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KEY COMPONENTS FOR POWER FACTOR CORRECTION IN 50Hz MAINS

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MSD™ FKD-MV™ DSC™

FOR POWER FACTOR CORRECTION IN MEDIUM VOLTAGE MAINS:

CAPACITORS
AND OTHER KEY COMPONENTS FOR POWER FACTOR CORRECTION IN 50 Hz MAINS

ELECTRONICON KONDENSATOREN GMBH GERA · GERMANY

Issue 01/2016

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BASICS OF POWER FACTOR CORRECTION

Under normal operating conditions certain electrical loads (e.g. induction motors, welding equipment, arc furnaces and fluorescent lighting) draw not only active power from the supply, but also inductive reactive power (kvar). This reactive power is necessary for the equipment to operate correctly but could be interpreted as an undesirable burden on the supply. The power factor of a load is defined as the ratio of active power to apparent power, i.e. kW : kVA and is referred to as cosφ. The closer cosφ is to unity, the less reactive power is drawn from the supply.

A capacitive reactive power resulting from the connection of a correctly sized capacitor can compensate for the inductive reactive power required by the electrical load. This ensures a reduction in the reactive power drawn from the supply and is called Power Factor Correction.

CALCULATION OF REQUIRED CAPACITOR POWER

The reactive power which is necessary to achieve a desired power factor is calculated by the formula: $Q_C = P \cdot F$

Q_C ...reactive power of the required power capacitor
P ... active power of the load to be corrected
F ... conversion factor acc. to chart 1

original power factor $\cos\varphi_1$	conversion factor F for a target power factor $\cos\varphi_2$									
	0.70	0.75	0.80	0.85	0.90	0.92	0.94	0.96	0.98	1.00
0.20	3.879	4.017	4.149	4.279	4.415	4.473	4.536	4.607	4.696	4.899
0.25	2.853	2.991	3.123	3.253	3.389	3.447	3.510	3.581	3.670	3.873
0.30	2.160	2.298	2.430	2.560	2.695	2.754	2.817	2.888	2.977	3.180
0.35	1.656	1.795	1.926	2.057	2.192	2.250	2.313	2.385	2.473	2.676
0.40	1.271	1.409	1.541	1.672	1.807	1.865	1.928	2.000	2.088	2.291
0.45	0.964	1.103	1.235	1.365	1.500	1.559	1.622	1.693	1.781	1.985
0.50	0.712	0.85	0.982	1.112	1.248	1.306	1.369	1.440	1.529	1.732
0.55	0.498	0.637	0.768	0.899	1.034	1.092	1.156	1.227	1.315	1.518
0.60	0.313	0.451	0.583	0.714	0.849	0.907	0.97	1.042	1.130	1.333
0.65	0.149	0.287	0.419	0.549	0.685	0.743	0.806	0.877	0.966	1.169
0.70		0.138	0.27	0.4	0.536	0.594	0.657	0.729	0.817	1.020
0.75			0.132	0.262	0.398	0.456	0.519	0.59	0.679	0.882
0.80				0.13	0.266	0.324	0.387	0.458	0.547	0.75
0.85					0.135	0.194	0.257	0.328	0.417	0.62
0.90						0.058	0.121	0.193	0.281	0.484
0.95								0.037	0.126	0.329

chart 1

Example

A. Calculation based on the consumption data

- consumption of active energy: E_W = 300.000 kWh
- consumption of reactive energy: E_B = 400.000 kvarh
- number of working hours: t = 600 h

1) Calculation of average active power P

$$P = \frac{E_W}{t} = \frac{300.000\ \text{kWh}}{600\ \text{h}} = 500\ \text{kW}$$

2) Calculation of initial power factor $\cos\varphi_1$

$$\cos\varphi_1 = \frac{1}{\sqrt{\left(\frac{E_B}{E_W}\right)^2 + 1}} = \frac{1}{\sqrt{\left(\frac{400{,}000\ \text{kvar}}{300{,}000\ \text{kWh}}\right)^2 + 1}} = 0.6$$

3) From chart 1, we read the factor 1.13 for the improvement of the power factor from 0.6 to 0.98.

4) Calculation of required capacitor power

$$Q_C = 500\ \text{kW} \cdot 1.13 = 565\ \text{kvar}$$

B. Calculation based on the Energy Bill

- reactive power tariff: T/kvarh
- monthly costs for reactive energy: C
- number of working hours: h

Calculation of required capacitor power for $\cos\varphi = 1$

$$Q_c = \frac{C}{h \cdot \frac{T}{\text{kvarh}}}$$

COMMON METHODS OF POWER FACTOR CORRECTION

SINGLE OR FIXED PFC, compensating for the reactive power of individual inductive loads at the point of connection so reducing the load in the connecting cables (typical for single, permanently operated loads with a constant power),

GROUP PFC - connecting one fixed capacitor to a group of simultaneously operated inductive loads (e.g. group of motors, discharge lamps),

constant power demand and long duty cycle →	single- or group-fixed PFC
variable power demand and/or variable duty cycle →	automatic ("bulk") PFC

BULK PFC, typical for large electrical systems with fluctuating load where it is common to connect a number of capacitors to a main power distribution station or substation. The capacitors are controlled by a microprocessor based relay which continuously monitors the reactive power demand on the supply. The relay connects or disconnects the capacitors to compensate for the actual reactive power of the total load and to reduce the overall demand on the supply.

A typical power factor correction system would incorporate a number of capacitor sections determined by the characteristics and the reactive power requirements of the installation under consideration. Sections of 12.5 kvar, 25 kvar, and 50 kvar are usually employed. Larger stages (e.g. 100 kvar and above) are best achieved by cascading a number of smaller sections. This has the beneficial effect of reducing fluctuations in the mains caused by the inrush currents to the capacitors and minimizes supply disturbances. Where harmonic distortion is of concern, appropriate systems are supplied incorporating detuning reactors.

INFLUENCE OF HARMONICS, HARMONIC FILTERING

Developments in modern semiconductor technology have led to a significant increase in the number of thyristor- and inverter-fed loads. Unfortunately these non-linear loads have undesirable effects on the incoming AC supply, drawing appreciable inductive reactive power and a non-sinewave current. The supply system needs to be kept free of this harmonic distortion to prevent equipment malfunction.

A typical inverter current is composed of a mixture of sinewave currents; a fundamental component at the supply frequency and a number of harmonics whose frequencies are integer multiples of the line frequency (in three phase mains most of all the 5th, 7th, and 11th harmonic). The harmonics lead to a higher capacitor current, because the reactive resistance of a capacitor reduces with rising frequency. The rising capacitor current can be accommodated by constructional improvements in the manufacture of the capacitor. However a resonating circuit between the power factor correction capacitors, the inductance of the feeding transformer and/or the mains may occur. If the frequency of such a resonating circuit is close enough to a harmonic frequency, the resulting circuit amplifies the oscillation and leads to immense over-currents and over-voltages.

