FRAKO

CAPACITORS FOR POWER ELECTRONICS

Be on the safe side with FRAKO

NEW
IEC 61071

APPLICATION NOTE

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- Key to symbols

SOLUTIONS

AREAS OF APPLICATION

Power electronics capacitors are capacitors designed especially for use with non-sinusoidal voltages and pulse currents. Power electronics capacitors are available for DC and AC applications.

AC capacitors are used for input filters / output filters, damping capacitors and for erasing semiconductor elements. These capacitors run at **FRAKO** under the abbreviation "LKT-F-".

DESIGN

FRAKO power electronics capacitors are manufactured in a unique dry design. Each comprises up to three interconnected capacitor coils wound in a low-loss, metallized polypropylene film and enclosed in a cylindrical aluminium casing provided with an M12 mounting stud. In addition to a PCB-free, flame-resistant mineral filler material, the casings also contain an adhesive stabilizer. Cables are connected by means of the tried-and tested spring clamps of the AKD range, which are 'finger-safe' and maintenance-free.

The use of rigorously inspected materials and their careful processing guarantee excellent quality and a long product service life. **FRAKO** manufactures its power electronics capacitors to its own in-house specifications, which are far more exacting than the requirements of the applicable standards.

Quality control inspections after each individual manufacturing step ensure that the final product is of a high quality. These demanding quality standards, together with specially developed manufacturing technology, enable **FRAKO** power electronics capacitors to achieve a longer-than-average service life. At the end of the manufacturing process, each capacitor is inspected individually. The in-house requirements for this special inspection are considerably more stringent than those of the routine tests specified by the relevant standards.

Standards

All **FRAKO** power electronics capacitors comply with the international standard IEC 61071.

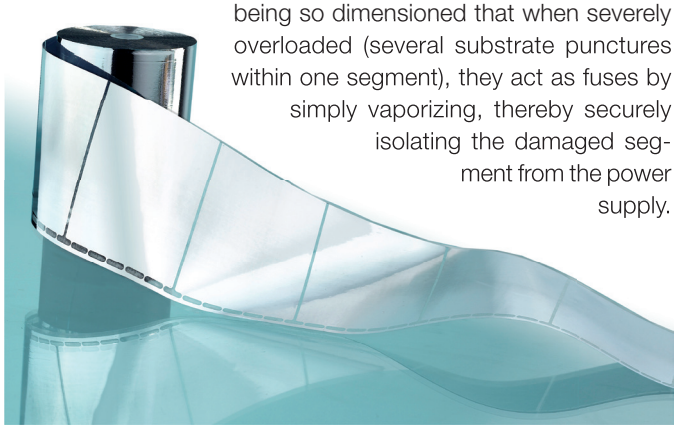
Four safety features ensure uninterrupted operation

The reliability of capacitors for power electronics is crucially important for the problem-free operation of power factor correction systems and passive filters. **FRAKO**'s measures to ensure this are now fourfold: Power electronics capacitors nowadays usually use polypropylene as the dielectric material, its surfaces being metallized. This design has the important property that if local overloading occurs and punctures the substrate film, the fault automatically isolates itself, a phenomenon known as **self-healing**.

Self-healing is due to the heavy short-circuit current that flows between the films immediately vaporizing the very thin metal coating at the damaged location, thus ending the flow of current.

If several punctures occur in a small area of metallized film, the amount of energy involved might be too much for the **self-healing** action alone to cope with. This could lead to complete failure of the capacitor. However, in this case the second fail-safe function of the fourfold safety design comes into play: the **segmented metallization.**

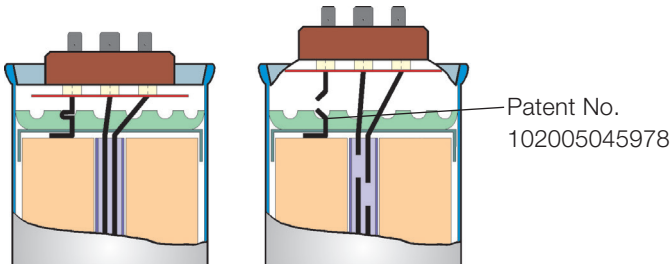
In the manufacturing process, the polypropylene film for **FRAKO** power electronics capacitors is metallized by vapour deposition to form a pattern of separate individual segments. Each segment is connected to the power supply by slender contact bridges, these being so dimensioned that when severely overloaded (several substrate punctures within one segment), they act as fuses by simply vaporizing, thereby securely isolating the damaged segment from the power supply.



