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Application Notes

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Dynamic PFC:Thyristor Modules TSM Series

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Foreword

An increasing number of applications call for technologies that respond in real time to fast-changing loads. Conventional, i.e. static power factor correction is being replaced by dynamic PFC systems that can switch PFC capacitors within milliseconds. This can only be done by electronic thyristor switches in conjunction with the appropriate power factor controller.

Thanks to a broad range of products customized to dynamic PFC, EPCOS offers all components required for effective dynamic PFC from a single source:

- High-quality power capacitors
- Seven types of thyristor modules, covering capacitive loads from 10 to 200 kvar
- A dynamic PF controller in 6 and 12 steps
- A hybrid PF controller for mixed compensation

This application note gives an overview of the benefits and advantages of dynamic PFC compared to its conventional counterpart.

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Power Factor Correction

Dynamic PFC: Thyristor Modules TSM Series

A change in technology is taking place in power factor correction. Static PFC systems are being progressively replaced by dynamic systems that offer new technical advantages and cost benefits.

1. Electromechanical contactors vs. electronic switches

Conventional PFC systems consist of a power factor controller and power capacitors. They are connected to the power line via electromechanical switching contactors. Due to the discharge time of the capacitors, however, the **resetting times** of the contactors are longer than 60 seconds.

New applications are increasingly calling for technologies that respond in real time. This is where dynamic PFC systems such as **electronic thyristor modules** are replacing slow electromechanical switches. As well as shorter response times, their longer service life is an important advantage of dynamic systems, because thyristors are not subject to mechanical wear. Dispensing with mechanical contactors eliminates a further problem: high inrush currents. The thyristor modules switch the capacitors at the zero crossing of the current, thus avoiding inrush currents that can be as high as 200 times the rated current.

2. Advantages of dynamic PFC

Dynamic systems open up new applications and offer a host of advantages:

- **Reduction of reactive power** and lower energy costs in power distribution systems, even with rapidly changing loads
- **Switching times** shorter than 20 ms
- **Reduced capital expenditure** for new plant (power distribution systems, transmission systems, cable cross-sections, etc.) thanks to the avoidance of peak currents
- **Stabilization of line voltage**, e.g. no voltage dip during welding
- **Prevention** of flicker
- **Smooth, transient-free** switching
- **Longer service life** of the PFC system and connected equipment

Dynamic power factor correction is used in a **broad range of applications:** welding equipment, industrial presses in the automotive industry, wind parks, cranes, elevators and main motor starting, where it obviates the soft starter.

When a low-voltage power capacitor is connected straight to a power line without damping, the effect on the capacitor is similar to that of a short circuit. Capacitors connected in parallel, and charged capacitors in particular, cause extremely high inrush currents. To avoid adverse effects on power quality and capacitor service life, the **inrush currents** must be adequately damped.

An inrush current 157 times higher than the rated current is shown in Fig. 1: it is caused by capacitors connected in parallel with a conventional motor contactor.

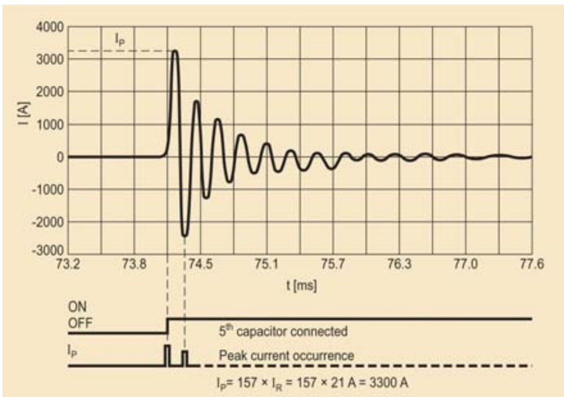

Fig. 1: Capacitor inrush current for a contactor circuit

An inrush current 157 times higher than the rated current results in severe line pollution (e.g. voltage dips), trips fuses and causes severe wear of contactor contacts.

The effect on the power line voltage is shown in Fig. 2: **voltage transients** can have serious consequences such as insulation breakdown, damage to other loads or malfunctions in data systems and instruments.

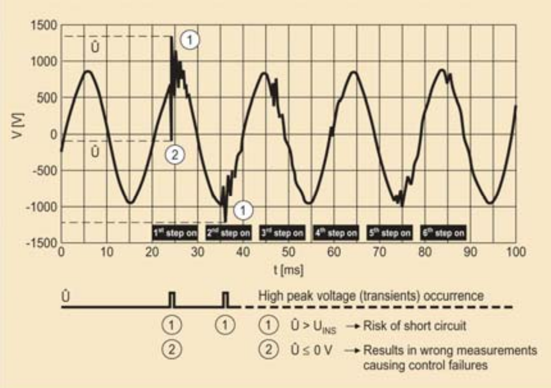

Fig. 2: Voltage transients caused by current peaks

Transients can cause flashover or insulation breakdown and endanger the installation. They can also cause malfunctions in data systems and instruments.