Harmonic distortion of an AC supply can result in any or all of the following:

- Premature failure of capacitors.
- Nuisance tripping of circuit breakers and other protective devices.
- Failure or maloperation of computers, motor drives, lighting circuits and other sensitive loads

Typical non-linear loads (generating harmonics)

- converters, rectifiers, inverters, choppers
- thyristor controls, three-phase controllers
- electronic valves
- phase controls
- UPS units (inverter technology)
- discharge lamps with magnetic ballasts

WHEN IS IT NECESSARY TO INSTALL A DETUNED PFC SYSTEM?

The installation of detuned (reactor-connected) capacitors is designed to force the resonant frequency of the network below the frequency of the lowest harmonic present, thereby ensuring no resonant circuit and, by implication, no amplification of harmonic currents. Such an installation also has a partial filtering effect, reducing the level of voltage distortion on the supply, and is recommended for all cases where the share of harmonic-generating loads ("non-linear loads") is more than 10% of the rated transformer power. The resonance frequency of a detuned capacitor is always below the frequency of the lowest harmonic present. A close-tuned filter circuit however is tuned to a certain harmonic frequency and presents a very low impedance to the individual harmonic current, diverting the majority of the current into the filter bank rather than the supply.

Detuned capacitors can in general be operated in any mains. In any case, they are a safer choice than non-detuned capacitors and future-proof under the conditions of more and more deteriorating power quality in modern mains.

Attention: Non-detuned and detuned capacitors must never be combined together.

We strongly advise to conduct a comprehensive mains analysis, including measurement of the harmonic content, before designing and installing your power factor correction equipment. In cases, however, where such analysis is not possible, cautious and conservative assessment of the situation to be expected shall be made by means of the general rules in chart 3.

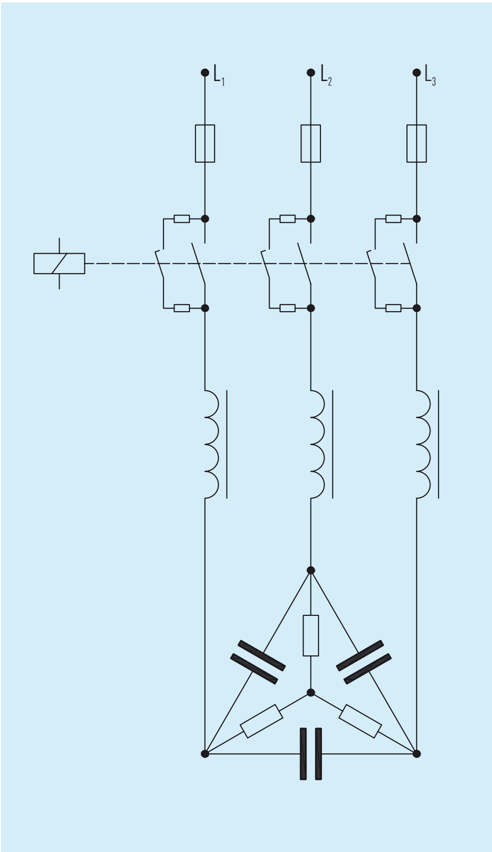
A detuned PFC system is also necessary
- if one or more harmonic voltages in the MV mains are > 2 %, and/or
- if certain audio frequency control signals are used (see page 8)

$S_{OS} : S_T$	Detuning
0 % ... 100 %	non-detuned
> 10 % ... 50 %	detuned
> 40 % ... 100 %	detailed calculation needed, installation of filter circuit if necessary

Abbreviations
S_{OS} ... power of harmonic generating („non-linear") loads in the own network
S_T ... rated transformer power or connection power

chart 3

Installation of detuned (reactor-connected) capacitors



pic. 1

DOES THE MV MAINS CONTAIN AUDIO FREQUENCY CONTROL SIGNALS?

Some energy supply companies use higher-frequency signals in their medium voltage mains for the transmission of control pulses and data. These so-called "audio frequency signals" ranging typically from 160 to 1350 Hz may become absorbed or distorted by, or cause resonance problems with capacitor installations. Such problems may be prevented by the selection of proper detuning reactors.

Capacitor/PFC system	audio frequency	reactive power	activity
non-detuned	< 250 Hz	$Q_C \leq 35$ % of S_T	no specific activity
		$Q_C >$ 35 % of S_T	consult your power supply company and conduct mains analysis
	> 250 Hz	$Q_C \leq 10$ kvar	no specific activity
		$Q_C >$ 10 kvar	consult your power supply company and consider special PFC system
detuned	< 250 Hz	no restrictions	consult your power supply company and consider special PFC system
	250 Hz ... 350 Hz	no restrictions	detuning factor ≥ 7 %
	> 350 Hz	no restrictions	detuning factor ≥ 5 %