The **segmented metallization** technique increases the reliability of the capacitors and prolongs their service life.

The third design feature for increases product safety is the three-phase **overpressure disconnector**, a mechanical fuse included in every **FRAKO** capacitor.

If an excessive internal pressure develops due to overloading, or at the end of the capacitor's service life, the mechanical fuse isolates the capacitor safely from the power supply by disconnecting all poles. Should puncturing of the dielectric occur on a major scale, this results in the substrate film melting and generating gases inside the casing, thus building up pressure in the capacitor. This causes the diaphragm lid to bulge outwards, thereby tensioning the internal leads to the coils until they act as mechanical fuses, breaking cleanly at defined locations. The bulging of the lid also increases the internal volume, therefore reducing the pressure inside the capacitor.



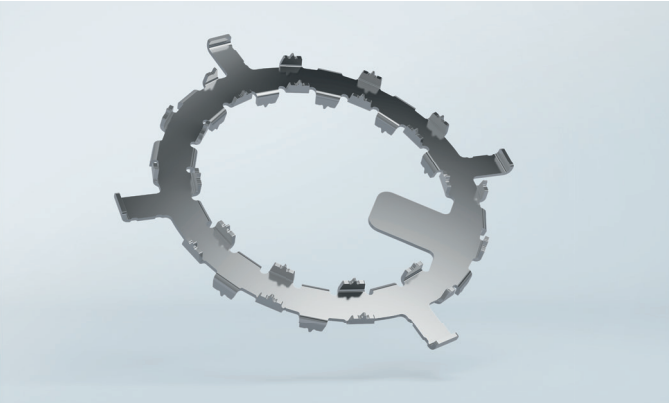
Overpressure disconnection system

In 2015, **FRAKO** added the patented **contact ring** to the other safety and reliability features, thus making them fourfold.

These patented rings are stamped from a special alloy and are formed with a number of pointed teeth that press into the zinc end-face contact layers on the windings to make electrical contact. The internal connecting leads are spot-welded to the **contact rings** before final assembly of the capacitor.

The great advantage of this solder-free design: it has completely excluded the risk of damaging the capacitor windings at the manufacturing stage due to overheating during soldering of the connecting leads. The quality of the winding connection is significantly increased, and the reliability of the mechanical fuse that protects against excessive internal pressure is improved by its being securely spot-welded in place.

The **contact ring** also enables **FRAKO** to produce completely lead-free capacitors, acc. to RoHS, and make yet another improvement to their operating reliability.



Contact ring

Special technical features

In our ongoing development work on **FRAKO** power electronics capacitors, we always focus on those attributes that are called for in present-day applications. The three following factors are especially important:

- Overvoltage tolerance
- Current-carrying capacity
- Thermal endurance

This has been tested in-house with a laboriously programmable voltage source.

GENERAL TECHNICAL DATA

Design

Dielectric	Metallized polypropylene film, if necessary with segmentation
Impregnation	Mineral filler material + adhesive stabilizer
Contact	Solder-free connections inside the housing with contact rings
Fuse	All pole overpressure disconnector
Casing	Aluminium casing with mounting stud
Connection	Via spring tension technology max. 16 mm²
Ingress protection	IP00, IP20 or IP54
Discharge resistors	as required

