

# Capacitors for Power Factor Correction and Filtering (MKK)

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# Capacitors for Power Factor Correction and Filtering

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PhaseCap™ power capacitors of the MKK series are designed for AC applications in the range of 230 to 1000 V. In addition to power factor correction, PhaseCap™ capacitors are becoming increasingly popular in filter circuits to improve energy quality. The compact design, extremely high stability of capacitance, highest pulse current withstand capability of more than 300 times rated current, ease of installation and service life of more than 100 000 h are indispensable advantages in applications like reactive-power compensation equipment, wind farms, high-power converters and uninterruptible power supplies.

## 1 Product advantages

### Compact design for low height, low weight and small dimensions

The PhaseCap™ MKK capacitor in compact design is a metallized polypropylene film capacitor with self-healing properties. The current carrying metal layer of an MKK capacitor is vapor-deposited onto one side of the polypropylene film.

Three electrically separated partial capacitors are wound concentrically in a single operation on an insulated metal core tube, which guarantees excellent winding precision. The electrodes are connected by metal spraying (schooping) at the front surface of the winding element. The partial capacitors can be connected in star, delta or series circuits. The compact MKK winding element is housed in a cylindrical aluminum case with a metal lid, press-rolled onto it.

### Extended service life of more than 100000 h

After an extended drying period impregnation (filling the capacitor case with protection gas) is carried out under high vacuum to reduce moisture at the active element. Finally, the case is hermetically sealed and the gas proofness is inspected in routine tests using a special leakage tester.

This design avoids oxidation as well as partial discharges, and ensures therefore capacitance stability over an extended period of time, which is essential especially in filter circuit applications.

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You can find out all about PhaseCap™ MKK series from your local Siemens sales office for passive components or direct from

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For information on our entire product range look in on internet under <http://www.siemens.de/pr/inf/20/55/d0000000.htm>

## Highest inrush current withstand capability is crucial

Capacitors used in power factor correction systems are frequently switched. The related inrush currents must be handled without affecting the service life. The pulse handling capability of this technology depends mainly on the contact zone area. Enlargement of the sensible contact zone is of major importance. The S+M patent, the "wave cut", has brought the breakthrough in this critical matter. Inrush currents of 300 times rated current and above can be easily handled.

Highest inrush current withstand capability is crucial in the following applications:

- Parallel switching of capacitors
- Non-detuned capacitors
- Capacitor banks using "standard contactors"

## Customer-oriented output range

- 25 kvar units over all voltage ranges (above 230 V) available
- Outputs adapted for detuned capacitor banks

## The MKK capacitor offers a triple safety system

- Dry-type design. Due to the fact that the assembly is free of liquid impregnating agents, such as oil or PCB, the risk of fire caused by spurting or leaking oil is eliminated. In ecologically sensitive applications as well as for insurance aspects the dry-type design is a must.
- Self-healing technology.
- The overpressure tear-off fuse prevents the capacitor from bursting at the end of service life, or due to inadmissible electrical or thermal overloads.

## Innovative and reliable connection technology: SIGUT®

The SIGUT terminal ensures a reliable and easy connection also for parallel connection of a number of capacitor units.

Major customer benefits are:

- Parallel connection of connection cable
- Protection against electric shock hazard (IP20, according to VDE 0106 part 100)
- Separate connection of discharge resistors increases reliability
- Clamping principle prevents loosening of the screws
- Cable cross sections up to 16 mm<sup>2</sup>

## Easy mounting and grounding

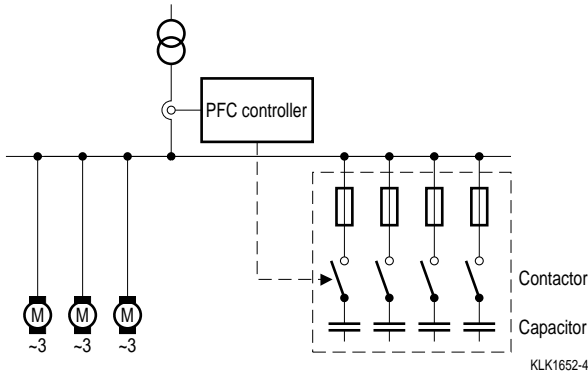
- Any mounting position of the capacitor is possible. The mounting position is chosen to obtain optimum cost effectiveness and ease of engineering for the intended application.
- A threaded stud (M12) at the bottom of the case serves for both grounding and mounting.