chart 4

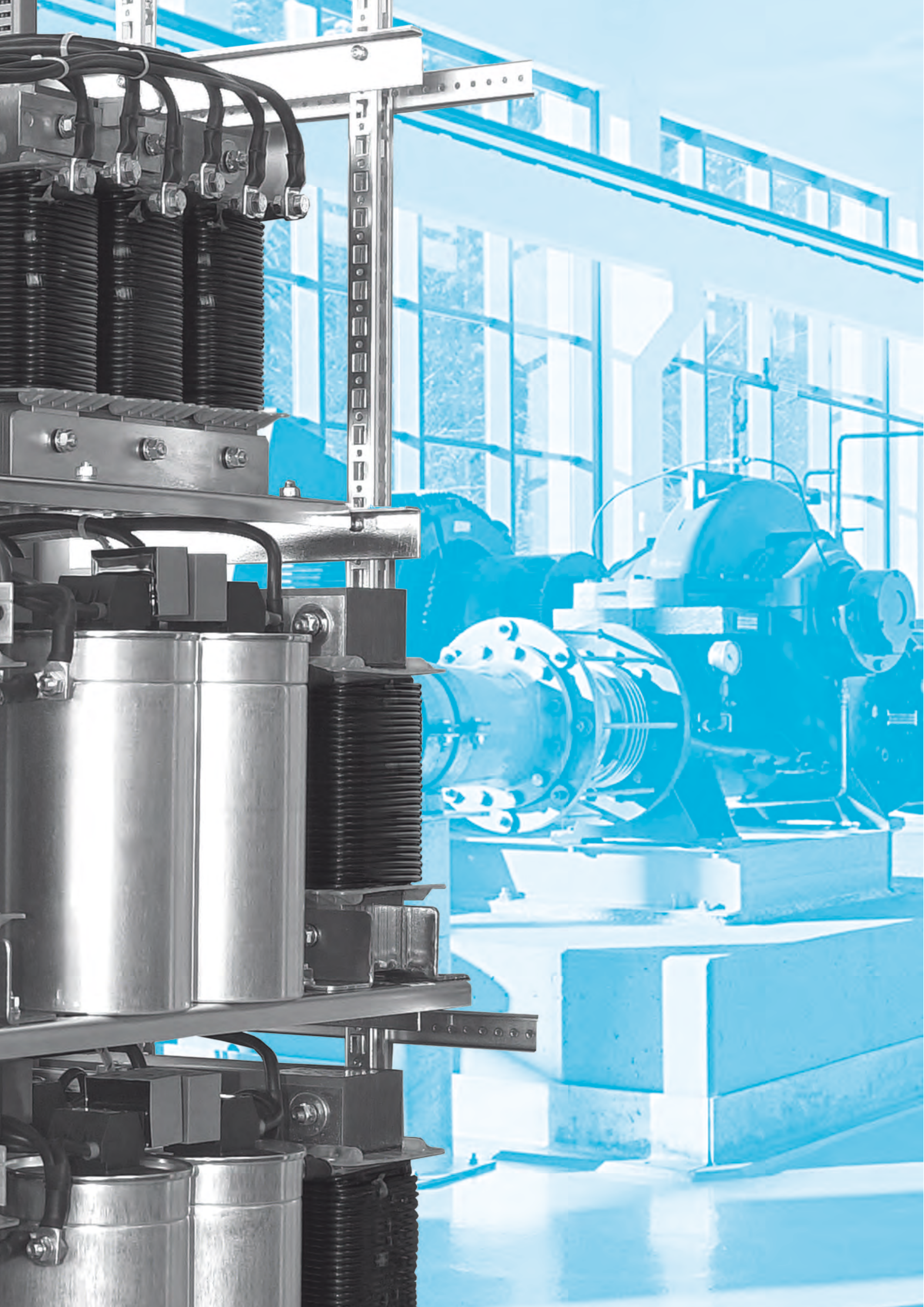
OPERATION OF CAPACITORS IN HIGH-FREQUENCY-FILTERS OR WITH A VERY HIGH SHARE OF LF OR HF HARMONICS

Capacitors which are operated in filters or other systems with a very high share of harmonic distortion, or with harmonics of high frequencies, must be especially selected and prepared for the specific requirements of such applications.

We offer special single and three phase capacitors that are optimized for the operation under such circumstances in our following ranges:

- 280 MKP-UHD: three phase Ultra Heavy Duty capacitors for demanding operating conditions in power factor correction (such as high harmonic content and high operating temperatures), see page 31
- E62-3ph: three phase capacitors for filters with harmonic frequencies of up to 1.3 kHz
- E62-3HF: three phase capacitors for filters with harmonic frequencies of >1.3 kHz
- E62: single phase capacitors for filters with substantial unbalanced loads.

Consult our catalogue brochures for details of the a.m. capacitor ranges. Please refer also to our Application Notes for specific instructions and formulas related to high frequency filters.



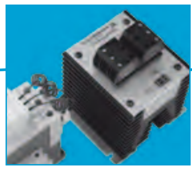
FACTORY MATCHED TO WORK IN PERFECT HARMONY. ALL KEY COMPONENTS FROM ONE SOURCE.

The construction of reliable equipment for power factor correction requires not only your excellent experience, but also top-class components. No compromise in quality and safety should be permitted when it comes to the key parts of your PFC equipment. Because we do care, we are offering you the full set of essential components for your capacitor bank.

THE HEART:

Capacitors. Without them, PFC is impossible. They are the most sensitive and most important component.

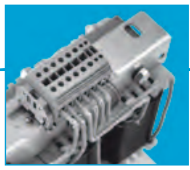
Pages 14 to 37



THE MUSCLE:

Switching is one of the key functions in your PFC, and switching capacitors means maximum stress.

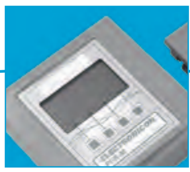
Pages 38 to 52



THE PROTECTION:

Most PFC nowadays cannot do without detuning reactors for harmonic protection anymore.

Pages 54 to 68



THE BRAIN:

The controller shall know what to do, and when.

Pages 70 to 74

POWER CAPACITORS

Apart from your excellent experience, the construction of reliable and competitive equipment for power factor correction requires top-class components at reasonable cost. No compromise in quality and safety should be permitted when it comes to the key part of your PFC equipment. Germany's largest manufacturer of power capacitors manufactures all components with highest care and expertise and is your best choice for power capacitors.

The dry-type phase shifters of our renowned MKPg™-series are environmentally friendly, compact, and very convenient to handle. They contain no liquids, are filled with a neutral, inert gas entirely harmless to environment and may be mounted in any desired position. Should leakage occur, the leaking gas would escape into the atmosphere causing no undesirable effects to the adjacent equipment, e.g. damage, pollution, or staining. Hence when disposing of the capacitors, no liquids or toxic gasses need to be considered. The plant oil in our MKP(D) and MKP-UHD capacitors is biodegradable and does not cause any trouble either, be it in the unlikely event of leakage or during disposal.

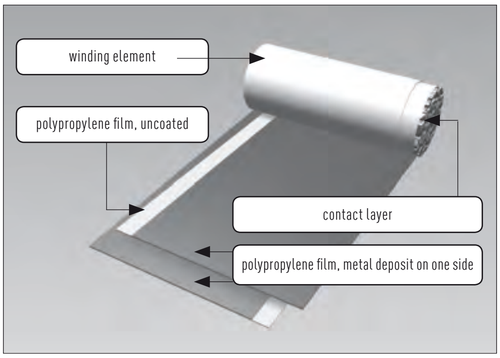
All our three-phase capacitors contain three separate capacitor elements connected in delta, preferably of short height and large diameter which substantially reduces inherent power losses and improves their current strength as compared with slim, tall capacitors. By using the market's best low-loss, self-healing polypropylene films and sophisticated manufacturing techniques such as high-vacuum drying and special coating patterns, they provide long service life with constant capacitance and high switching strength. As a matter of course, all our power capacitors are provided with BAM™ (overpressure break-action mechanism) as standard, for safe mode of failure.

