Application Notes

PQS

Economical and Environmentally Friendly

Power Quality Solutions

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The collection of “PQS Application Notes” is a library with in-depth information on PFC applications, case studies and reference projects. It also serves as a helpdesk for all topics relating to PFC and PQS, is suitable for training purposes and is designed to answer frequently asked questions.

Each issue will focus on a particular application topic, a specific solution or a topic of general interest. The aim is to share the extensive knowledge gained globally by EPCOS PFC experts with regional staff who deal with PFC and PQS. The authors of the PQS Application Notes have extensive experience in the field of PFC and PQS and a professional background as electrical/design engineers or product marketing managers throughout the world.

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Foreword

"The day after tomorrow" has not yet arrived. In terms of climate, however, Mother Earth is showing the red flag: cool, rainy summers and mild winters have become almost commonplace and natural disasters are far too frequent. The century-long reckless exploitation of natural resources has had a serious impact on the climate. All the world's countries must consider changing their ways of using energy.

This application note shows how natural resources can be saved by power factor correction and what a positive impact it will have on the environment.

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1. Outlook

In the year 2007, there were 6.5 billion people on earth, and an extrapolation by the United Nations estimates this figure to rise to 8.7 billion by 2030. This increase will lead to **demand on energy** rising by approximately 50% while natural resources become increasingly scarce: crude oil is currently the primary source of global energy supply with 34%, charcoal with 26% and natural gas with 22% of the total. We consume ten million tons of crude oil every day, with an **upwards tendency**.

No wonder that the words "climate protection" have been so widely heard during the last few years. Whereas many people felt that the movie "The day after tomorrow" showed a very pessimistic picture of the world's future, it is perhaps not so exaggerated after all in view of snow in Buenos Aires, melting ice in Antarctica, torrential rains in India and cool summers in Europe.

According to studies conducted by the Intergovernmental Panel on Climate Change (IPCC), the concentration of atmospheric carbon dioxide has increased by almost 40% since 1750. The main reason for this rise, accounting for 78% of the total, is the **use of fossil fuels** such as charcoal and natural gas.

2. Efficient energy consumption

The **German ZVEI**[*)] has issued a paper on the efficient consumption of energy by means of power factor correction. **Optimizing the consumption of electrical energy** is an effective way of reducing noxious emissions. So power factor correction (PFC) with power capacitors is important not only in terms of cost, but also for improving environmental protection. According to the ZVEI, calculations show that the **PFC systems** installed in Germany alone cut network losses by approximately 5.5 billion kilowatt-hours in 2007 – equivalent to reducing CO_2 emissions by almost 3 million tons!

Power factor correction is a **proven way**:

- Of relieving the power network of an additional load
- Of reducing the cost of energy consumption
- Of saving natural resources by avoiding needless consumption.

3. How reactive currents are produced

Many electrical machines such as AC and three-phase motors use both **active and reactive currents**. Whereas active power is converted into mechanical power, the reactive current assures the necessary magnetization and de-magnetization and thus commutes periodically between the generator and load. As the PFC system is situated as close as possible to the load, less apparent current – the sum of active and reactive current – flows in the power grid. This reduces losses as well as the need for primary energy, ultimately leading to lower CO_2 emissions.

The following **figures, based on the ZVEI study**, impressively show what power factor correction means for the environment:

Increase of energy efficiency thanks to:	48 TWh
• a reduction of CO_2 emissions of	0.40 kg/kWh 19 mil. tons
• a saving of Mtoe[1)]	0.086 Mtoe/TWh
Saving the energy consumption of	13.6 mil. households (3.525 kWh/a)
This equals the energy production of:	
• wind turbines	4,444 (11 GWh/a)
• gas-fired power plants at 405 MW – 7,000 h/a	15 (3,150 GWh/a)
• nuclear power plants at 1,600 MW - 8,000 h/a	4 (12,800 GWh/a)

[1)] Million tons of oil equivalent

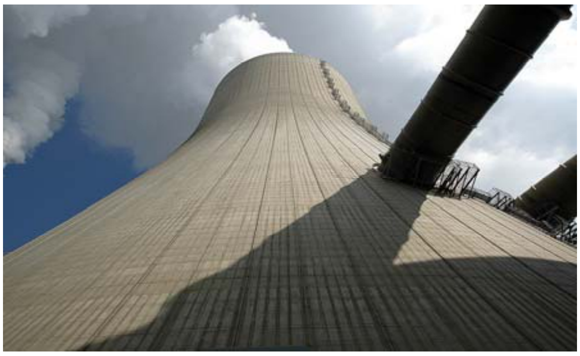

Fig. 1: Power plant

Apart from these **important environmental benefits**, power factor correction offers **economic advantages** as well. Lower losses mean higher profits. In terms of power factor correction, this means:

