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# MKV Capacitors: Rugged Types for Rough Conditions

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## Foreword

MKV capacitors for power factor correction look back on a field experience in heavy duty applications of more than 30 years. The well-know self-healing capacitor technology offers significant benefits such as very low losses, high inrush current withstandability and a high thermal stability.

With a temperature class of -40 … +70 °C, MKV capacitors are the ideal solution wherever rough ambient conditions are formative for the application. Their rugged design and their long service life mean a significant benefit for industrial applications. The recent enhancement of the product range allows the design of customized PFC-banks.

**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

# MKV Capacitors: Rugged Types for Rough Conditions

When designing a PFC system, the **temperature class** is always of major importance. According to the IEC and EN60831 standards, the **minimum recommendation** is temperature class -25/D. All PFC capacitors from EPCOS fulfil these recommendations (PhaseCap and WindCap series -40/D). But what if the ambient conditions are much higher and the current **exceeds the IEC limit** due to harmonics? This is where the **MKV PFC series** from EPCOS is the right solution! Its compact design offers a variety of benefits that makes it suitable for heavy-duty (HD) applications (Fig.1).

## 1. MKV technology

MKV capacitors are based on the **self-healing principle** and an **oil-impregnated** polypropylene-paper capacitor winding. This winding element consists of double-sided metallized paper as the **electrode** carrier and an unmetallized polypropylene film as the **dielectric**. This combination is especially well suited for high power dissipations.

**Fig. 1:** MKV PFC capacitors for HD applications

The film-paper arrangement that forms the winding is wound in a slightly staggered alignment: one edge of each double-sided metallized paper projects from the winding.

These edges are electrically contacted with vaporized zinc. The **schooping** or metal-spray process uses zinc of the highest purity (Fig. 2).

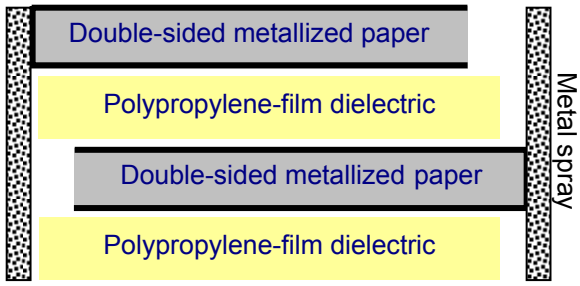


**Fig. 2:** MKV film-paper arrangement

The winding is then subjected to a **clearing process**: a specific voltage is applied to it so that any imperfections of the dielectric are corrected by means of self-healing.

Oil is used for the impregnation. In combination with the paper electrode, it enables **good heat dissipation** from the winding element to the aluminum housing. This results in the low thermal resistance $R_{th}$ typical of MKV capacitors.

## 2. Safety first

MKV capacitors from EPCOS feature a **triple safety system**:

- Self-healing properties
- Overpressure disconnector
- Touch-proof terminal

This is backed up by more than **30 years of field experience** in HD power-electronics applications.

### a) Self-healing properties

Figure 3 shows the **principle of self-healing**. In the event of thermal or electrical overload, an electric breakdown occurs. The dielectric in the breakdown channel is broken down into highly compressed plasma that explodes out of the breakdown channel und pushes the dielectric layers apart. The discharge continues within the spreading plasma via the metal layers so that the metal surrounding the faulty area is completely burnt out. This produces perfect isolation of the faulty area within microseconds. The self-healing process results in a negligible capacitance loss – less than 100 pF per event. The capacitor remains fully functional during the process.

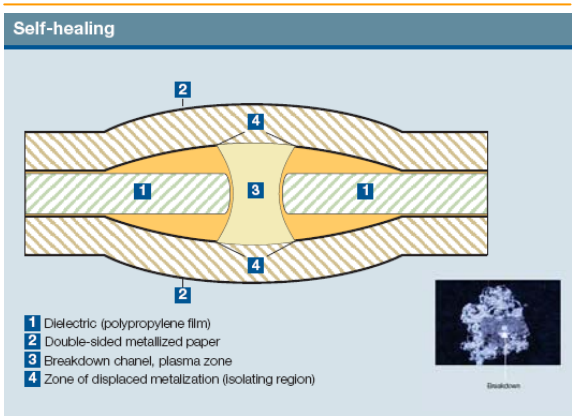


**Fig. 3:** Self-healing principle

### b) Overpressure disconnector

At the end of the capacitor's service life or if a high pressure forms inside it, the overpressure disconnector is activated.

The specially designed cover with an expansion bead moves upwards. Expansion beyond a certain degree will separate the wires and disconnect the capacitor safely from the line (Fig. 4). The disconnector is separated at its break point (small notch) and the flow of current to the capacitor windings is interrupted.

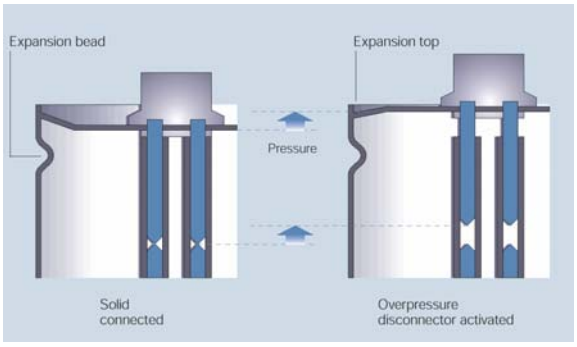


**Fig. 4:** Overpressure disconnector

## 3. Temperature class - definitions

Capacitors are divided into temperature classes. Thus -25/D specifies the lowest ambient temperature (25 °C) to which the capacitor should be exposed (see Table 1). The letter D indicates the highest ambient temperature, 55 °C in this case. However, some applications produce very much higher temperatures, stressing both the equipment and the maintenance staff.