Our original CAPAGRIP™ terminals guarantee optimum sealing of the capacitors, and offer convenient connection of cables up to 50mm². A special spring system guarantees reliable and durable operation of the clamp. They are rated IP20, i.e. protected against accidental finger contact with live parts. Whilst the options K and L4 ("CAPAGRIP II") include bleeding resistors for a discharge below 50 V within up to 60 sec as standard, options L and M also permit the direct connection of discharge reactors and discharge resistor modules, as well as easy parallel connection of additional capacitors within the current limits of the terminal.

CAPAGRIP™

POWER CAPACITORS

INTERNAL CONSTRUCTION



pic.2

Dielectric

MKP-/MKPg-type capacitors are based on a low-loss dielectric formed by pure polypropylene film. A thin mixture of zinc and aluminium is metallized directly on one side of the PP-film under vacuum. Our long term experience as well as on-going research and improvements in this technology ensure the excellent self-healing characteristics of the dielectric and a long operating life of our capacitors. The plastic film is wound into stable cylindrical windings on the most modern automated equipment. The ends of the capacitor windings are contacted by spraying with a metal contact layer, facilitating a high current load and ensuring a low-inductance connection between the terminals and windings.

The link between PP-film and zinc contact layer is highly stressed during high surge or rms currents and therefore considered very critical for operating life and reliability of the capacitor. By cutting the film for selected types in a wavelike manner, our SINECUT™ technology increases the contact surface between film and zinc layer which substantially reduces this strain.

PCB

Impregnants

The use of impregnants and/or filling materials in capacitors is necessary in order to insulate the capacitor electrodes from oxygen, humidity, and other environmental interference. Without such insulation, the metal coating would corrode, an increasing number of partial discharges would occur, the capacitor would lose more and more of its capacitance, suffer increased dielectric losses and a reduced operating life. Therefore, an elaborate vacuum-drying procedure is initiated immediately after insertion of the capacitor elements into the aluminium case and dried insulation gas (MKPg), or biologically degradable plant oil (MKP(D), MKP-UHD), is introduced. Both protect the winding from environmental influence and provide an extended life-expectancy and stable capacitance.

MKPg 275 – Leakage Proof and Environmentally Friendly

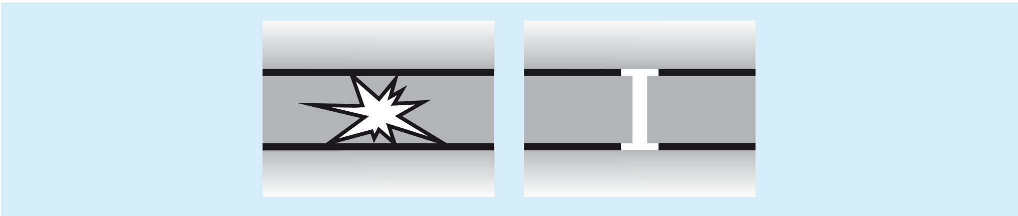
The gas in our MKPg-Capacitors is inert and entirely harmless to environment. When disposing of the capacitors, no liquids or toxic gasses need to be considered. Leakage of gas is extremely unlikely if the capacitors are handled and operated properly. It is possible to mount these capacitors in any desired position. However, should leakage occur, the leaking gas would escape into the atmosphere causing no undesirable effects to the adjacent equipment, e.g. damage, pollution, or staining. In the long run, such an unlikely event would result in a degradation of the capacitance; however, this process would take many months, during which the capacitor remains functional. By using gas, we are reducing the weight of a capacitor on average by 15% compared with resin or oil filled capacitors. This makes transportation and handling of the units easier. It also supports the concept of mounting the capacitors in almost any position.

SAFE OPERATION

Protection against Overvoltages and Short Circuits: Self-Healing Dielectric

All dielectric structures used in our power capacitors are "self-healing": In the event of a voltage breakdown the metal layers around the breakdown channel are evaporated by the temperature of the electric arc that forms between the electrodes. They are removed within a few microseconds and pushed apart by the pressure generated in the centre of the breakdown spot. An insulation area is formed which is reliably resistive and voltage proof for all operating requirements of the capacitor. The capacitor remains fully functional during and after the breakdown.

For voltages within the permitted testing and operating limits the capacitors are short-circuit- and overvoltage proof. They are also proof against external short circuits as far as the resulting surge discharges do not exceed the specified surge current limits.



Self-healing breakdown

pic.3

Protection Against Accidental Contact

All capacitors are checked by routine test (voltage test between shorted terminations and case: $U_{BG} \geq 2\ U_N + 2000$ V, at least 3000V) in accordance with IEC 60831. Accessible capacitors must be earthed at the bottom stud or with an additional earthing clamp.

CAPA**GRIP**™

The CAPAGRIP™ terminal blocks are rated IP20, i.e. they are protected against accidental finger contact with live parts. The discharge modules are designed in the same way (compare page 48). Unused contact cages of design M terminal blocks must be covered by a proper blank (available as standard accessory, see page 52).

Capacitors in design D are not provided with protection against accidental contact as standard. They are available with protective caps on request (see page 52).