Although extremely high inrush currents can be avoided by using special capacitor switching **contactors with leading and precharging resistors**, a certain pulse current is inevitable (Fig. 3).

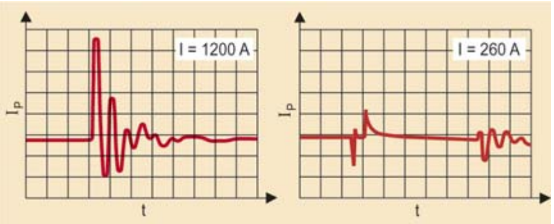

Fig. 3: Contactor configuration with and without damping resistors

Current flowing through a PFC capacitor for a reactive power of 12.5 kvar with a rated current of 18 A at 400 V with damping resistors (right) and without them (left).

3. Thyristor switches

This problem can be remedied with thyristor modules that permit any **number of switching cycles** and offer short switching times for rapidly changing loads. As the capacitors are switched by the thyristor at current zero crossing, high inrush currents are avoided.

The thyristor **switches the capacitor virtually without delay.** As soon as the controller signal is applied to the thyristor, the current starts to flow through the capacitor and increases from zero to its peak value without any inrush current. As no inrush current peaks occur, no dangerous voltage transients are generated either.

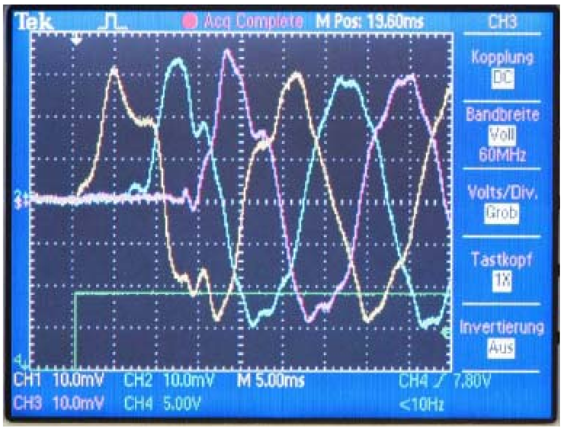

Fig. 4: Capacitor current switched by thyristor

The thyristor switches the capacitor virtually without delay. The current rises from zero to its peak value without any inrush current peak, so no dangerous voltage transients occur.

In case of **harmonic contamination**, a dynamic PFC system with appropriate capacitors combined with inductors should be used to avoid overloading the capacitors.

A **typical application** of dynamic PFC is found in the steel industry. Presses and welding equipment are operated in parallel with the power line. Fast switching times are inevitable due to the **fast load changes**.

Dynamic PFC systems allow *de facto* **real-time control** to be achieved. The design of the dynamic system results in a **significant reduction of apparent power** (see Fig. 7). Capital expenditure for the low-voltage power supply (new busbar system, new transformer, low-voltage main distribution board, etc.) was thus substantially reduced.

4. One-stop shopping for dynamic PFC

EPCOS offers a **comprehensive range of products** for dynamic power factor correction with **seven types of thyristor modules**. These include TSM-LC/HV modules that can handle reactive powers from 10 to 200 kvar, the dynamic power factor controller **BR6000-T** Version 5.0, or the hybrid PF controller BR6000T6/R6 for mixed compensation, PhaseCap® PFC capacitors and complete dynamic PFC systems. The self-monitoring TSM-LC/HV thyristor module is a dynamic electronic switch that can switch PFC capacitors on free of transients in a few milliseconds.

Fig. 5: BR6000T – Version V5.0

A text-based menu-driven display makes the PF controller very easy to use.

It is distinguished by the following **features**:

- Ease of assembly: the thyristor module can be used like a capacitor switching contactor; it has extensive intelligence integrated into it
- Self-monitoring for capacitors handling up to 200 kvar
- No harmonics generated because a complete sine wave is switched
- Fast response times of less than 7 ms
- Continuous self-monitoring of voltage, capacitor current and thyristor-switch temperature
- Control and error message LEDs

The dynamic PF controller BR6000-T (Fig. 5) is the result of the ongoing development of the BR6000 series, to which new functions have been added. It was developed specifically to control the thyristor modules for dynamic switching and the corresponding power factor correction. A typical configuration with a BR6000-T is shown in Fig. 6.

