

EPCOS Application Note

Controlling the Power

Power Quality Solutions



PQS

Application Note

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Foreword

Power factor controllers measure the actual power factor and connect or disconnect capacitors to achieve the desired value (cos-phi). With the micro-processor based series BR604, BR6000 and BR7000, EPCOS offers a broad range of PF-controllers for all kind of applications and loads. Customized PFC-solutions are possible with versions for conventional and dynamic PFC and a hybrid version for mixed (conventional and dynamic) applications. User-friendly menu-driven handling, compact dimensions and easy installation apply for all available versions.

The usage of a PF-controller ensures an even utilization of capacitor stages, a minimized number of switching operations – thus ensuring an optimized life cycle of the PFC-system.



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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.

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Application Note

Controlling the Power – PF Controller Series BR604, BR6000 (V6.0) and BR7000

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-phi value and will automatically **switch** capacitor steps on or off whenever this differs from its pre-set value.

The microprocessor-controlled PF controllers from EPCOS represent a broad **product range** suitable for all kinds of PFC applications.

- BR604: Smallest device with 4 relay outputs for conventional PFC-systems with slow changing loads
- BR6000-R: Available with 6 and 12 relay outputs for conventional PFC-systems with slow changing loads. HD-version with OLED display, white characters
- BR6000-T: 6 transistor outputs for dynamic PFC-systems with fast changing loads
- BR7000-I and BR7000-I/S485: 12 relay outputs for conventional PFC-systems with slow changing loads; version BR7000-I/S485 with RS485-interface
- BR7000-I-TH and BR7000-I-TH/S485: 12 relay and 12 transistor outputs for mixed and dynamic compensation; version BR7000-I-TH/S485 with RS485-interface.
- BR7000-R: 15 relay outputs for conventional PFC-systems with slow changing loads. Two independent isolated RS485-interfaces as a standard. HD-version with OLED-display, white characters; 3-phase measuring system and controlling
- BR7000-T: 15 transistor outputs for dynamic PFC-systems with fast changing loads. Two independent isolated RS485-interfaces as a standard. HD-version with OLED-display, white characters; 3-phase measuring system and controlling

2. Features

A whole bunch of characteristics and features make the range of PF-controllers by EPCOS the right solution for customized PFC-systems:

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/BR7000 series)
- Powerful alarm output (for the BR6000/BR7000 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.

All versions with interface RS485 allow the usage of the evaluation software BR7000-SOFT (included in the delivery for the particular types) and processing of measured and recorded values on a PC.

Menu driven handling is a standard for all different types of PF-controllers. Apart from the BR604 who features five languages (E/ES/GER/PT), all other types feature ten languages (CZ/E/ES/F/GER/NL/PL/PT/RU/TR).

All BR6000-types are equipped with an illuminated LCD-display, 2 x 16 characters (BR604 without illumination). All BR7000 types have an illuminated graphic display with 128 x 64 dots. The HD-versions of all types have an OLED-display with white characters for easy read-out even in darker surroundings and a wider temperature range (up to -20 °C).

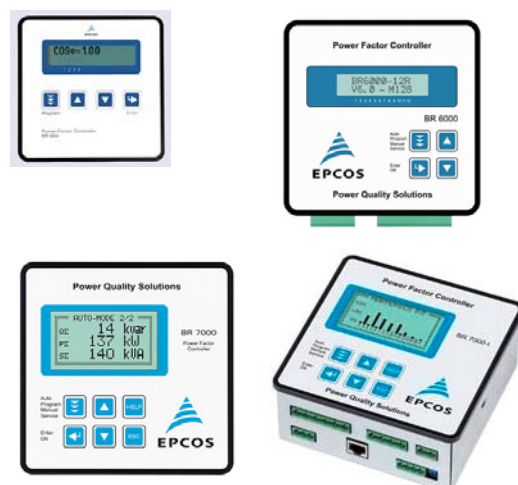


Fig. 1: Overview PF controllers

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3. Dimensioning a PFC system

After the required capacitor output has been determined, the **number of steps should be defined**. The BR604 is suited for small PFC systems with max. four steps. For medium and large systems, the BR6000 series is available with six and twelve steps, the follow-on series BR7000-I with 12 resp. 13 outputs and of course the BR7000-series (3-phase) with 15 outputs. Version BR7000-I-TH with twelve relay and twelve transistor outputs.

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 contactor.

4. Conventional, dynamic or mixed?

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

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

All types with the option interface RS485 allow messages to be read out on a computer. An RS485-USB adapter is available from EPCOS. The evaluation software BR7000-SOFT is included in the delivery for these types (see page 8). The RS485 interface is also important for use in conjunction with the MMI6000 or MMI7000 (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 **BRxxx-T-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.

BR7000-I-series features all characteristics of the BR6000 and BR7000 series. Versions BR7000-I-TH and BR7000-I-TH/S485 with 12 relay and 12 transistor outputs are perfectly suited for dynamic and mixed compensation. Version /S485 with an additional RS485 interface allows controlling of up to 32 thyristor modules type TSM-LC-S.

