to be switched in series and the step size (smallest step) of both systems has to be as identical as possible.

Programming is just as easy as for each individual system. The current transformer ratios of both systems have to be programmed in the same way.

In the “14 message relay” program, the master has to be marked as “Remote Control R1” and the slave as “Remote Control R2”.

The network operates in master-slave mode. When all the stages of the first controller have been connected, the second controller takes over and switches the remaining stages.

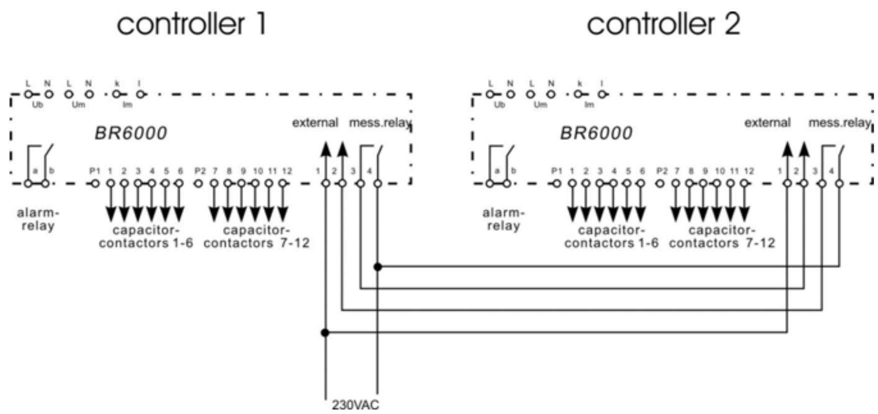


Fig. 4: Controller coupling (programming in “14 message relay”)

For coupling, the controllers of the two installations have to be connected as shown in Fig. 4 above.

**b) Application: PF controller coupling for two separate feeders with coupler breaker**

Figure 5 shows a diagram of this application. As it allows autonomous operation of each system as well as coupled operation, a current transformer is needed for adaptation. The PF controller has to be programmed as described under a).

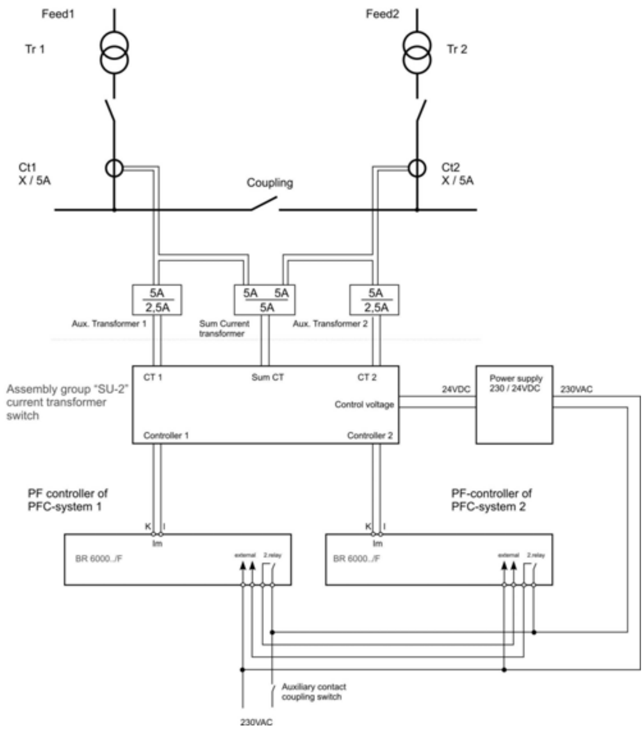


**Fig. 5:** Coupling two PFC systems without retroactivity

**Function:**

Operating status 1 (coupling switch open):

Both PFC systems operate separately on their respective feeders. A special accessory is needed for coupling two PFC systems: the assembly group "SU-2" switches the current transformer input directly to the controller. The auxiliary contact of the coupling switch is open – so no control coupling occurs.

Operating status 2 (coupling operation on busbar – coupling switch closed ):

In this case, the auxiliary contact of the coupling switch is closed. Voltage control is applied to "SU-2". The sum current transformer is connected to the measuring current inputs of both controllers (series connection). This ensures that the controllers measure the current of the whole PFC system (feed-ins 1 and 2). At the same time, the PF controllers are switched to controller coupling. This is done by the external switching according to the drawing and BR6000 controllers ../F , ../S and ../T The PFC systems now work in master-slave mode so that all steps are first switched to system 1 and any subsequent steps to system 2. This avoids mutual interaction of the PFC systems.

Note:

When programming the controller, you must determine which PFC system will operate as the master and which one as the slave for controller coupling.

Auxiliary current transformers 1 and 2 are used to adjust the measuring current in normal operation. There is consequently no need to change the current transformer ratio when the sum current transformer is switched on. This has to be considered when programming the current transformer ratio at the controller.

