Application Notes

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More Power with PhaseCap

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Foreword

This application note was first issued in 1998 in the Components Magazine by EPCOS. Now, almost 10 years later, it has not lost its topicality.

In this version, we have done some slight changes that were necessary due to the enhancement the PhaseCap-series has experienced since its introduction to the market.

The high number of PhaseCap sold all over the world is a self-speaking proof for the continuous success of this series and the technology behind it.

The Author

Harald Vetter holds the Dipl. -Ing. Degree from University of Applied Sciences, Regensburg/Germany. Various milestones - especially as head of R&D department PC at EPCOS - mark his long career within the company with many new product developments. He played the major role in the development of dry MKK-AC PFC capacitors, well-known as PhaseCap-series. Holding numerous prices and patents for PEC and PFC, Mr. Vetter has been promoted Product Manager PEC beginning 2007.

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Power Factor Correction

More Power with PhaseCap

Their compact design and reliability have made the PhaseCap® series of power capacitors for power factor correction a true all-rounder among AC capacitors. Covering a voltage range from 230 to 800 V, outputs from 5 to 36 kvar, of single- and three-phase types, they have found wide acceptance on the market ever since their introduction in 1985.

1. Design

PhaseCap capacitors with their many unique features are used not only for power factor correction in low-voltage switchgear but also in countless other applications as well. The design of the PhaseCap is based on the innovative **MKK technology**[1]. This change in film from pure aluminum metallization (**MKP**[2]) to **zinc/aluminum alloy** resulted in better capacitor performance and materialized a **decrease of film thickness** allowing significantly **smaller dimension and weight**.

Their advanced metallization and winding technology including excellent self-healing properties have made EPCOS the world leader in capacitors for power factor correction. PhaseCap offer an economical and space saving alternative to banks of several smaller capacitors that are connected in parallel with elaborate wiring and lower reliability.

More than two million of these **gas-impregnated** power capacitors with metallized polypropylene film housed in cylindrical aluminum cans have been sold worldwide.

Fig. 1: PFC capacitor of the PhaseCap series: compact design and maximum reliability

2. Advanced winding technology

There are powerful arguments in favor of using PhaseCap capacitors for power factor correction. Thanks to an **optimized production technology**, the windings of PhaseCap capacitors are produced with the highest precision.

Electrically separate capacitor elements are **concentrically wound** (Fig. 2) onto an insulated metal or plastic core tube in a single operation. Three-phase windings for delta connections or one to three single-phase windings can be produced without major retooling.

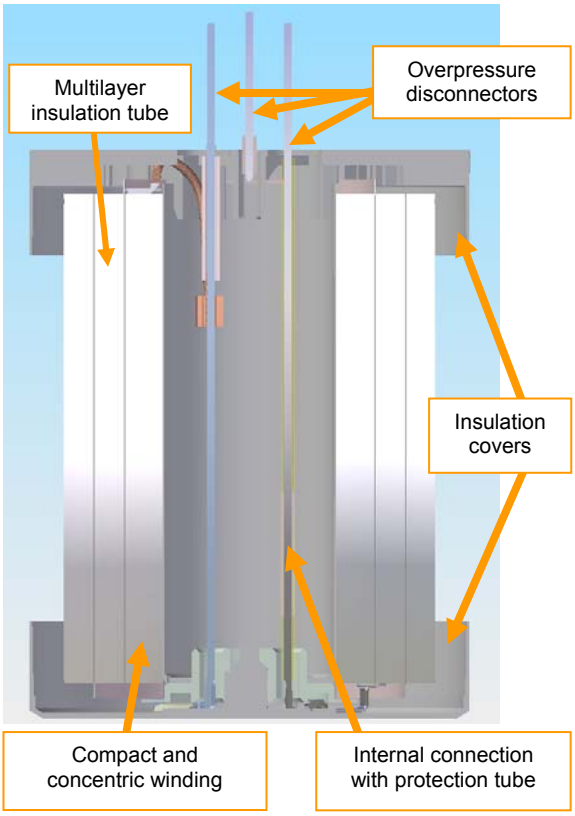

Fig. 2: Concentric 3-phase-winding

[1] **MKK** – **M**etallisierter **K**unststoff **k**ompakt
= metallized polypropylene compact

[2] **MKP** – **M**etallisierter **K**unststoff **P**olypropylen
= metallized polymer polypropylene

3. High inrush current withstand capability

Capacitors in low-voltage switchgear systems are exposed to **frequent switching operations**. They must be able to handle peak surge currents without any reduction of service life. During a 1,500-hour **aging test** to IEC 60831-2/EN 60831-2, PhaseCap capacitors are put through 1,000 discharge cycles at a defined inductance. Technological improvements, such as a heavy edge metallization and a combined **wavy/straight cut** (Fig. 3) for an increased contact area in conjunction with **winding machines of high precision,** have increased their pulse handling capability far beyond the minimum requirements laid down in IEC and EN standards.