# Capacitors for Power Factor Correction and Filtering

## 2 Applications

### 2.1 Power factor correction

Inductive devices like motors or transformers load generators, supply lines and electrical distribution systems with reactive current as well as active current. PhaseCap™ MKK capacitors, specially developed for power factor correction and use in filters, are able to prevent most of this reactive current from reaching power generation/transmission plant.



**Figure 1**  
Standard power factor correction

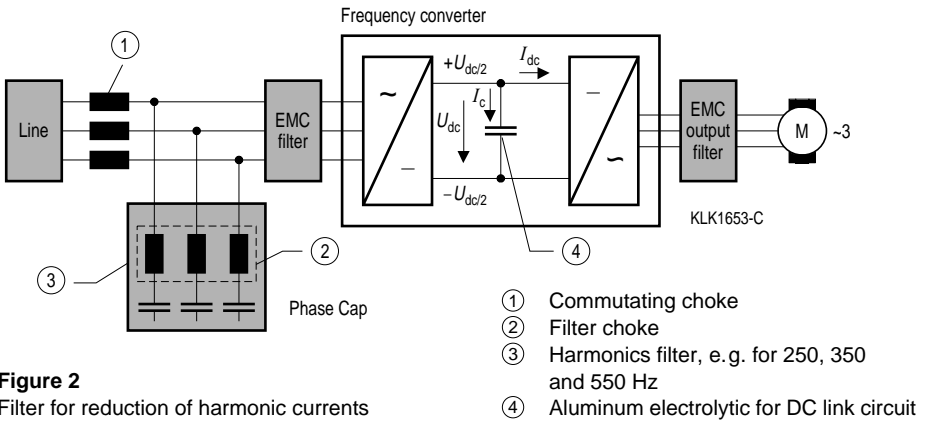
Benefits of power factor correction:

- Amortization in 8 to 24 months  
Power factor correction equipment reduces the amount of reactive power in an installation. As a result electricity bills drop in proportion. Generally investment in PFC equipment pays off within 8 to 24 months of installing it.
- Effective utilization of electrical power  
An improved power factor means higher active power for the same apparent power. This makes an electrical system more economical.
- Reduction of losses  
Cables carry less reactive current when the power factor is improved. This reduces the conduction losses in a cable.
- Optimum dimensioning of cables  
The required cable size reduces with the improvement of power factor. In an existing application the same cable can be used to serve an additional load.
- Reduction of transmission losses  
Since the transmission and switchgear equipment carry reduced current, only the active current, electrical losses will be reduced.
- Improvement of power quality

## 2.2 Harmonics filter in power electronics

Power converter current is actually a current mix, with a fundamental component of line frequency and a number of harmonics whose frequencies are integral multiples of line frequency. The harmonic currents are impressed on the three-phase line. This results in harmonic voltages on the network impedances that are superimposed on the fundamental and cause distortion of the line voltage. This can lead to disturbance in the network and to outage of other loads.

PhaseCap™ MKK capacitors, used in harmonics filters, reduce the harmonics and improve energy quality.