## 7. Use of BR6000 in high-voltage applications

**Example:** Connecting a BR6000 for high-voltage measurement via voltage converter 20,000/100 V to an outer conductor voltage L2-L3; capacitors on LV side:

a) If the secondary winding of the voltage converter is connected on a single side to N, then this BR6000 connection must also be connected to the input clamp “N” of the measuring voltage.

b) If the voltage converter measures the outer conductor voltage (see example L2-L3) and not the line voltage against N in the high voltage, the appropriate phase shift 90° must be programmed at the BR6000. (This is the phase angle between the voltage L2/L3 and the voltage L1/N)

c) The voltage converter ratio in this example is calculated as follows:

20,000 / 100 = 200
200 / 1.732 = 115.4 (conversion to line voltage)
Input value: 115

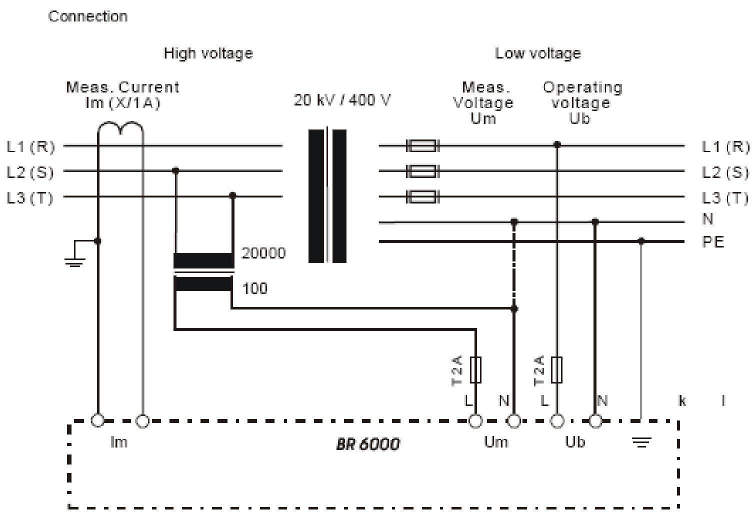


**Fig. 6:** BR6000 in HV applications

**Summary:**

For the example given above, the following values must be programmed at the BR6000:

| Menu | Menu item | Value |
|---|---|---|
| Programming | 8 measuring voltage | 100 V |
| Programming | 9 V-converter ratio | 115 |
| Expert mode | 12 phase V/I | 90 ° |

All other values are programmed as usual.

## 8. Accessories for BR6000

*A) USB to RS485*

With the interface converter USB to RS485, also available from ECPOS, the PF controller BR6000 or other devices with Interface RS485 can be connected to a PC by USB interface. Connection of several devices at RS485 is also possible.

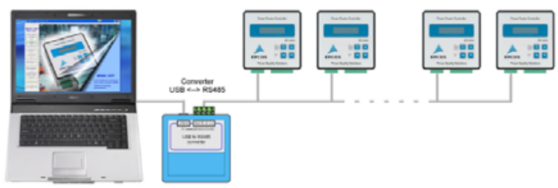

**Fig. 7:** Connection diagram USB to RS485

*B) RJ45 – converter*

This terminal to RJ45 converter allows:

- Connection of the interface terminal of a BR6000/BR7000 or MMI6000 via an RJ45-standard cable (1:1)
- Connection of several devices at the RS485 bus with simple connection (one click)

  Example:
  - Connection of several BR6000 or BR7000 to a PC with BR7000-SOFT.
  - Coupling of several BR6000 with each other
  - Coupling of BR6000 or BR7000 with MMI6000

The converter is available in three different variants; please refer to the data sheet in the Internet.

Application example: connection of several PF controller BR6000 to a PC for visualisation

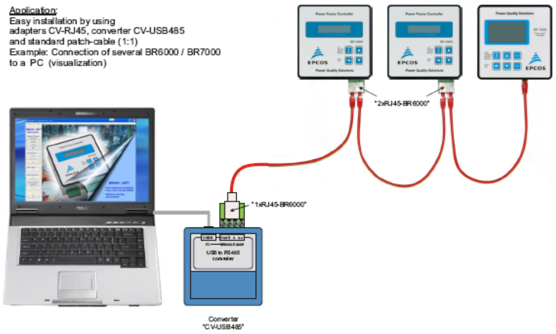


Fig. 8: Connection diagram RJ45 – converter

## 9. Conclusions

With its broad range of key components, EPCOS offers products for all kinds of applications. All devices needed for conventional and dynamic PFC are available from a single source. Distributors, dealers, panel builders and partners worldwide guarantee the global presence of Power Quality Solutions from EPCOS.

## 10. Standards

The recommendations and proposals stated in this Application Note are based (amongst others) on several international standards for PFC capacitors, LV switchgear design and electrical systems:

- IEC60831: LV-PFC Capacitor Standard
- IEC61921: Power Capacitors LV PFC Banks
- DIN EN61921: Leistungskondensatoren für Kondensatorbatterien zur Korrektur des Niederspannungsleistungsfaktors
- EN 50160: Voltage Characteristics of Electricity Supplied by Public Distribution Systems
- Engineering Recommendation G5/4: Planning levels for harmonic voltage distortion and the connection of non-linear equipment to transmission systems and distribution networks in the United Kingdom
- IEEE Standard 519-1992: IEEE Recommended practices and requirements for harmonic control in electrical power systems
- IEC60439-1/2/3: Low-voltage switchgear and control gear assemblies

The specifications in the standards and manufacturers' data sheets should always be observed.

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