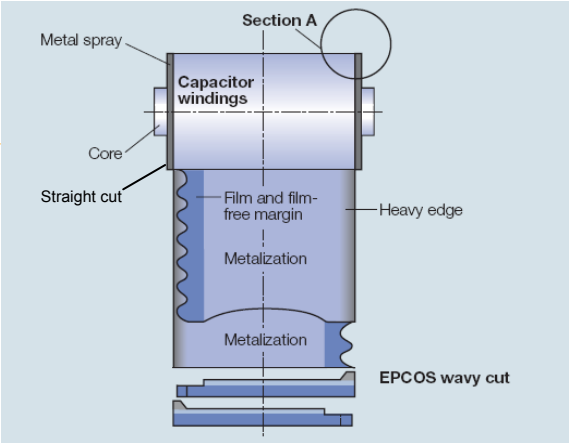

Fig. 3: EPCOS wavy cut/straight cut combination

4. Innovative SIGUT terminal

The three-pole SIGUT clamp terminal is insulated at both ends and makes **connection easy**. The insulator has a tracking resistance greater than 600 to DIN 53480. The terminal clamps are designed for reliable connection of untreated wires in several strands with **cross sections** up to 16 mm^2. This innovative clamp design also prevents loosening of screws under heavy mechanical and thermal stress. The M12 threaded stud on the base is used for both grounding and mounting. SIGUT technology satisfies all relevant requirements for **finger-touch safety** and contact by the back of the hand.

Fig. 4: Three-pole SIGUT clamp terminal

5. Discharge module

The discharge module is already **pre-mounted** and thus simplifies assembly and increases reliability. This innovative discharge module on a **hybrid ceramic base** between the clamps ensures **shock-hazard protection (IP20),** so that inadvertent body contact or short circuits between phase and housing are prevented. The connection to the capacitor is simply achieved by insertion of the module. A **high current surge capability** and **outstanding thermal dissipation** mean further benefits for the customer.

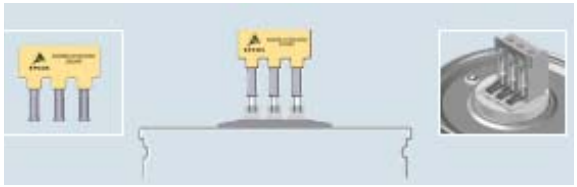

Fig. 5: Pre-mounted discharge module

6. Triple safety built in

PFC equipment for low-voltage switchgear must be largely maintenance-free. **Straightforward disconnection** of gas-impregnated PhaseCap capacitors is expected after extended periods of operation. As a result of non self-healing regeneration processes, especially when the capacitor is overloaded or

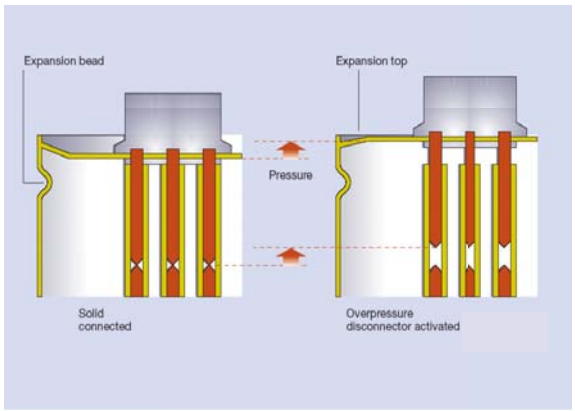

Fig. 6: Safety device overpressure disconnector

approaches the end of its service life, gas escaping from the dielectric increases the pressure inside the can. The specially shaped snap lid then deforms in a controlled manner, simultaneously elongating the wires of the **overpressure disconnector** until the three phases are disconnected (Fig. 6). This safety mechanism reacts quickly as a result of the small volume of gas in the case. A ceramic insulating tube reliably envelops the preset breaking point of the wires to prevent the risk of arc travel during disconnection. The **dry technology** used for PhaseCap avoids the risk of leaking oil. PhaseCap capacitors have passed **destruction tests** to IEC 60831-2:1995 and EN 60831-2:1993. Under these standards, no drops of liquid may fall to the floor at the end of the test, the case must not rupture, no live parts may be exposed, no flames may appear and no flashover or breakdown may occur in the AC voltage test of the coating/case. Tests have also shown that no inflammable or explosive gases escape.

7. Thermal load

PhaseCap capacitors are certified under **temperature class D** of IEC 60831-1:1996/EN 60831-1:1993, i.e. permissible ambient temperatures of +45 °C on a 24-hour average and +55 °C momentarily. For planning compensation equipment in low-voltage switchgear, VDE 0660, Part 500 calls for an annual mean **ambient temperature** of +35 °C. PhaseCap capacitors have a thermal resistance R_{th} of approximately 2 – 3 K/W, depending on can size (see table 1), comparable to that of liquid-impregnated capacitors. Their thermal resistance is also influenced by their mounting position. **Horizontal mounting** has the benefit of good air flow with natural convection. Thanks to their low weight, the capacitors can be mounted horizontally and fastened by the threaded stud on the base without additional support.