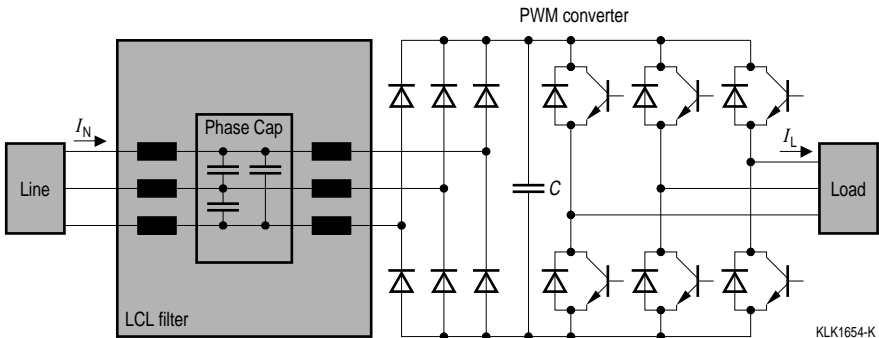


**Figure 2**

Filter for reduction of harmonic currents

## 2.3 Damping of harmonics in power electronics

PWM converters generate harmonics in the range of 3 to 12 kHz. This has a negative effect on energy quality. Harmonic currents cause considerable disturbance in other loads. PhaseCap™ capacitors are used in filters to keep disturbing harmonic currents away from supply networks.



**Figure 3**

Damping of harmonic currents

# Capacitors for Power Factor Correction and Filtering

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## 3 General technical information and formulas for power factor correction

### 3.1 Definitions

#### Active power

The amount of input power converted into output power is termed active power and generally represented by  $P$ .

Active power is defined by the following formula:

$$P = U \cdot I \cdot \cos \varphi \quad [\text{W}]$$

The formula  $P = \sqrt{3} \cdot U \cdot I \cdot \cos \varphi$  applies to three-phase systems.

Ideally the entire input, i.e. apparent power, should be converted into useful output, i.e. active power, e.g. the motor output on a shaft. In such a case  $\cos \varphi$  is unity and the system is said to work at unity power factor.

#### Reactive power

Electric machines work by converting electromagnetic energy (e.g. electric motors, transformers). Part of the input energy is used to create and maintain the magnetic field. This part of the input energy cannot be converted into active energy and is returned to the electrical network upon removal of the magnetic field. This power is therefore called reactive power  $Q$  and defined as follows:

$$Q = U \cdot I \cdot \sin \varphi \quad [\text{var}]$$

The formula  $Q = \sqrt{3} \cdot U \cdot I \cdot \sin \varphi$  applies to three-phase systems.

#### Apparent power

Applications of electric equipment are based on conversion of electrical energy into some other form of energy. The electrical power drawn by the equipment from the source is termed apparent power and consists of active and reactive power. It is defined as follows:

$$S = U \cdot I \quad [\text{VA}]$$

The formula  $S = \sqrt{3} \cdot U \cdot I$  applies to three-phase systems.

#### Power factor

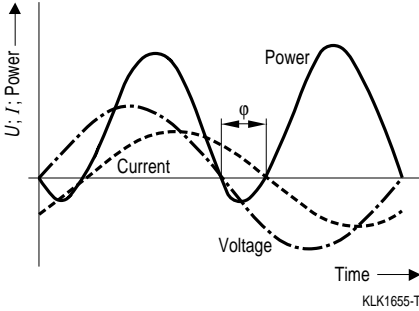
Electrically, the power factor of a circuit is defined as the cosine of the phase angle between the fundamental of the voltage and current waveforms.

Power factor is also defined as the ratio of active power to apparent power:

$$\text{power factor} = \frac{\text{active power}}{\text{apparent power}} = \frac{P}{S} = \cos \varphi$$

## 3.2 Inductive circuits

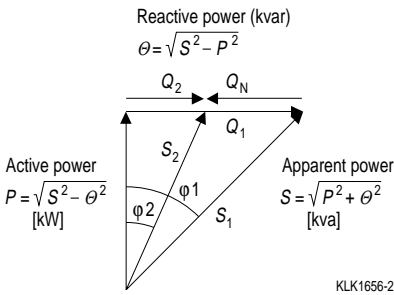
Most industrial loads are inductive in nature, e.g. motors and transformers. Due to the inductive reactance of the load, the current drawn by the load lags behind the voltage waveform electrically by an angle  $\varphi$ . The magnitude of  $\varphi$  is proportional to the inductive reactance. Since the current lags behind the voltage, inductive loads are said to have a lagging power factor.



**Figure 4**  
Lagging power factor condition

## 3.3 How do capacitors correct power factor?

Capacitors are characterized by leading kvar in the phasor diagram or power triangle. This is opposite to the inductive kvar (refer to the following diagram).