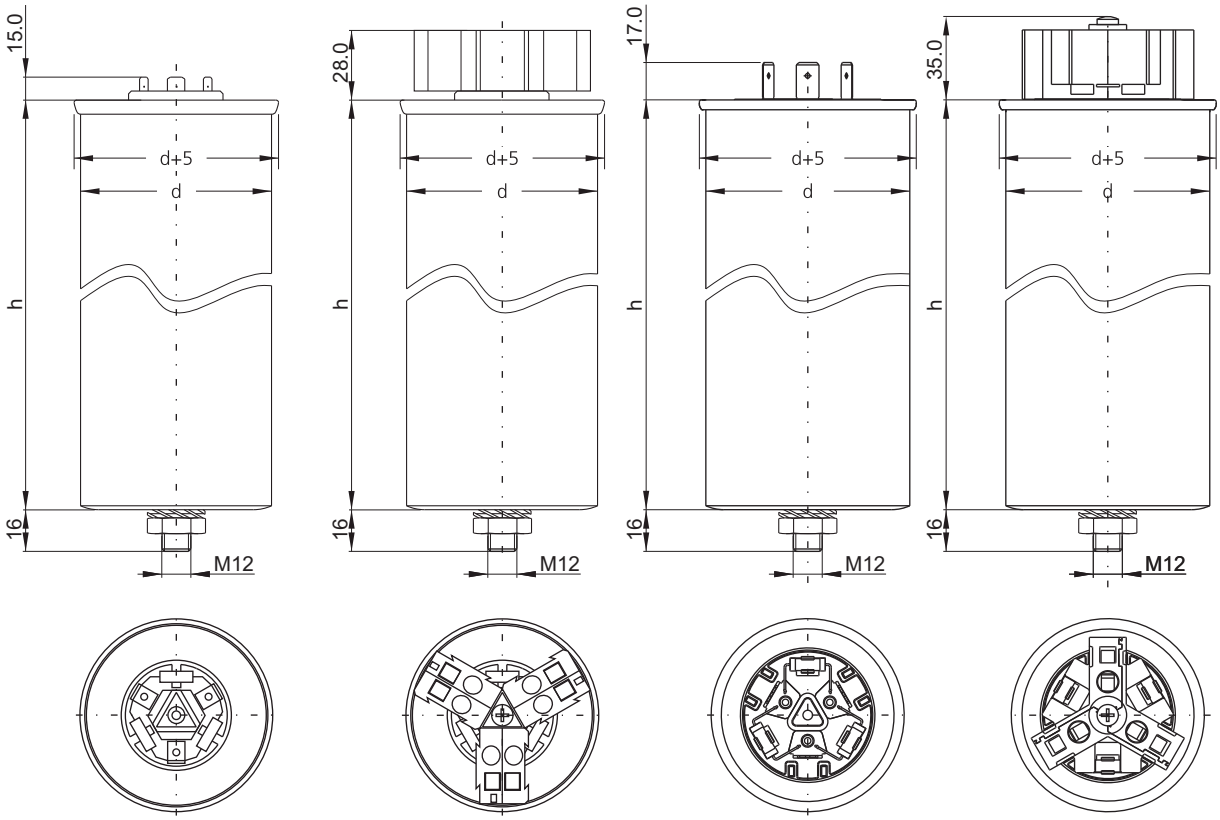
Electrical data

$U_{B/B}$	$1.5 * U_N$ +10 % for 2 sec.
$U_{B/G}$	U_{rms} < 690 V = 3.9 kV, U_{rms} > 690 V = 4.3 kV
U_i	1.3 kV o. 1.5 kV
Endurance test / thermal stability	Acc. to 61071
Capacitance tolerance	± 5 %, closer tolerances on request
Loss factor tan δ (50 / 60 Hz)	< 10*10 - 4
Inductance	< 300 nH

Ambient conditions

Min. temperature	- 40° C
Max. ambient temperature	55° C
Max. casing temperature	75° C
Max. humidity	95 %
Max. site altitude	4 000 m
Min. max. storage temperature	- 40° C – 85° C
Service life	>100 000 h
Failure rate	< 300 FIT