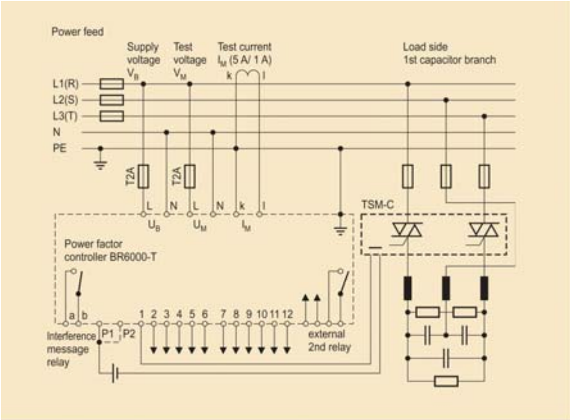

Fig. 6: Circuit diagram of a dynamic PFC system

PF controller BR6000-T is combined with a thyristor module. The controller can drive up to 12 modules for control in stages. The module shown here operates with PFC capacitors and inductors.

In this example, the PF controller drives a TSM thyristor module, which controls PFC capacitors combined with inductors. Thanks to the fast processor, **short switching cycles** are achieved. In addition to a switching time of less than 20 ms, the BR6000-T offers very fast setting of the power factor by simultaneous switching of several stages. Various parameters can be adjusted to assure perfect matching of the PF controller to different thyristor modules.

Another innovation makes it easy to **couple two power factor controllers**. For example, two power feeds can be supported with a single coupling switch. This can also be done without a controller interface. The BR6000-T is available with six or twelve transistor outputs and one alarm terminal.

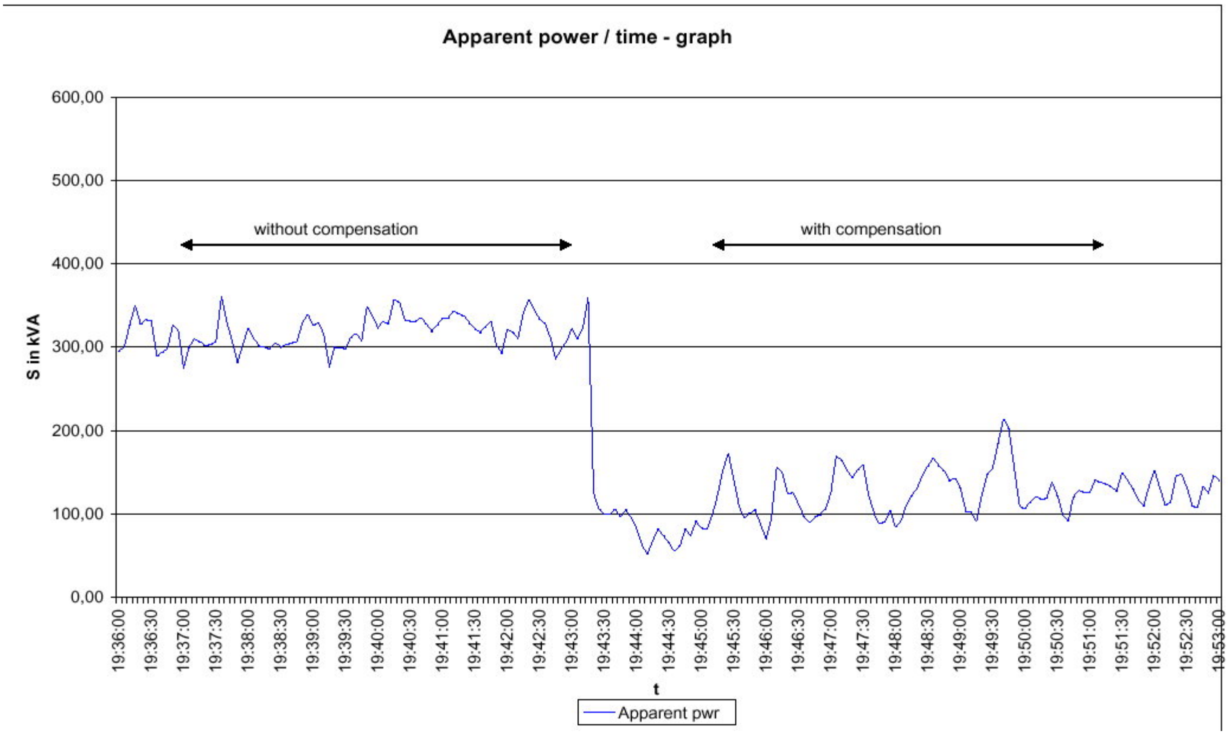

Fig. 7: Significant reduction of apparent power

A text-based menu-driven display makes the PF controller very easy to use. The new features permit intuitive operation. Self-explanatory symbols and supporting text in the respective user language (eight languages available) make handling simple.