- Less expenditure on reactive power
- Reduced resistance losses and thus lower costs per kilowatt-hour
- Avoidance of costly capacity expansion in power distribution installations
- Higher transmission capacities for effective power
- Reduction of downtimes and maintenance costs
- Improvement of power quality
- Reduced operating costs

4. Example and calculation

A **practical example** will illustrate the potential savings. An industrial plant has an average power factor (cos φ) of 0.7 for an average consumption of 500 kW and 4000 hours of operation annually. In terms of active power, the company draws 50% of its reactive power at no cost. Without this reactive power, the power factor of 0.9 demanded by the public utility would have been achieved. The remaining 1,040,408 kvarh cost approx. €13,500 annually at an estimated operating cost of 0.013 €/kvarh.

Power factor correction of 268 kvar would be required to raise the power factor to 0.9. The complete installation of a 300 kvar system would require capital expenditure of €8,000. This means that a **return on investment** is already obtained after less than ten months.

Awareness of both environmental protection and cost reduction is increasing, and the market requirements for components suppliers are changing accordingly. As PFC applications become more and more complex and demanding, the solutions have to keep up with them. The basic PFC systems consisting of a PFC capacitor, a controller, contactors and – in the best case – harmonic filter reactors, are overloaded, especially on manufacturing sites where high-tech equipment operates with varying and/or fast-changing loads. A **customized PFC solution** is of major importance in order not to jeopardize the benefits. Various conditions and circumstances have to be considered to make the system pay for itself. Over-dimensioning of a system can be as harmful as under-dimensioning, at least for the end-customer's wallet. In the worst case, both the environment and the end-customer will suffer from an overpriced PFC system: it simply will not be installed for cost reasons. This will in turn result in needless power consumption, higher energy bills and probably in a poor, unstable power supply with voltage sags and production stoppages.

Work done at daytime rate	2 000 000 kWh
Reactive power at daytime rate	2 040 408 kvarh
Reactive power free	1 000 000 kvarh
Reactive power remaining	1 040 408 kvarh
1 040 408 kvarh × €0.013/kvarh	€13,525
Power factor correction, calculated	268 kvar
Standard PFC system, selected	300 kvar
Capex incl. installation approx.	€8,000
Payback period (months)	Approx. 7 months

5. Cornerstones for success

The **application conditions** represent the cornerstones of an efficiently operating PFC system. An appropriate design must be selected on the basis on an analysis of the given parameters. These include the following:

- kind of loads
- presence of harmonics
- surrounding conditions
- ambient temperature
- number of switching operations
- kvar size

These will determine the specific solution. Of course, each component must be of high quality, approved over the long term and manufactured according to the relevant standards. It must also be made of non-polluting material, be free of PCB or other hazardous constituents and easy to dispose of at the end of its service life.

6. PQS products

As the leading manufacturer of capacitors for power factor correction worldwide, EPCOS not only satisfies all these requirements but also offers all key components from a single source. Five series of PFC capacitors allow designs appropriate to the prevailing conditions, such as MKV capacitors for applications with ambient temperatures of up to 70 °C, the PoleCap series for outdoor use or in surroundings with high dust or moisture concentrations. But also PhaseCap HDs with outputs of up to 60 kvar in a single can for applications with limited space or WindCaps for installation in wind turbine or industrial applications. PhaseCap Premium and PhiCap complete the range – as the basis for most of the available series. All other key components available from EPCS are carefully harmonized with respect to each other. Thus the BR6000-T controller works perfectly together with the TSM series of thyristor modules for dynamic PFC. The range of components also includes capacitor contactors without pre-charging resistors for detuned systems. EPCOS follows the **Power Quality Solutions strategy** by offering not only these components, but also joint solutions together with its strategic partners for an optimized PFC system that is environmentally friendly and cost-effective!

*) ZVEI Zentralverband Elektrotechnik- und Elektronikindustrie e.V., Germany

Fig. 2: PQS products from EPCOS

7. 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 for 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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