Dimensions



TYPE LIST 3-PHASE

$V_N = 450\,V$ $V_{rms} = 320\,V$ $V_s = 970\,V$								
Article-No.	Type	Capacitance in µF	I_{max} in A	Î in kA	R_{th} in K/W	Diameter in mm	Height in mm	Weight in kg
31-13000	LKT-F-020.0-3-450-BC	3 × 20	22	0.7	≤ 4.2	60	150	0.590
31-13001	LKT-F-030.0-3-450-BC	3 × 30	22	1.0	≤ 4.2	60	150	0.590
31-13002	LKT-F-040.0-3-450-BF	3 × 40	28	1.4	≤ 3.5	70	225	1.090
31-13003	LKT-F-050.0-3-450-BF	3 × 50	28	1.7	≤ 3.5	70	225	1.090
31-13004	LKT-F-075.0-3-450-BF	3 × 75	28	2.6	≤ 3.5	70	225	1.090
31-13011	LKT-F-100.0-3-450-BJ	3 × 100	45	3.5	≤ 2.9	85	215	1.550
31-13012	LKT-F-135.0-3-450-BK	3 × 135	50	4.7	≤ 2.6	85	278	1.900
31-13013	LKT-F-150.0-3-450-BK	3 × 150	50	5.2	≤ 2.6	85	278	1.900

$V_N = 680\,V$ $V_{rms} = 480\,V$ $V_s = 1460\,V$								
Article-No.	Type	Capacitance in µF	I_{max} in A	Î in kA	R_{th} in K/W	Diameter in mm	Height in mm	Weight in kg
31-13005	LKT-F-010.0-3-680-BC	3 × 10	22	0.5	≤ 4.2	60	150	0.590
31-13006	LKT-F-015.0-3-680-BC	3 × 15	22	0.8	≤ 4.2	60	150	0.590
31-13007	LKT-F-020.0-3-680-BD	3 × 20	25	1.0	≤ 3.8	60	225	0.840
31-13014	LKT-F-030.0-3-680-BI	3 × 30	40	1.6	≤ 3.0	85	163	1.200
31-13015	LKT-F-050.0-3-680-BJ	3 × 50	45	2.6	≤ 2.9	85	215	1.550
31-13016	LKT-F-090.0-3-680-BL	3 × 90	55	4.7	≤ 2.1	85	320	2.200

$V_N = 1080\,V$ $V_{rms} = 760\,V$ $V_s = 2320\,V$								
Article-No.	Type	Capacitance in µF	I_{max} in A	Î in kA	R_{th} in K/W	Diameter in mm	Height in mm	Weight in kg
31-13008	LKT-F-005.0-3-1080-BC	3 × 5	22	0.4	≤ 4.2	60	150	0.590
31-13009	LKT-F-010.0-3-1080-BD	3 × 10	25	0.8	≤ 3.8	60	225	0.840
31-13010	LKT-F-015.0-3-1080-BF	3 × 15	28	1.2	≤ 3.5	70	225	1.090
31-13017	LKT-F-020.0-3-1080-BJ	3 × 20	45	1.7	≤ 2.9	85	215	1.550
31-13018	LKT-F-025.0-3-1080-BK	3 × 25	50	2.1	≤ 2.6	85	278	1.900
31-13019	LKT-F-030.0-3-1080-BK	3 × 30	50	2.5	≤ 2.6	85	278	1.900
31-13020	LKT-F-035.0-3-1080-BL	3 × 35	55	2.9	≤ 2.1	85	320	2.200

TYPE LIST 1-PHASE

$V_N = 680\,V$	$V_{rms} = 480\,V$	$V_s = 1450\,V$						
Article-No.	Type	Capacitance in µF	I_{max} in A	Î in kA	R_{th} in K/W	Diameter in mm	Height in mm	Weight in kg
31-13021	LKT-F-010.0-1-680-BA	1 × 10	15	0.5	≤ 6.30	60	90	0.355
31-13022	LKT-F-015.0-1-680-BA	1 × 15	15	0.8	≤ 6.30	60	90	0.355
31-13023	LKT-F-020.0-1-680-BA	1 × 20	15	1.0	≤ 6.30	60	90	0.355
31-13024	LKT-F-025.0-1-680-BA	1 × 25	15	1.3	≤ 6.30	60	90	0.355
31-13025	LKT-F-035.0-1-680-BB	1 × 35	22	1.8	≤ 4.70	60	138	0.530
31-13026	LKT-F-045.0-1-680-BB	1 × 45	22	2.4	≤ 4.70	60	138	0.530
31-13046	LKT-F-050.0-1-680-BH	1 × 50	40	1.5	≤ 2.00	85	131	1.200
31-13047	LKT-F-060.0-1-680-BH	1 × 60	40	1.8	≤ 2.00	85	131	1.200
31-13048	LKT-F-070.0-1-680-BH	1 × 70	40	2.1	≤ 2.00	85	131	1.200
31-13049	LKT-F-095.0-1-680-BI	1 × 95	45	2.9	≤ 1.60	85	163	1.200
31-13050	LKT-F-105.0-1-680-BI	1 × 105	45	3.2	≤ 1.60	85	163	1.200
31-13051	LKT-F-120.0-1-680-BI	1 × 120	45	3.6	≤ 1.60	85	163	1.200