Protection against Overload and Failure at the end of Service Life

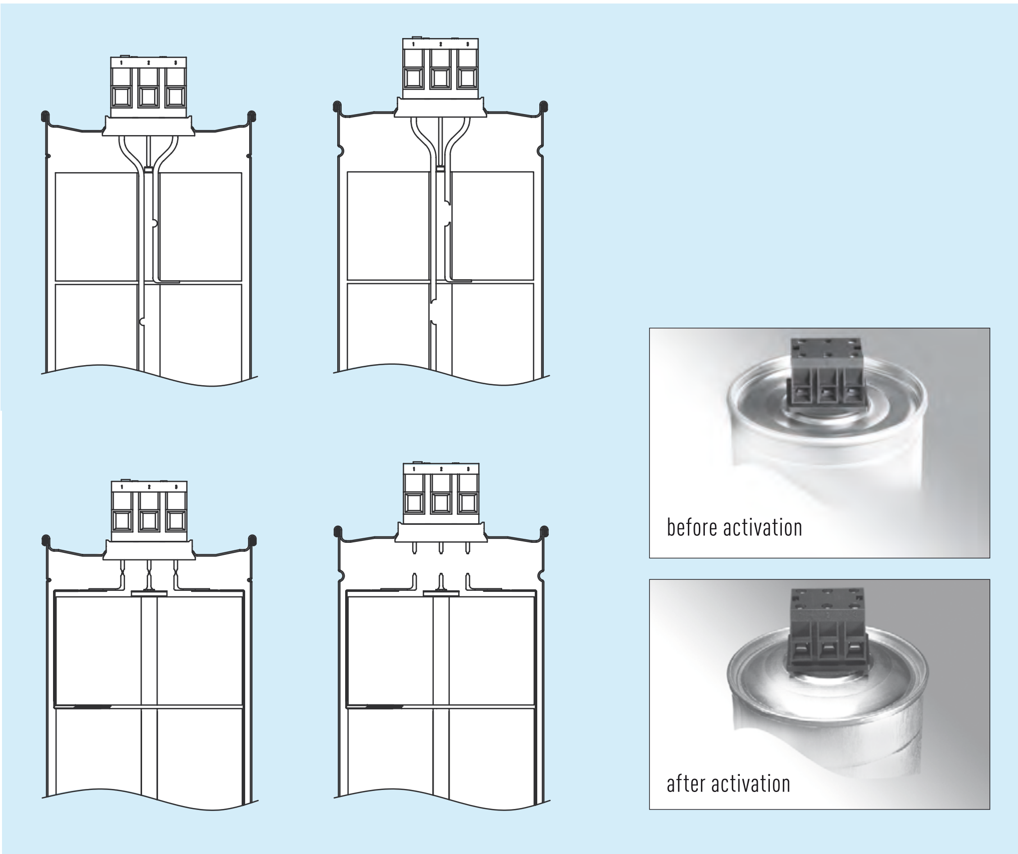
In the event of overvoltage, thermal overload or ageing at the end of the capacitor's useful service life, an increasing number of self-healing breakdowns may cause rising pressure inside the capacitor. To prevent it from bursting, the capacitor is fitted with an obligatory **«break action mechanism» (BAM**™**)**. This safety mechanism is based on an attenuated spot at one, two, or all of the connecting wires inside the capacitor.

All capacitors with diameters < 85 mm as well as some traditional models with large diameters are provided with BAM 1 mechanism. All new models with diameters ≥ 85 mm will be provided with BAM 2 mechanism.

With rising pressure the case begins to expand, mainly by opening the folded crimp and pushing the lid upwards. As a result, the prepared connecting wires are separated at the attenuated spot, and the current path is interrupted irreversibly. It has to be noted that this safety system can act properly only within the permitted limits of loads and overloads.

BAM 1

BAM 2



pic.4

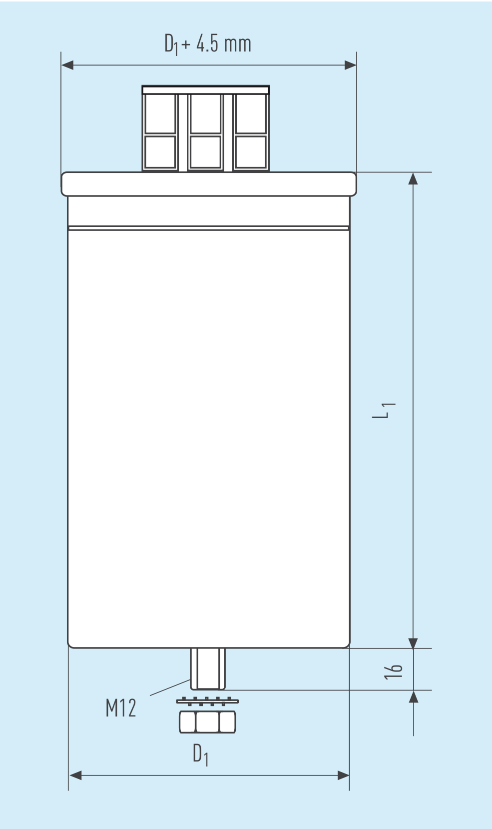
Mind hazards of explosion and fire

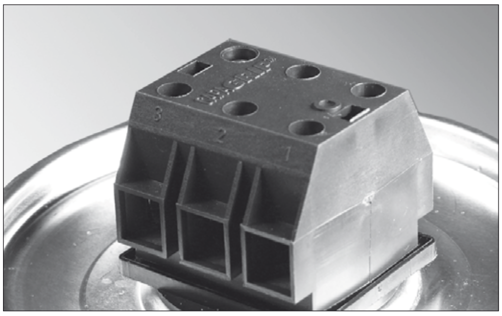
Capacitors consist mainly of polypropylene (up to 90 %), i.e. their energy content is relatively high. They may rupture and ignite as a result of internal faults or external overload (e.g. temperature, over-voltage, harmonic distortion). It must therefore be ensured, by appropriate measures, that they do not form any hazard to their environment in the event of failure or malfunction of the safety mechanism.

Fire Load: approx. 40 MJ/kg

Extinguish with: dry extinguisher (CO_2, foam), or other fire extinguishants suitable for this voltage level

CAPAGRIP™ K, L, M AND CAPAGRIP II™:
EASE OF ASSEMBLY WITH HIGH DEGREE OF PROTECTION





CAPAGRIP™

The CAPAGRIP™ terminals guarantee optimum sealing of the capacitors, and offer convenient connection of cables up to 50 mm^2. A special spring system guarantees reliable and durable operation of the clamp.
Whilst CAPAGRIP™ K and CAPAGRIP II™ ("L4") incorporate bleeding resistors, designs L and M permit the direct connection of discharge reactors and discharge resistor modules, as well as easy parallel connection of additional capacitors within the limits of the current capability of the respective terminal.
For single phase versions, the central screw has no contact.

Series	**MKPg 275, MKP 276, MKP-UHD**
Protection	IP20
Humidity class	C
Creepage distance	16 mm
Air clearance	16 mm

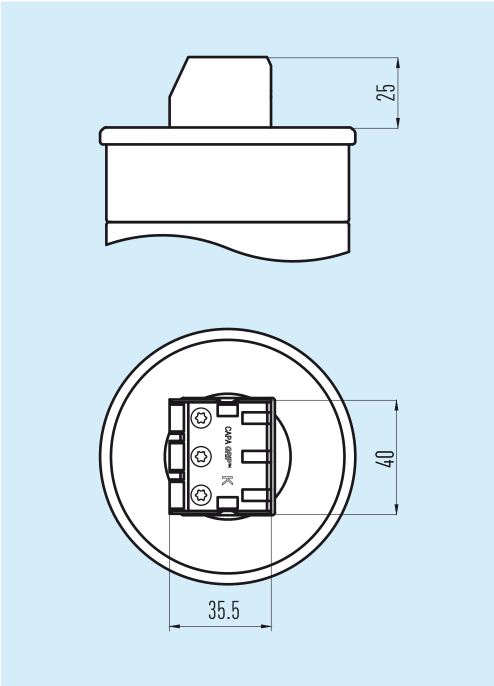
If flat over the entire width of the cage, the body inserted into the terminal must have a thickness of at least 1.2 mm in order to get gripped and fixed by the clamp cage. See chart 5 for minimum thickness of inserted conductor if round-shaped and/or NOT ranging over the entire width of the cage.
See also chart 9 on page 36 for more detailed instructions on connectors and cables sizes.