Height H_{case} = 200 mm → R_{th} ≈ 2 K/W

Height H_{case} = 164 mm → R_{th} ≈ 3 K/W

This approach is independent of can diameter.

Table 1: R_{th}-values related to can size

Thumb rule for calculation of temperature difference hot spot - ambient, dT_{hs-a}:

dT_{hs-a} [K]≈R_{th} [K/W]xQ [kvar]x0,45 [W/kvar]

Check for overload short time operation:

T_{amb} ≤ 70 [°C]-R_{th} [K/W]xQ [kvar]x0,45 [W/kvar]

8. Long service life

Capacitance losses can occur at high temperatures and AC voltage loads through corrosion of the metallization layer, especially if it is exposed to humidity and atmospheric oxygen. In PhaseCap capacitors, a **metalization** based on a special zinc/aluminum alloy developed by EPCOS and a carefully monitored **dry production process** rule out corrosion from the start. This ensures constant capacitance throughout their long service life. The rated voltage is limited by parameters such as the permissible partial-discharge inception voltage determined by the capacitor design. Most partial discharges appear in regions of higher field strength, e.g. at the metallization edges, in air gaps between films, in the cracks and gaps of solid impregnation and in air bubbles of liquid agents. Complete bubble free impregnation is not possible with an average spacing of about 0.1 µm between the smooth film, and partially impregnated all-plastic windings contain residual atmospheric oxygen, at least on the inside, which shortens the service life of the dielectric.

To improve the general usability of PhaseCap capacitors vis-à-vis other capacitor technologies and in particular to raise their partial-discharge-inception-voltage, an N_2 **inert-gas impregnation** has been used. Just like liquid impregnating agents, this non-toxic and incombustible gas floods the capacitor after it is vacuum-dried, ensuring verifiable, constant quality. The case is then hermetically sealed and examined with a leakage tester. In addition to endurance tests, feedback from numerous users has contributed to the constant capacitance and **long-term reliability** of PhaseCap capacitors.

The dry design of PhaseCap Premium capacitors makes them ideal for PFC applications because, in contrast to all oil or PCB-impregnated capacitors, no liquid can escape in the event of mechanical damage or excessive overload and thus pollute the environment or damage the compensation system.

9. Expected service and failure rate

The service life of power capacitors is determined by various **parameters** which must be carefully optimized, e.g. scaling of the dielectric, film quality, metallization structure, static winding pressure and partial-discharge inception voltage. The production of PhaseCap capacitors is **permanently monitored**, and the data for all process parameters is logged and analyzed. In addition, their contact quality is checked in **regular discharge tests**.

The failure rates quoted for PhaseCap capacitors are calculated on the basis of statistical distributions and include confidence intervals whose limits can be more narrowly defined as component hours increase. Well over three million PhaseCap capacitors have been sold since the first series of MKK capacitors was launched in 1985. Results of endurance tests and feedback from the field both indicate that if PhaseCap capacitors of the B25667-series are used as intended, they can achieve a **service life** up to more than 115,000 hours. The B25668-series even reaches a service life of up to 130,000 hours; both series with a maximum failure rate of 50 FIT.

Figures like these show that PhaseCap capacitors for power factor correction meet user demands for **maintenance-free operation** in full.

10. Follow-on developments

PhaseCap capacitors are today the state-of-the-art for most conventional and dynamic PFC-applications in a voltage range up to 800 VAC and an output of 33 kvar/50 Hz (36 kvar/ 60 Hz). In case of need for higher output or different requirements, the add-on-developments of MKK-PhaseCap product family should briefly be mentioned:

- **PhaseCap HD**-series offer highest output in only one can: available at different voltages, 40 to 60 kvar can be realized at small dimensions, therefore suited for applications where space is crucial.
- **PhaseCap Compact**, offers highest life expectancy (up to 180,000 h at temperature class -40/C); allowing up to 10 000 switching operations per year. Compact design for optimum utilization of space inside a panel.
- **PoleCap** capacitors for outdoor usage are available in MKK-technology also.

11. Conclusion

Features and benefits at a glance

- **Self-healing design, inert gas impregnation:** Maintenance-free operation with highly constant capacitance, high temperature class, flameproof
- **Optimized manufacturing with statistical process control:** Long service life of up to 115,000 hours for B25667-series, up to 130,000 hours for B25668-series
- **Combined wavy/smooth cut with increased contact area:** High pulse strength, inrush current withstand capability of up to 200 times the rated current for B25667-series, up to 300 times for B25668-series; capacitors can be connected in parallel and standard contactors can be used
- **Special Zn/Al metallization:** Reduced losses, customer-specific power factor correction for reactive powers
- **Overpressure disconnector:** Straightforward disconnection at end of service life
- **Three-pole SIGUT® clamp terminal:** Enhanced shock hazard protection, no screws to lose, reduced assembly costs, discharge resistors can be added for increased reliability
- **Use of non-hazardous materials** Easy, environmentally friendly disposal at end of service life
- **Low weight and height:** Universal mounting for low-profile design

12. 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. These include:

- 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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