$V_N = 850\,V$	$V_{rms} = 600\,V$	$V_s = 1800\,V$						
Article-No.	Type	Capacitance in µF	I_{max} in A	Î in kA	R_{th} in K/W	Diameter in mm	Height in mm	Weight in kg
31-13027	LKT-F-010.0-1-850-BA	1 × 10	15	0.7	≤ 6.30	60	90	0.355
31-13028	LKT-F-015.0-1-850-BA	1 × 15	15	1.0	≤ 6.30	60	90	0.355
31-13029	LKT-F-020.0-1-850-BA	1 × 20	15	1.3	≤ 6.30	60	90	0.355
31-13030	LKT-F-025.0-1-850-BB	1 × 25	22	1.6	≤ 4.70	60	138	0.530
31-13031	LKT-F-035.0-1-850-BB	1 × 35	22	2.3	≤ 4.70	60	138	0.530
31-13052	LKT-F-045.0-1-850-BH	1 × 45	40	1.7	≤ 2.00	85	131	1.200
31-13053	LKT-F-050.0-1-850-BH	1 × 50	40	1.9	≤ 2.00	85	131	1.200
31-13054	LKT-F-060.0-1-850-BH	1 × 60	40	2.3	≤ 2.00	85	131	1.200
31-13055	LKT-F-068.0-1-850-BH	1 × 68	40	2.6	≤ 2.00	85	131	1.200
31-13056	LKT-F-095.0-1-850-BI	1 × 95	45	3.6	≤ 1.60	85	163	1.200
31-13057	LKT-F-120.0-1-850-BJ	1 × 120	50	4.5	≤ 1.60	85	215	1.550

$V_N = 1080\,V$	$V_{rms} = 760\,V$	$V_s = 2320\,V$						
Article-No.	Type	Capacitance in µF	I_{max} in A	Î in kA	R_{th} in K/W	Diameter in mm	Height in mm	Weight in kg
31-13032	LKT-F-010.0-1-1080-BA	1 × 10	15	0.8	≤ 6.30	60	90	0.355
31-13033	LKT-F-015.0-1-1080-BB	1 × 15	22	1.2	≤ 4.70	60	138	0.530
31-13034	LKT-F-020.0-1-1080-BB	1 × 20	22	1.7	≤ 4.70	60	138	0.530
31-13035	LKT-F-025.0-1-1080-BN	1 × 25	28	2.1	≤ 4.70	70	138	0.650
31-13058	LKT-F-035.0-1-1080-BH	1 × 35	40	1.7	≤ 2.00	85	131	1.200
31-13059	LKT-F-045.0-1-1080-BI	1 × 45	45	2.1	≤ 1.60	85	163	1.200
31-13060	LKT-F-050.0-1-1080-BI	1 × 50	45	2.4	≤ 1.60	85	163	1.200
31-13061	LKT-F-060.0-1-1080-BJ	1 × 60	50	2.9	≤ 1.60	85	215	1.550
31-13062	LKT-F-070.0-1-1080-BJ	1 × 70	50	3.3	≤ 1.60	85	215	1.550