**Figure 5**  
Phasor diagram for power factor correction

- $\cos \varphi = P/S$
- $\sin \varphi = Q/S$
- $Q = S \sin \varphi$
- $Q = P \tan \varphi$
- $\varphi =$  phase displacement angle
- $S_1 =$  uncompensated apparent power
- $S_2 =$  compensated power with capacitors for compensation

# Capacitors for Power Factor Correction and Filtering

The angle  $\varphi$  is the phase angle between the voltage and current waveforms. The reactive power is defined by

$$Q = \sqrt{S^2 - P^2} \quad [\text{var}]$$

A capacitor of Q kvar will compensate for the inductive kvar and produce  $\cos \varphi = 1$ .

It is not common practice to produce  $\cos \varphi = 1$  with capacitors because this may result in overcompensation due to load changes and the response time of the controller. Generally public utilities specify a value ( $\cos \varphi_2$ ) to which the existing power factor ( $\cos \varphi_1$ ) should be corrected.

The reactive power to be compensated is determined as follows.

$$Q_N = P \cdot (\tan \varphi_1 - \tan \varphi_2) \quad [\text{var}]$$

### 3.4 Connection and rating of capacitors

A general expression for the kvar rating of a capacitor (single-phase connection) is:

$$Q_N = U_N \cdot I_N \quad [\text{var}]$$

$$Q_N = U_N \cdot \frac{U_N}{X_N}$$

$$X_N = \frac{1}{\omega \cdot C_N} = \frac{1}{2\pi \cdot f_N \cdot C_N}$$

$$Q_N = U_N^2 \cdot \omega \cdot C_N = U_N^2 \cdot 2\pi \cdot f_N \cdot C_N$$

#### 3.4.1 Capacitor in single-phase PFC application

The capacitor is connected across the phase and neutral and is subjected to the phase voltage. The above equation, without any change, is applicable to such capacitors.

#### 3.4.2 Capacitor in three-phase PFC application

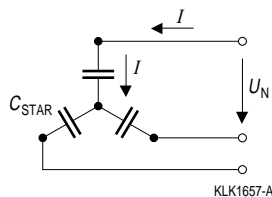
*Star connection*

The partial capacitor is subjected to a voltage of  $\frac{U_N}{\sqrt{3}}$

Thus total kvar compensation of all three partial capacitors:

$$Q_N = 3 \cdot \left(\frac{U_N}{\sqrt{3}}\right)^2 \cdot \omega \cdot C_{\text{STAR}} = U_N^2 \cdot \omega \cdot C_{\text{STAR}}$$

$$C_{\text{STAR}} = \frac{Q_N}{U_N^2 \cdot \omega} = \frac{Q_N}{U_N^2 \cdot 2\pi \cdot f_N}$$



**Figure 6**  
Star connection

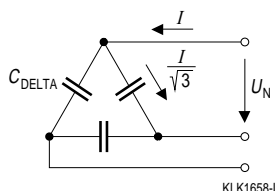
## Delta connection

The capacitor is subjected to line voltage  $U_N$ , phase to phase.

Thus total kvar compensation:

$$Q_N = 3 \cdot U_N^2 \cdot \omega \cdot C_{\text{DELTA}}$$

$$C_{\text{DELTA}} = \frac{Q_N}{3 \cdot U_N^2 \cdot \omega} = \frac{Q_N}{3 \cdot U_N^2 \cdot 2\pi \cdot f_N}$$



**Figure 7**  
Delta connection

From the above equations it follows that for the desired  $Q$  kvar:

$$C_{\text{DELTA}} = \frac{C_{\text{STAR}}}{3}$$

Thus for the same amount of kvar compensation a star connection requires the triple capacitance of a delta connection. On the other hand, for the same nominal voltage  $U_N$  in delta connection a  $\sqrt{3}$  thicker dielectric film is required to get similar values of electric field strength.

### 3.4.3 Calculation of capacitor ratings using standard tables

Capacitors can be rated by multiplying the active power  $P$  given on the rating plate of the motor by the value in the table below.