CAPA**GRIP**™	**Clamp width (mm)**	**minimum conductor height (if < 0.8 × clamp width)**
K	5	2
L, L4	7	2.5
M	10	2.5

chart 5

DESIGN DRAWINGS

CAPA**GRIP**™K



Available for diameters 60 ... 85 mm.

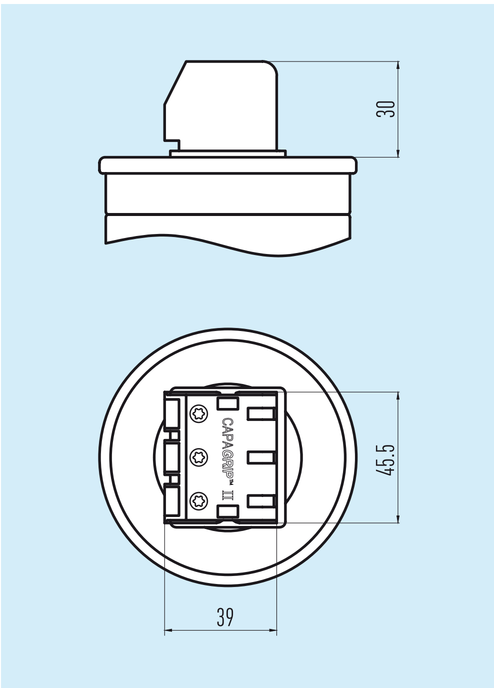
Case
extruded aluminium can with base mounting stud M12, hermetically sealed by aluminium lid (folded edge)

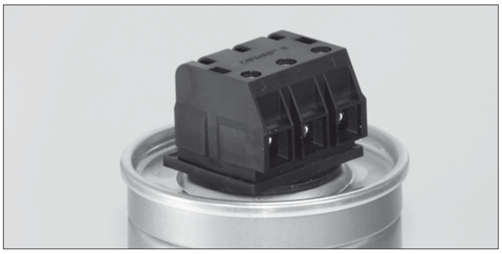
Terminal block
Steel clamp with T20 M4 screws in flame retardant plastic body (UL94:V0)

max. cable cross section:	1 × 10 mm² per phase
max. terminal rating:	39 A/phase

Internal resistors for discharge < 50 V within < 60 s

CAPA**GRIP**II™L4





Available for diameters 85 ... 136 mm.

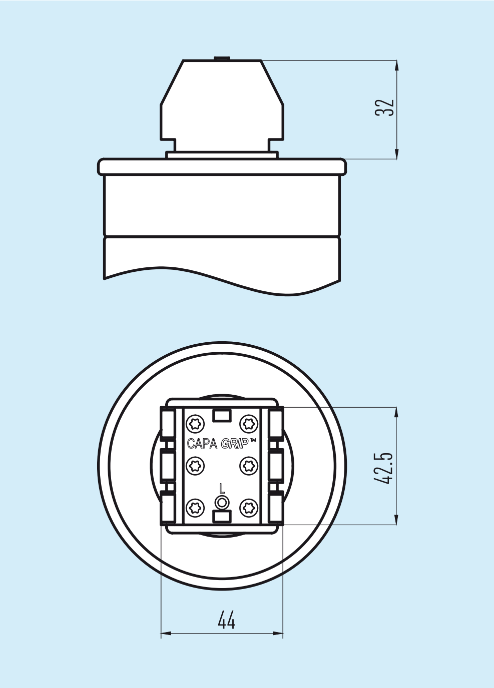
Case
extruded aluminium can with base mounting stud M12, hermetically sealed by aluminium lid (folded edge)

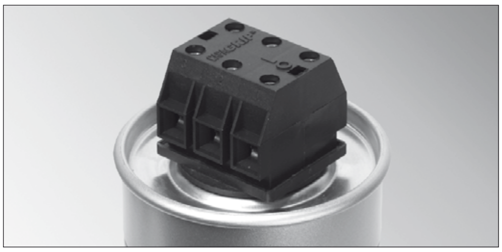
Terminal block
Steel clamp with T20 M5 screws in flame retardant plastic body (UL94:V0)

max.cable cross section:	1 × 25 mm² per phase
max. terminal rating:	56 A/phase

Internal resistors for discharge < 50 V within < 60 s

CAPA**GRIP**™ L





Available for diameters 85 ... 136 mm.

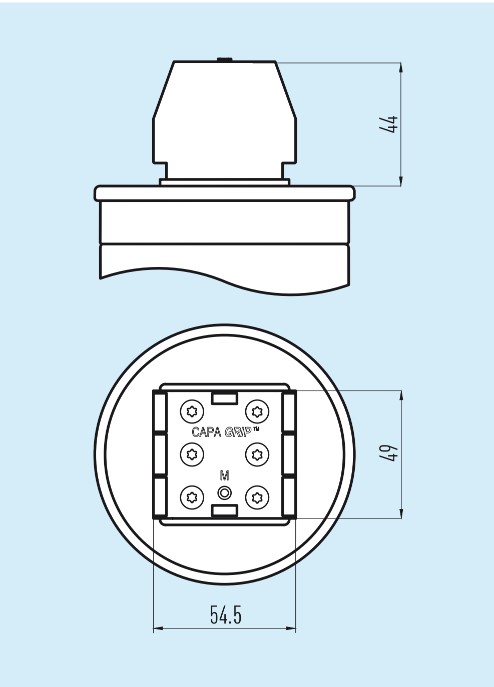
Case
extruded aluminium can with base mounting stud M12,
hermetically sealed by aluminium lid (folded edge)

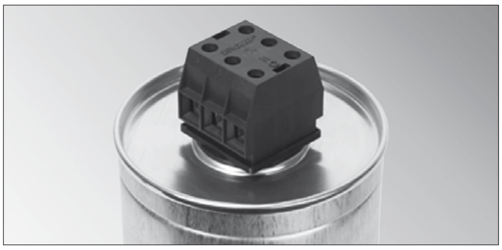
Terminal block
Steel clamp with T20 M5 screws in flame retardant plastic body (UL94:V0)

max. cable cross section:	2 × 25 mm² per phase
max. terminal rating:	56 A/phase

discharge resistors: available as separate item (see pgs. 47ff)

CAPA**GRIP**™ M





Available for diameters 95 ... 136 mm.