^{*)} applicable for all devices with interface

5. Zero voltage release

A very important feature of a PF controller is the zero voltage release – a standard for all types of PF-controllers.

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.

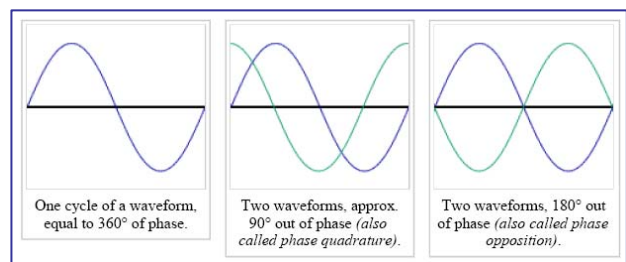


Fig. 2: Waveform cycles

The most critical situation would be when the capacitor is fully charged to a positive **peak voltage**.

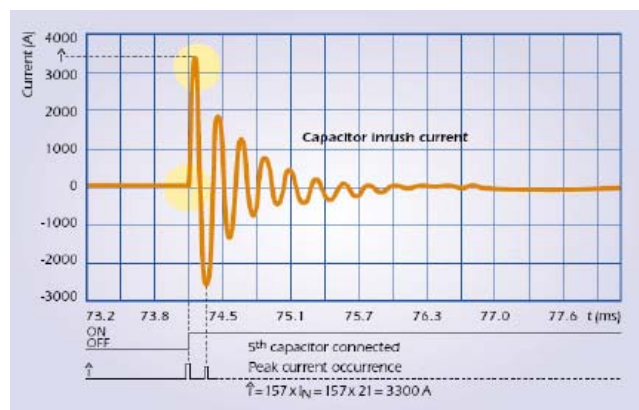


Fig. 3: Excessive stress causing high inrush currents

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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 $2 \cdot V_R \cdot 1.41$, leading to a high voltage and consequently to a very high inrush current as shown in Fig. 3.

These short interruptions are extremely hazardous for PFC systems because the contactors briefly disconnect and 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 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. Accessories for PF-controller

A) Multi Measuring Interfaces

MMI6000

- Coupling with PF controller types with RS485 via interface for determination of real capacitor current
- Capacitor protection by step switch-off at current limit
- Fast trigger for dynamic PFC
- Independent switching of a single capacitor step
- Stand-alone measuring device with interface for read-out
- Single-phase measurement of V, I, P, Q, S, cos phi, f, W, T (read out via RS485)

MMI7000

Coupling with PF controller types with RS485 via interface

- Display of harmonics as bar chart: harmonic of voltage up to 51st and harmonic of current up to 51st
- Oscilloscope mode
- Scan mode
- Three-phase measuring and display of numerous parameters

MMI8003

- Measuring device for 3-phase-measuring via BR7000-SOFT
- Without display for usage inside a cabinet
- With interface (2 x RJ45)
- Measured values displayed and processed via PC or external control system

B) USB to RS485 for BR7000, BR7000-HD, BR7000-T, BR7000-I/S485 and BR7000-I-TH/S485

With the interface converter USB to RS485, also available from EPCOS, the PF controllers mentioned above with interface RS485 can be connected to a PC by USB interface. Connection of several devices at RS485 is also possible.

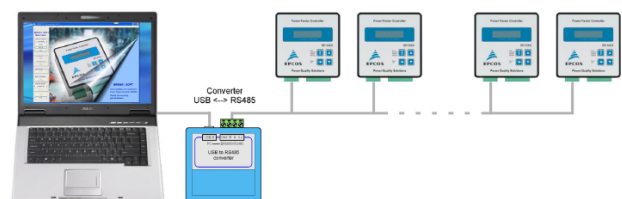


Fig. 4: Example Connection diagram USB to RS485

C) RJ45-converter for BR7000, BR7000-HD, BR7000-T, BR7000-I/S485 and BR7000-I-TH/S485

This terminal to RJ45 converter allows:

- Connection of the interface terminal of the particular devices mentioned above or MMI6000/MMI7000 via an RJ45-standard cable (1:1)
- Connection of several devices at the RS485 bus with simple connection (one click)

Example:

- Connection of several BR7000 to a PC with BR7000-SOFT.
- Connection of several controllers with each other - for coupling systems
- Coupling of BR6000 or BR7000 with MMI6000/MMI7000

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

Application example: connection of several PF controller BR7000 to a PC for visualisation.

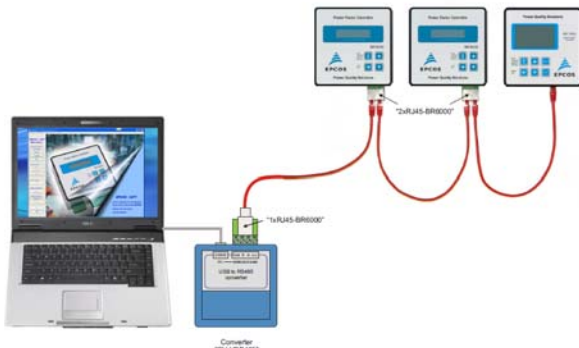


Fig. 5: Connection diagram RJ45 – converter

D) Data logger DataLog SD for recording, visualization and evaluation of grid parameters. Comfortable evaluation of acquired data (recorded on SD-card) via Windows-based software BR7000-SOFT.