To find the right value, choose your existing power factor (here 0,7), then move horizontally to the column of the desired power factor (here 0,9). The value you find there is the one to multiply by the active power of the motor (0,54).

Thus, for the last example:

$$Q_N = P \cdot 0,54$$

### Capacitor output in case of operating voltage and/or frequency different to nominal ratings

$$Q_{\text{NEW}} = \left( \frac{U_{\text{NEW}}}{U_N} \right)^2 \cdot \frac{f_{\text{NEW}}}{f_N} \cdot Q_N$$

Note:

- 1)  $U_{\text{NEW}} < U_N$
- 2)  $f_{\text{NEW}}$ : 50 or 60 Hz; in case of higher frequencies, losses have to be taken into consideration, thermal data sheet can be used.

## Capacitors for Power Factor Correction and Filtering

| Existing power factor ( $\cos \varphi_1$ ) | Desired power factor $\cos \varphi_2$ |      |      |      |      |             |      |      |      |      |
|--|---------------------------------------|------|------|------|------|-------------|------|------|------|------|
|  | 1,0                                   | 0,98 | 0,96 | 0,94 | 0,92 | <b>0,90</b> | 0,85 | 0,80 | 0,75 | 0,70 |
| 0,40                                       | 2,29                                  | 2,09 | 2,00 | 1,93 | 1,86 | 1,81        | 1,67 | 1,54 | 1,41 | 1,27 |
| 0,45                                       | 1,99                                  | 1,79 | 1,70 | 1,63 | 1,56 | 1,51        | 1,37 | 1,24 | 1,11 | 0,97 |
| 0,50                                       | 1,73                                  | 1,53 | 1,44 | 1,37 | 1,30 | 1,25        | 1,11 | 0,98 | 0,85 | 0,71 |
| 0,55                                       | 1,52                                  | 1,32 | 1,23 | 1,16 | 1,09 | 1,04        | 0,90 | 0,77 | 0,64 | 0,50 |
| 0,60                                       | 1,33                                  | 1,13 | 1,04 | 0,97 | 0,90 | 0,85        | 0,71 | 0,58 | 0,45 | 0,31 |
| 0,65                                       | 1,17                                  | 0,97 | 0,88 | 0,81 | 0,74 | 0,69        | 0,55 | 0,42 | 0,29 | 0,15 |
| <b>0,70</b>                                | 1,02                                  | 0,82 | 0,73 | 0,66 | 0,59 | <b>0,54</b> | 0,40 | 0,27 | 0,14 | –    |
| 0,75                                       | 0,88                                  | 0,68 | 0,59 | 0,52 | 0,45 | 0,40        | 0,26 | 0,13 | –    | –    |
| 0,80                                       | 0,75                                  | 0,55 | 0,46 | 0,39 | 0,32 | 0,27        | 0,13 | –    | –    | –    |
| 0,85                                       | 0,62                                  | 0,42 | 0,33 | 0,26 | 0,19 | 0,14        | –    | –    | –    | –    |
| 0,90                                       | 0,48                                  | 0,28 | 0,19 | 0,12 | 0,05 | –           | –    | –    | –    | –    |

### 3.4.4 General rules for rating capacitors

In a plant that is still in the design phase an average power factor of  $\cos \varphi_1 = 0,7$  can be assumed for the reactive power loads. To compensate to  $\cos \varphi = 0,9$ , the value 0,54 for  $(\tan \varphi_1 - \tan \varphi_2)$  can be taken from the table above. In this case a capacitor rating of about 50 % of the active power rating would be selected.

$$Q_N = P \cdot 0,5$$

With existing operating plant the necessary values can be taken by measurements.

To determine the correct capacitor rating, accurate values of the connected power and operating times should be known.

This calculation is only valid where the load conditions are more or less constant. Under extreme load variations, e.g. heavy motor loads (inductive) during production hours and only heating and lighting during the night, the average values used to determine capacitor ratings would not be sufficient for peak inductive loads. In such cases it is recommended to take meter readings during a one-day period, for example, to obtain exact instantaneous values of current, voltage and  $\cos \varphi$ .