$V_N = 1200\,V$ $V_{rms} = 850\,V$ $V_s = 2580\,V$								
Article-No.	Type	Capacitance in µF	I_{max} in A	Î in kA	R_{th} in K/W	Diameter in mm	Height in mm	Weight in kg
31-13036	LKT-F-001.0-1-1200-BA	1 × 1	15	0.1	≤ 6.30	60	90	0.355
31-13037	LKT-F-001.5-1-1200-BA	1 × 1.5	15	0.1	≤ 6.30	60	90	0.355
31-13038	LKT-F-002.2-1-1200-BA	1 × 2.2	15	0.2	≤ 6.30	60	90	0.355
31-13039	LKT-F-003.0-1-1200-BA	1 × 3	15	0.3	≤ 6.30	60	90	0.355
31-13040	LKT-F-003.3-1-1200-BA	1 × 3.3	15	0.3	≤ 6.30	60	90	0.355
31-13041	LKT-F-004.5-1-1200-BA	1 × 4.5	15	0.4	≤ 6.30	60	90	0.355
31-13042	LKT-F-006.8-1-1200-BA	1 × 6.8	15	0.6	≤ 6.30	60	90	0.355
31-13043	LKT-F-007.1-1-1200-BA	1 × 7.1	15	0.7	≤ 6.30	60	90	0.355
31-13044	LKT-F-010.0-1-1200-BB	1 × 10	22	0.9	≤ 4.70	60	138	0.530
31-13045	LKT-F-015.0-1-1200-BB	1 × 15	22	1.4	≤ 4.70	60	138	0.530
31-13063	LKT-F-020.0-1-1200-BH	1 × 20	40	1.1	≤ 2.00	85	131	1.200
31-13064	LKT-F-025.0-1-1200-BH	1 × 25	40	1.3	≤ 2.00	85	131	1.200
31-13065	LKT-F-035.0-1-1200-BH	1 × 35	40	1.9	≤ 2.00	85	131	1.200
31-13066	LKT-F-045.0-1-1200-BI	1 × 45	45	2.4	≤ 1.60	85	163	1.200
31-13067	LKT-F-050.0-1-1200-BI	1 × 50	45	2.7	≤ 1.60	85	163	1.200
31-13068	LKT-F-060.0-1-1200-BJ	1 × 60	50	3.2	≤ 1.60	85	215	1.550

REGULATIONS AND SAFETY INSTRUCTIONS

General

FRAKO capacitors for power electronics are supplied ready to install, and have been submitted to thorough routine testing to assure their quality and verify their good working order before they leave our factory. Some important points must be observed to prevent injury to personnel or damage to assets when installing, commissioning and maintaining power electronics capacitors. When installing and using capacitors for power electronics, it is essential to follow and comply with the instructions given here, together with the applicable international standards, such as IEC and (in Europe) EN standards, and the relevant national codes and regulations. In Germany, for example, these are issued by the VDE (German Association for Electrical, Electronic & Information Technologies). Please comply with the relevant legal requirements when recycling the packaging materials.

Safety instructions

Caution! Capacitors for power electronics operate at a dangerously high voltage that can cause loss of life. Furthermore, the capacitors are able to retain this high voltage for long periods! All work on capacitors must therefore only be carried out by qualified electricians. Before the current-carrying parts of a capacitor are touched, they must be discharged and short-circuited by means of suitable components. The installation of power electronics capacitors and the inspection to verify their correct application may only be carried out by appropriately qualified specialists who have been instructed about the electrical hazards. Safety notices drawing attention to the potential dangers associated with power electronics capacitors must be prominently displayed. Capacitors must be installed so that any inadvertent contact with live components is completely prevented.

Before any work is done on power electronics capacitors, it must be verified that their current-carrying components are at zero potential. To achieve this, the capacitor must first be discharged and then short-circuited.

Capacitors must be permanently and securely earthed.

Low voltage, high breaking capacity (LV HBC) fuses installed in series with power electronics capacitors as short-circuit protection may only be removed or replaced when they are not carrying current. Similarly, fuse switch disconnectors installed for the same purpose may not be operated when under load, since this might produce a dangerous arc, which could cause injury and damage. This is a life-threatening danger! Do not expose the capacitors to direct sunlight and do not locate them near to heat sources. Ensure that the capacitors kept within the specified range of storage and operating temperatures at all times. Temperatures outside these ranges can permanently damage the capacitors without this being visible externally.