The BR6000-T is optionally available with an **RS485 interface** (BR6000-T12/S485). By using a multi measuring interface **MMI6000** together with this controller type, the currents of the particular capacitor branches can permanently be monitored in the PFC-system. This protects the components and increases the safety and the service life of the system. Defective branches (e.g. over current) are directly displayed at the controller. The affected branch is automatically switched off.

Fig. 8: MMI6000

5. Conclusion

Dynamic power factor correction with thyristor modules offers significant advantages over static solutions with capacitor switching contactors:

- Short switching times of less than 7 ms
- No current peaks, therefore no dangerous transients and line pollution
- Lower installation requirement for distribution at the low-voltage level

Overview dynamic PF controllers and MMI6000

Type	Ordering code
BR6000-T6	B44066R6106E230
BR6000-T12	B44066R6112E230
BR6000-T6R6	B44066R6066E230
BR6000-T12/S485	B44066R6412E231
BR6000-T6R6/S485	B44066R6466E230
MMI6000-R standard relay	B44066M6000E230
MMI6000-T optocoupler	B44066M6100E230

EPCOS offers one-stop shopping for dynamic power factor correction:

- Processor-controlled PF controllers with up to 12 outputs
- Fast-switching thyristor modules
- PCB-free PFC capacitors with integrated overload protection
- Inductors for damping PFC capacitors
- Consultancy and installation service

Overview TSM series

Type	Ordering code
TSM-LC10	B4406T0010E402
TSM-LC25	B44066T0025E402
TSM-LC50	B44066T0050E402
TSM-LC100	B44066T0100E402
TSM-LC200	B44066T0200E402
TSM-HV50	B44066T0050E690
TSM-HV200	B44066T0100E690

Fig. 9: TSM series by EPCOS

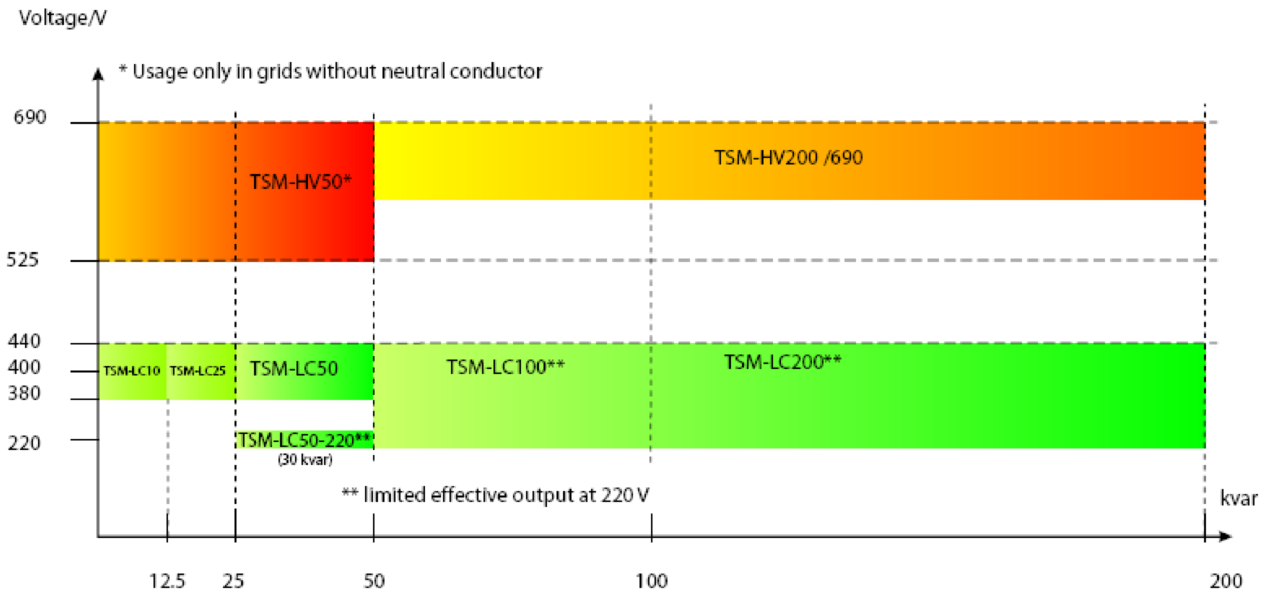

Fig. 10: Selection table TSM series related to case of operation (voltage/output)

6. 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 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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