## 4 Thermal design of capacitors for power factor correction

Capacitors of the PhaseCap series can handle a certain amount of harmonic current in addition to the nominal 50 Hz current. How large the extra currents may be depends on various parameters like the frequency of the current, the type of capacitor and ambient temperature. The maximum permissible currents can be determined with the aid of thermal data sheets.

The total power dissipation  $P$  is composed of the dielectric losses  $P_D$  and the resistive losses  $P_R$ :

$$P = P_D + P_R$$

$$P_D = U^2 \cdot 2 \cdot \pi \cdot f_0 \cdot C \cdot \tan \delta_0$$

$U$  rms value of AC voltage applied to capacitor (between two phases)

$f_0$  fundamental frequency

$C$  total capacitance  
(for delta connection  $3 \times C_N$ , for star connection  $C_N$ )

$\tan \delta_0$  dielectric dissipation factor ( $2 \cdot 10^{-4}$ )

For the dielectric losses it is normally sufficient to consider the frequency and voltage of the fundamental for a nonlinear load.

$$P_R = I^2 \cdot R_S$$

$I$  rms value of capacitor current (for one phase)

$R_S$  total series resistance of capacitor at maximum hot-spot temperature  
(refer to thermal data sheet)

For a nonlinear load the rms currents of the harmonics must be added to the rms current of the fundamental according to the following formula:

$$I = \sqrt{I_0^2 + I_1^2 + \dots + I_n^2}$$

$I_0$  rms current of fundamental

$I_1$  rms current of 1st harmonic

...  $I_n$  rms current of nth harmonic

## Calculation example

for MKK-440-D-18,8-01 (B25667-A4307-A365, refer to data sheet, [page 328](#))  
use in 400 V/50 Hz supply network with 5,67 % choke filtering

*Electrical operating point:*

$$C_N = 3 \times 103,1 \mu\text{F}$$

$$U_N = \text{AC } 440 \text{ V}$$

$$U = \text{AC } 424 \text{ V} \quad (\text{voltage applied to capacitor, due to chokes})$$

$$f_0 = 50 \text{ Hz}$$

$$I_0 = 25 \text{ A}$$

$$I_5 = 13,5 \text{ A} \quad (\text{harmonic currents caused by nonlinear loads like power converters, uninterruptible power supplies})$$

$$I_7 = 4,5 \text{ A}$$

$$\tan \delta_0 = 2 \cdot 10^{-4}$$

$$R_S (70 \text{ }^\circ\text{C}) = 13 \text{ m}\Omega$$

*Calculation of rms current:*

$$I = \sqrt{I_0^2 + I_5^2 + I_7^2} = \sqrt{25^2 + 13,5^2 + 4,5^2} \text{ A} \approx 29 \text{ A}$$

# Capacitors for Power Factor Correction and Filtering

## a) Dielectric power dissipation $P_D$

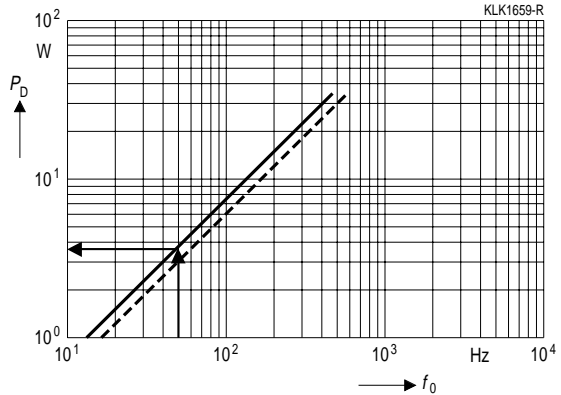
This can be read as a function of frequency from the top diagram of the thermal data sheet (the diagram applies to operation at  $U_N$ , there is also a curve for  $0,9 \cdot U_N$ ) or calculated by equation. The voltage drops caused by the harmonic currents are comparatively small and unknown for most applications, so they can be ignored in this calculation.