E) SO-Impulse-Module UCM-5

- Recording and evaluation of counter values for processing (via RS485 interface) to PF controller BR7000.
- Bus compatible SO-Impulse-Module for software MMI-energy and BR7000 for conversion of counter impulses on RS485 (MODBUS-RTU protocol)
- Accessory for the processing of counter values in the PF controller (controlling of reactive power related to counter impulses instead of current transformer)
- Allows processing of counter values via Windows-software MMI-energy (included in the delivery): cost centre management, visualization and evaluation
- Cross-linking of up to 32 devices (UCM-5, MMI6000, MMI7000) at MODBUS
- Evaluation software MMI-energy included in the delivery

F) Evaluation software BR7000-Soft



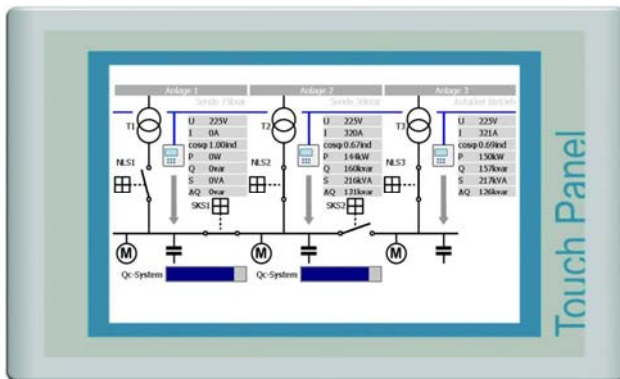
Windows based software for parameterization of PF controller BR7000 / BR7000-I/S485. It allows a comfortable visualization and analysis of grid parameters during online-operation. At the same time, the storage and graphical analysis of all recorded data inclusive export and printing function can be performed. The spectrum of harmonics can promptly be displayed as bar chart.

- Connection to RS485-bus
- Administration of several PF controllers possible
- Mixed operation of several devices (BR7000/ BR7000-I/S485) possible on a PC
- Convenient analysis of recorded values
- Direct connection at USB port of PC via accessory USB adapter
- For operating system Windows 2000 onwards
- CD-ROM for BR7000/ BR7000-1/S485 included in delivery

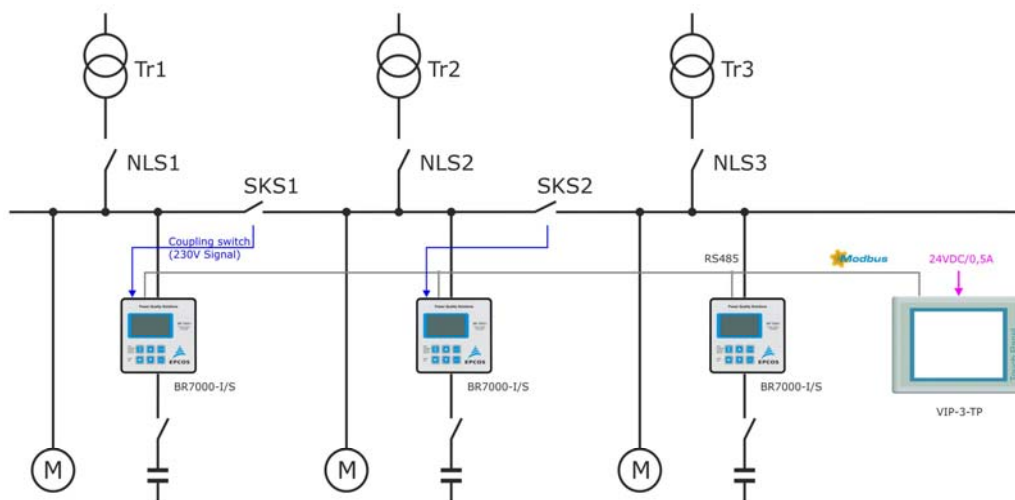
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G) Touch panel "VIP-3-TP"



Example: Coupling of more than two systems (controller) via an additional touch panel



Example:

In practice, several compensation systems are often operated at different feed-ins. This inevitably causes the parallel operation of several compensation systems due to the temporary or permanent coupling of the transformers.

The consequence is a mutual interference of the systems, resulting in increased switching operations (thus shorter service life). In the worst case there is a permanent mutual switching – they are commuting.

For this reason a comfortable control device has been developed which enables to operate compensation systems in parallel for three coupled feeding transformers without any retroactivity. With this solution the a.m. problems can be avoided. Another big

advantage is the symmetrization, e.g. when the coupling switches are closed, the necessary capacitor steps of the systems are symmetrically "distributed". This symmetrical distribution is needed to relieve the feeding bus bars as the single loads distribute optimally to the different branches.

7. Conclusion

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.

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8. 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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