Case
extruded aluminium can with base mounting stud M12,
hermetically sealed by aluminium lid (folded edge)

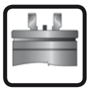
Terminal block
Steel clamp with T20 M6 screws in flame retardant plastic body (UL94:V0)

max. cable cross section:	2 × 50 mm² per phase
max. terminal rating:	104 A/phase

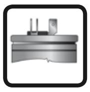
discharge resistors: available as separate item (see pgs. 47ff)

MKP(D): THE LOW-COST ALTERNATIVE

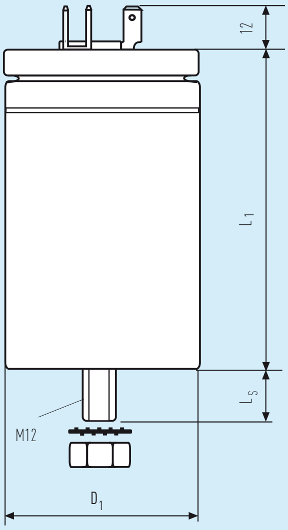
MKP(D)

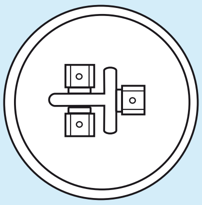


D1/D2

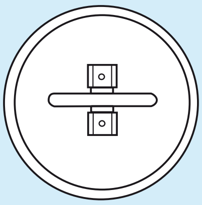


D3

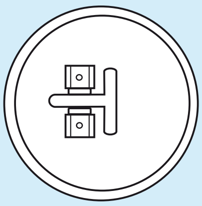




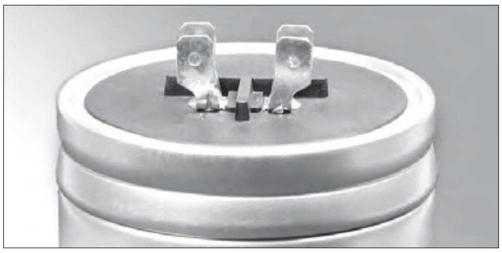
D3
3ph



D1
1ph
ø ≤ 60 mm



D2
1ph
ø = 65...75 mm



The low-cost alternative for single and three phase capacitors with a rated current of up to 16 A/phase and diameters of 40 to 75 mm. Also available with plastic protective cap and mounted discharge resistors.

Series	**MKP(D) 276**
Protection	IP00
Humidity class	F
Creepage distance	10 mm
Air clearance	8 mm

Available for diameters 40 ... 75 mm.

Case
Extruded aluminium can with base mounting stud (M12)
Hermetically sealed by plastic lid with rubber gasket

Terminals
Dual tab connectors, tinned steel 6.3 × 0.8 mm
max. terminal current: 21 A/phase using both terminal tabs

Discharge resistors available as separate item (see page 48)

DESIGN DRAWINGS

DEFINITIONS AND SELECTION CRITERIA

Rated Voltage U_N
Root mean square of the max. permissible value of sinusoidal AC voltage in continuous operation. The rated voltage of the capacitors indicated in the data charts must not be exceeded even in cases of malfunction. Bear in mind that capacitors in detuned equipment are exposed to a higher voltage than that of the rated mains voltage; this is caused by the connection of detuning reactor and capacitor in series. Consequently, capacitors used with reactors must have a voltage rating higher than that of the regular mains voltage (compare U_C on page 57). Unless indicated otherwise, all voltages stated in this catalogue are rms values.

U_N

Maximum RMS Voltage U_{max}
Maximum rms voltage, which the capacitor can be exposed to permanently. This value also considers the maximum reactive power and the resulting power losses of the capacitor.

U_{max}

Test Voltage Between Terminals U_{BB}
Routine test of all capacitors conducted at room temperature, prior to delivery. A further test with 80 % of the test voltage stated in the data sheet may be carried out once at the user's location.

U_{BB}

Voltage test between terminals and case U_{BG}
Routine test of all capacitors between short-circuited terminals and case, conducted at room temperature. May be repeated at the user's location.

U_{BG}

Rated power Q_C
Reactive power resulting from the ratings of capacitance, frequency, and voltage: $Q_C = 2\pi f \cdot C \cdot U_N^2$

Q_C

Maximum RMS Current Rating I_{max}
Maximum rms value of permissible current in continuous operation. The maximum permitted rms current for each particular capacitor is related either to construction features or to the current limits of the terminals. In accordance with IEC 60831 all ELECTRONICON capacitors are rated at least $1.3 \times I_N$ (with I_N being the nominal current of the capacitor at rated voltage and frequency), allowing for the current rise from permissible voltage and capacitance tolerances as well as harmonic distortion. As a rule, our values of maximum permitted continuous current are substantially higher. The exact value for each capacitor can be found in the individual data sheet. Higher rms values can be implemented by adjustments in construction and are available on request.

I_{max}

Continuous currents that exceed the I_{max} values specified in the data charts will lead to a build-up of heat in the capacitor and may cause reduced lifetime or premature failure. Permanent excess current may even result in malfunction of the capacitor's safety mechanisms, i.e. bursting or fire (see page 18).

Care must be taken not to exceed the maximum voltage and current ratings when installing capacitors in close-tuned or detuned equipment (see data sheets for maximum ratings). The thermal monitoring of reactors, or the use of overcurrent protection relays in the capacitor circuit is recommended to protect against overloads.

Current rating I_N

RMS value of the current at rated voltage and frequency, excluding harmonic distortion, switching transients, and capacitance tolerance.

It can be calculated by the formula $I = \frac{Q_C}{U_N} = 2\pi f \cdot C \cdot U_N$ and is not stated in the data charts.

Pulse current strength I_S

Depending on construction and voltage rating, the design of our capacitors permits short term inrush currents of 100...400 × I_N and – in accordance with IEC 60831 – up to 5000 switching operations per annum as standard. However, when switching capacitors in automatic capacitor banks without detuning reactors, higher loads are very often the case. This may generate negative effects on the operational life, especially with capacitors which are frequently connected and disconnected (e.g. primary stages in automatic capacitor banks). Moreover, even detuned capacitors may experience switching currents exceeding the permissible maximum current of the reactor and causing consequential damage to both capacitor and reactor.

We strongly recommend the use of special capacitor contactors with inrush limiting resistors, or other adequate devices for limitation of the peak inrush currents.