$$P_D = U^2 \cdot 2 \cdot \pi \cdot f_0 \cdot C \cdot \tan \delta_0$$

Dielectric power dissipation  $P_D$  versus repetition frequency  $f_0$

$$U_N = AC\ 440\ V \quad \text{—————}$$

$$0,9 \cdot U_N = AC\ 396\ V \quad \text{- - - - -}$$



The result:  $P_D = 3,5\ W$

## b) Resistive power dissipation $P_R$

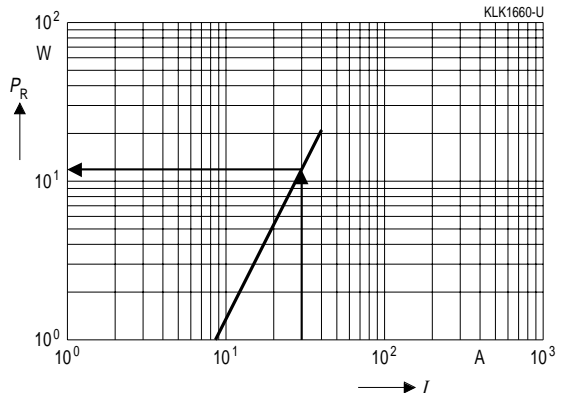
This can be read as a function of current (29 A in the example) from the middle diagram of the thermal data sheet or calculated by equation.

$$P_R = I^2 \cdot R_S$$

Ohmic power dissipation  $P_R$  versus rms current value  $I$

$$R_S (70\ ^\circ C) = 13\ m\Omega$$

$$I_{max} = 40\ A$$



The result:  $P_R = 11\ W$

## c) Permissible ambient temperature:

This can be read as a function of total power dissipation from the bottom diagram of the thermal data sheet.

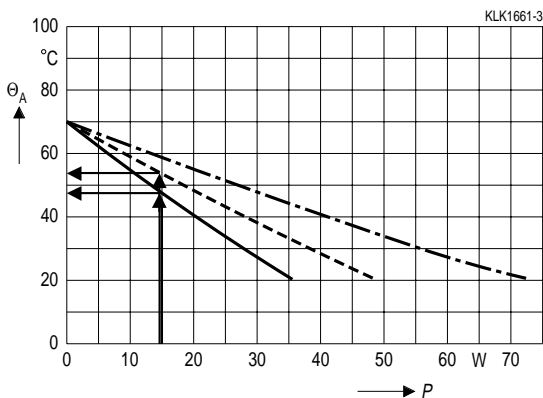
Total power dissipation:

$$P = P_D + P_R = 14,5 \text{ W}$$

Permissible ambient temperature  $\Theta_A$   
versus total power dissipation  $P$

(Upright mounting position)

Natural cooling —————  
Forced cooling 2 m/s - - - - -  
Permissible capacitor  
temperature - - - - -  
black painted



The result is the following permissible ambient temperature (for continuous operation):

for natural cooling:  $\Theta_{Amax} = 48 \text{ }^\circ\text{C}$

for forced convection cooling (2 m/s):  $\Theta_{Amax} = 54 \text{ }^\circ\text{C}$

## 5 Symbols and terms

### 5.1 Characteristics

|                    |                   |  |
|--------------------|-------------------|--|
| $C_N$              | [ $\mu\text{F}$ ] | Rated (or nominal) capacitance, the capacitance value for which the capacitor has been designed.                   |
| $C_{\text{DELTA}}$ | [ $\mu\text{F}$ ] | Capacitance value of one partial capacitor in delta connection.  |
| $C_{\text{STAR}}$  | [ $\mu\text{F}$ ] | Capacitance value of one partial capacitor in star connection.   |
| $\cos \varphi$     |                   | Power factor   |
| $f_N$              | [Hz]              | Rated (or nominal) frequency, the frequency for which the capacitor has been designed.                             |
| $I_N$              | [A]               | Rated (or nominal) current, rms value of the alternating current resulting from rated output and rated voltage.    |
| $P$                | [W]               | Active power   |
| $Q_N$              | [var]             | Rated (or nominal) output, the reactive power derived from the rated values of voltage, frequency and capacitance. |
| $S$                | [kva]             | Apparent power   |