MKV capacitors **are designed for extremely tough conditions**: their temperature class is -40 to +70 °C!

| Temperature class | Temperature of air surrounding the capacitor | | |
|---|---|---|---|
| | Maximum short time | Maximum 24 h mean | Maximum annual mean |
| B | 45 °C | 35 °C | 25 °C |
| C | 50 °C | 40 °C | 30 °C |
| D | 55 °C | 45 °C | 35 °C |
| **MKV:** | | | |
| -40…70 °C | 70 °C | 55 °C | 45 °C |

**Table 1:** Definition of temperature classes

Temperature plays an important role for the useful life of a capacitor. If the specified values are exceeded, their service life is shortened. The temperature also influences the capacitance. Figure 5 shows the characteristic change in capacitance ΔC/C as a function of temperature.

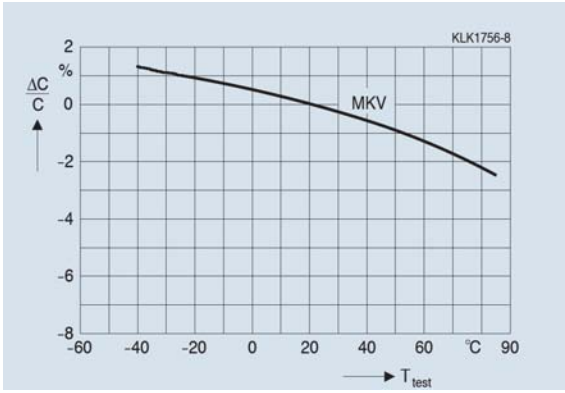


**Fig. 5:** Relative capacitance change ΔC/C versus test temperature

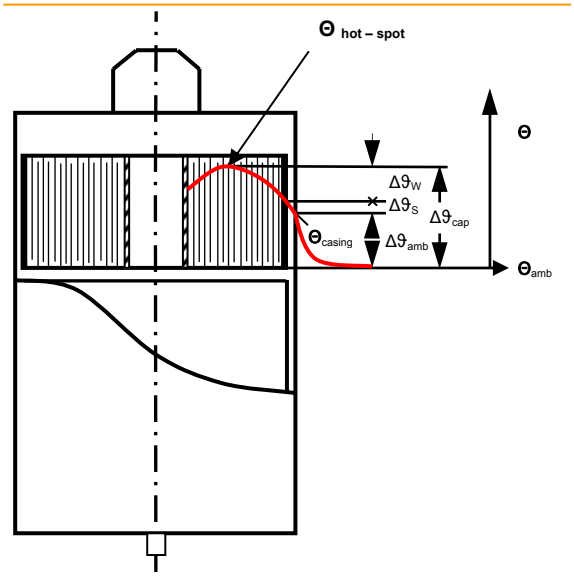


**Fig. 6:** Qualitative temperature characteristic of an MKV PFC capacitor in steady-state operation

Height $H_{case\ MKV}$ = 248 mm → $R_{th}$ ≈ 2,0 K/W

Height $H_{case\ MKV}$ = 325 mm → $R_{th}$ ≈ 1,5 K/W

This approach is independent of the can diameter.

**Table 2**: $R_{th}$ values related to can size

Rule of thumb for calculating the temperature difference hot spot – ambient $dT_{hs\text{-}a}$:

**(1)** $dT_{hs\text{-}a}\,[K] \approx R_{th}\,[K/W] \times Q\,[kvar] \times 0{,}35\,[W/kvar]$

Check for operation in overload condition:

**(2)** $T_{amb} \leq 80\,[°C] - R_{th}\,[K/W] \times Q\,[kvar] \times 0{,}35\,[W/kvar]$

## 4. Technical advantages

Apart from their suitability for applications with high ambient temperatures, MKV capacitors have many technical **benefits**:

- **Overcurrent capability** up to 2.5 x $I_R$ due to the low losses of the windings and the capacitor design with low $R_{th}$
- **Overvoltage capability** (this feature is outstanding compared with MKPs)
- **Inrush current withstand capability** up to 500 x $I_R$
- **Service life** of up to 150,000 hours at a hot-spot temperature $T_{hs}$ = 80 °C
- **SIGUT terminal** assures protection against electric shocks (IP20)
- **Cable cross sections** max. 16 $mm^2$, max. current 55 $A_{rms}$
- **Compact design** for higher packing density inside the panel
- **Simple installation** and connection (M12 threaded stud on bottom of case)
- **Highest proven reliability** based on more than 30 years of field experience
- **Maintenance-free**

## 5. Product range

The product range of MKV capacitors is increasing. A large number of **new types** has been added to the existing selection and will be available from April 2008.

- **Voltage range**: 400 V AC up to 800 V AC
- **Output range**: 5 to 25 kvar (50 Hz) / 30 kvar (60 Hz)

## 6. Conclusions

MKV capacitors are the ideal solution for power factor correction under tough conditions. With their compact design and technology proven in long-term use, they offer highest reliability and performance in environments where capacitors of a lower temperature class would lead to a high failure risk. Their metallization and winding technology permit attractive dimensions of less than 121.6 x 325 mm for the highest output of 25/30 kvar. This allows a high packing density in the PFC system that is vital in HD applications such as wind turbines with limited space.

## 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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