Temperature category

The average useful life of a capacitor depends very much on the ambient temperatures it is operated at. The permissible operating temperatures are defined by the temperature class stated on the label which contains the lower limit temperature (-40°C for design D, -50°C for all CAPAGRIP™ power capacitors) and a letter, which describes the values of the upper limit temperatures. Chart 6 is based on IEC 60831 and details the maximum permitted ambient temperatures for capacitors in each temperature category.

temperature category	ambient temperature limits		
	maximum	max. average 24 hrs	max. average 365 days
B	45°C	35°C	25°C
C	50°C	40°C	30°C
D	55°C	45°C	35°C
60	60°C	50°C	40°C
65	65°C	55°C	45°C
70	70°C	60°C	50°C

chart 6

Lifetime Statements

Even though all our lifetime statements are based on many years of empirical data, testing and field statistics, they will always remain just a general prognosis based on data of the past and accelerated laboratory tests which cannot reflect all aspects of modern operating conditions. The real "lifetime" of our capacitors depends on a multitude of influencing factors, such as ambient temperatures, operating voltages, frequency of overvoltages, frequency of switching, system faults a.o. The lifetime estimations given in our data sheets are therefore linked with specific operating conditions (voltage and temperature).

It has also to be noted that any lifetime statement considers a certain percentage of permitted failures within a given lot, reflecting the fact that any component has a FIT rate (failures in time). Under rated operating conditions, our capacitors can be expected to have a FIT rate of no more than 300 (corresponding to a maximum failure rate of 3 %) during their initial 100,000 hours of operation..

Please consult our sales teams if in doubt about the specific implications of your intended operating conditions on lifetime and reliability of our capacitors.

DATA CHARTS

General Technical Data

rated voltages	230 ... 800 V, 50 Hz
permitted overvoltages and test voltages	in accordance with IEC EN 60831-1/2 (see data charts for details)
tolerance of capacitance	– 5 ... + 10 %, ± 5 % on request
maximum permissible current	at least 1.3 I_N, see data charts for details
max. inrush current MKPg 275, MKP(D) 276	300 x I_N
MKP-UHD 280	400 x I_N
dissipation losses (capacitor)	approx. 0.25 ... 0.40 W/kvar
internal connection	delta
safety device	BAM™ (overpressure break action mechanism)
dielectric material	low-loss polypropylene, dry
impregnant (filling material) MKPg 275	inert insulation gas (N_2)
MKP(D) 276, MKP-UHD 280	resin, based on vegetable oil
mounting position MKPg 275	any position
MKP(D) 276, MKP-UHD 280	vertical position recommended
max. relative humidity	95 % (climatic class C; MKP(D) 276 only: climatic class F)
operating temperatures	see data charts for ambient temperature class
storage temperature	-50 ... +85°C
max. altitude abv.s.l.	4000 m a.s.l.
statistical life expectancy	100,000 ... 200,000 h depending on type range and operating temperatures (see charts for details)
applied standards	IEC EN 60831, VDE 0560-46/47 UL Standard No. 810, CSA C22.2 No. 190, GOST 1282-88, IS 13340/13341
approval marks UL® c CSA® us* only ≥ 75 × 230	**all capacitors in this catalogue:** UL/C-UL recognized component, 10,000AFC internally protected **selected items:** CSA (C/US)

All capacitors listed in this catalogue comply with the relevant regulations and guidelines of the European Union: 2014/35/EU (Low-Voltage Directive).
This is proven by the technical documentation and compliance with the following standard: IEC/DIN EN 60831-1/2:2014

CE

MKPg™

275.*** 3PH GAS-FILLED

400 ... 440 V 50Hz

for latest edition and updates
check www.powercapacitors.info

Torx T20 CAPAGRIP C US 10000 AFC C US * *only ≥ 75 × 230

Three-phase power capacitors, dry self-healing dielectric, gas-filled (N_2)
For detuned and non-detuned PFC equipment in mains with standard operating conditions

U_N	$\Theta_{ambient}$	statistical life
400...415 V	-50/D	>130,000 h
440 V	-50/D	>100,000 h

Permitted overvoltages

8h/d	485 V	1min (200×)	575 V
30min/d	510 V	max. peak voltage	1350 V ac
5min (200×)	530 V		

CAPA**GRIP**™ K and II (L4) including discharge resistors. For L and M see resistor modules on pages 48f.

Q_C 440 V (kvar)	Q_C 415 V (kvar)	Q_C 400 V (kvar)	C_N (µF)	I_{max} (A)	$D_1 \times L_1$ (mm)	m (kg)	CAPA GRIP	order no.	packg.lot / box
5	–	–	3 × 28	3 × 12	60 × 164	0.4	K	275.525-402800	10 / FB8
6	5.4	5	3 × 33	3 × 16	65 × 164	0.5	K	275.535-403300	10 / FB8
8.4	7.5	–	3 × 46	3 × 20	75 × 164	0.7	K	275.545-404600	5 / FB8
9.3	8.3	7.5	3 × 51	3 × 19	65 × 230	0.8	K	275.536-405100	10 / FB9
10	–	8.3	3 × 57	3 × 25	65 × 245	1	K	275.538-405700	10 / FB12
11.3	10	–	3 × 62	3 × 23	65 × 245	1	K	275.538-406200	10 / FB12
12.5	–	10	3 × 68	3 × 27	75 × 230	1	K	275.546-406800	5 / FB9
14.1	12.5	–	3 × 77	3 × 28	75 × 230	1	K	275.546-407700	5 / FB9
15	13.3	12.5	3 × 82	3 × 31	75 × 245	1.1	K	275.548-408200	5 / FB12
16.8	15	–	3 × 92	3 × 33	85 × 230	1.3	K	275.556-409200	5 / FB9
18.2	–	15	3 × 100	3 × 36	85 × 245	1.5	K	275.558-410000	5 / FB12
20	–	16.6	3 × 110	3 × 39	85 × 245	1.5	K	275.558-411000	5 / FB12
22.4	20	–	3 × 123	3 × 39	85 × 280	1.5	K	275.559-412300	5 / FB10
25	–	20	3 × 137	3 × 47	85 × 280	1.5	L4	275.259-413700	5 / FB10
28.2	25	–	3 × 154	3 × 56	100 × 245	1.8	L4	275.278-415400	3 / FB12
30	–	25	3 × 166	3 × 56	95 × 280	2	L4	275.269-416600	3 / FB10
50	–	–	3 × 274	3 × 86	136 × 295	4.1	M	275.39B-527400	2 / FB11
–	50	–	3 × 308	3 × 90	136 × 295	4.1	M	275.39B-530800	2 / FB11
–	–	50	3 × 331	3 × 94	136 × 295	4.1	M	275.39B-533300	2 / FB11

Other sizes and ratings are available on request. Single phase capacitors are available on request in same dimensions and design.
Mind Mounting and Operating Instructions on pages 34ff!