If power electronics capacitors appear to be visibly damaged, they must not be installed, wired up or put into service.

LKT-F type power electronics capacitors are only suitable for indoor applications. They are designed for use in clean, dry, dust-free rooms at elevations 4 000 m above sea level.

Storage and operating conditions

Power electronics capacitors can be stored in a dry, dust-free, non-corrosive environment at temperatures between - 25 (- 40) and + 80° C and elevations ≤ 4 000 m.

The capacitors are suitable for ambient temperatures of - 40° C up to 55° C. The ambient temperature is one of the main factors affecting power electronics capacitors and has a major impact on their service life. EN 61071 describes the conditions regarding the ambient temperature of power electronics capacitors in detail. The maximum permissible ambient humidity is 95 %, and the maximum operating elevation above sea level is 4 000 m. Power electronics capacitors must have been discharged to a voltage of less than 50 V before they are switched on again!!!

Installation

FRAKO power electronics capacitors are suitable for use indoors in a dry, dust-free, non-corrosive environment. The degree of protection (EN 600529) is IP 00 for standard versions and IP 20 when fitted with the terminal base. The ambient temperature must not exceed the limits specified above. Each capacitor case must be spaced at least 20 mm from the next one in order to ensure unrestricted circulation of air. Sources of heat, such as harmonic filter reactors, must not be installed directly adjacent to power electronics capacitors. If it is possible for hot air to accumulate at the location where the capacitors are installed, it is necessary to provide forced ventilation, for example with a fan / filter unit.

If dust is present at the location where the capacitors are installed, it must be removed from the ventilation air intake by means of filter mats. Regular maintenance and cleaning, particularly of the capacitor terminal bases, is an absolute necessity. If a layer of dust is allowed to accumulate, it can result in flashovers between conductors or from a conductor to earth!

The capacitors can be installed and will function correctly in any desired orientation. It must always be ensured, however, that they are adequately secured mechanically, especially if the capacitor bank may be transported! The enclosure for the capacitors must be provided with a reliable earth connection.

Commissioning, operation and maintenance

Before the supply voltage is applied to the system, a visual check should be carried out by a qualified technician to verify that no equipment or connections have worked loose during transport and no mechanical damage can be identified. Damaged capacitors must not be put into service. Capacitors should be checked once every year in a systematic inspection by a specialist.

General

Please ensure that the capacitors are kept clean at all times, if necessary having them cleaned without delay by skilled personnel. During the annual inspection the capacitors must be given a visual check by an electrician to verify good working order (sound electrical contacts, no evidence of overheating, no blown fuses, etc.). Any variation in capacitance or distortion by harmonics can be inferred from the operating currents measured. There must always be good electrical contact at the capacitor connections, which must remain clean and dry.

KEY TO SYMBOLS

C_N Nominal capacitance

V_N Maximum operating peak recurrent voltage of either polarity of a reversing type waveform for which the capacitor has been designed

V_{rms} Root-mean-square value of the maximum recurrent operating voltage

V_S Peak voltage induced by switching or any other disturbance of the system which is allowed for a limited number of times and for durations shorter than the basic period

V_i Root-mean-square value of the sine wave voltage designed for the insulation between the terminals of the capacitors to the casing or earth

I_{max} Root-mean-square value of the maximum current in continuous operation

$\hat{I}$ Maximum repetitive peak current that can occur for a short duration in continuous operation

I_S Peak non-repetitive current induced by switching or any other disturbance of the system which is allowed for a limited number of times, for durations shorter than the basic period

L_{self} Self-inductance

R_{th} Thermal resistance

R_S Effective ohmic resistance of a capacitor's conductors and metallic coating under specified operating conditions

P_V Maximum power loss at which the capacitor may be operated at the maximum casing temperature

f_1 Frequency at which the power loss of the capacitor is maximum at the nominal voltage

f_2 Maximum frequency at which the maximum current produces the maximum power loss in the capacitor

θ_{min} Lowest temperature at which the capacitor may be energized

θ_{max} Hottest temperature of the casing at which the capacitor may be operated

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