# Capacitors for Power Factor Correction and Filtering

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|                 |  |
|-----------------|--|
| $\tan \delta_0$ | Dielectric dissipation factor<br>The dissipation factor $\tan \delta_0$ of the dielectric is assumed to be constant for all capacitors in their frequency range of use. The figure stated in data sheets apply to rated operation  |
| $U_i$ [V]       | Insulation level, only for units having all terminals insulated from the case.<br>The insulation level shall be marked by means of two numbers separated by a stroke, the first number giving the rms value of the power frequency test voltage $U_{TC}$ (in kV) and the second number giving the crest value of the lightning impulse test voltage (in kV), e.g. 3/15 kV.<br>Units for non-exposed installation are not tested according to IEC 831 clause 15 ("Lightning impulse voltage test between terminals and container"). For this information should be e.g. 3/- kV. |
| $U_N$ [V]       | Rated (or nominal) voltage,<br>the rms value of the alternating voltage for which the capacitor has been designed.   |
| $X_N$           | Nominal reactance of capacitor   |

## 5.2 Maximum ratings

|                 |   |
|-----------------|---|
| $U_{max}$       | Maximum permissible AC voltage of the capacitor.<br>This value depends on the duration and is specified in the IEC standard as follows:<br>$U_N + 10 \% \text{ (up to 8 hours daily)}$ $U_N + 15 \% \text{ (up to 30 minutes daily)}$ $U_N + 20 \% \text{ (up to 5 minutes)}$ $U_N + 30 \% \text{ (up to 1 minute)}$  |
| $I_{max}$       | Maximum permissible AC current of the capacitor: Capacitors shall be suitable for continuous operation at an rms line current of 1,3 times rated current that occurs at rated sinusoidal voltage and rated frequency, excluding transients.<br>Taking into account the capacitance tolerances of 1,15 · $C_N$ , the maximum current can reach 1,5 · $I_N$ . |
| $I_s$           | Maximum allowed inrush current.   |
| $(du/dt)_{max}$ | Maximum repetitive rate of voltage rise.  |
| $(du/dt)_s$     | Maximum non-repetitive rate of voltage rise.<br>(The rate of voltage rise is limited by the peak current handling capability of the contacts or the self-inductance of a capacitor.)  |

## 5.3 Test data

|                       |   |
|-----------------------|---|
| $U_{TT}$              | Test voltage between terminals; each capacitor shall be subject to an AC test at $U_T = 2,15 \cdot U_N$ for a minimum time of 2 s.  |
| $U_{TC}$              | Test voltage between terminals and case;<br>$U_N \leq 660$ V: 3000 Vac for a period of 10 seconds,<br>$U_N > 660$ V: 6000 Vac for a period of 10 seconds  |
| $\tan \delta$ (50 Hz) | Tangent of the loss angle of a capacitor, the ratio between the equivalent series resistance and the capacitive reactance of the capacitor at specified sinusoidal alternating voltage and frequency. |

## 5.4 Climatic category

|                       |  |
|-----------------------|--|
| $\Theta_{\min}$       | Minimum ambient temperature  |
| $\Theta_{\max}$       | Maximum ambient temperature<br>(under forced cooling conditions higher ambient temperatures possible, see thermal data sheets) |
| Humidity              | Average relative humidity $\leq 75$ %  |
| $t_{LD(\text{co})}$   | Life expectancy  |
| $\Theta_{\text{stg}}$ | Storage and transport temperature range  |

## 5.5 Standards for low voltage power factor correction capacitors

|                         |  |
|-------------------------|--|
| VDE 0560 part 46 and 47 | Power capacitors of the self-healing types for AC systems having rated voltages up to and including 1 kV.<br>part 1: General-performance, testing and rating<br>– safety requirements – guide for installation and operation<br>part 2: Aging test, self-healing test and destruction test |
| IEC 831 part 1 and 2    | Most common international accepted standard for low voltage PFC capacitors, issue date 1996;<br>IEC = "International Electrotechnical Commission" in Geneva/Suisse   |
| EN 60831 part 1 and 2   | European standard, identical to the international standard IEC 831-1   |