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Reliable and high-quality power capacitors

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Product quality is essential for a long operating life and maximum use. This is especially true for power capacitors. They combine both high loading capacity and high levels of safety on overload or possible failure. Today's needs to withstand the harmonics of our power network system make these characteristics indispensable in meeting the increasing demands of the future.

Power capacitors are thus highly efficient components providing 15 kvar of reactive power within 1 litre volume due to their very low dissipation factor: $2*10^{-4}$ in the capacitor coil and less than $5*10^{-4}$ at the terminals. This also applies to the efficiency of dielectric used with test field strengths of up to 200 V/µ = 200.000 V per mm! If a long operating life is to be guaranteed, then partial discharges - which are very low electrical discharges within the dielectric - must be suppressed despite the high load capacity of the dielectric. This is done using state-of-the-art technology for the manufacture of FRAKO capacitors as well as using non-toxic and environmentally sound materials.

The FRAKO LKI capacitor, for instance, contains an impregnation agent with an exceptionally high flash point of more than 250 °C. When compared with other impregnation agents, e.g. those in older power capacitors containing a mineral oil with a flash point of roughly 130 °C, this impregnation agent can be considered non-inflammable.

The dry FRAKO LKT power capacitor has no liquid filling, resin, gel or jelly-like compound nor gas filling of SF6 or other similar materials, but has instead a flame retardant filler with a mineral-based stabiliser.

Field-Tried-and-tested operating life

Tests are described in the VDE and IEC regulations that are often used to specify the operating life expectancy. For example, with VDE 0560 Part 8, the expected operating life is calculated from the length of the test multiplied by $(U_{test}/U_N)^7$. This coefficient $(U_{test}/U_N)^7$ was first used with old paper capacitors which had dissipation factors of approximately 0.5%. For modern MKP capacitors, with a dissipation of ten times less, this is no longer justified. Furthermore 3% of the samples were permitted to fail these tests.

Such a test may be adequate for defining the general quality of capacitors. However, it does not give any information about the operating life expectancy of a power capacitor. For this reason, FRAKO does not support these tests for defining the expected operating life but instead is concerned with the actual characteristics of capacitors in the field.

type	Failure rate (ppm)	Failure quota* (% / 1000 h)	MTBF (h)
LKI 1991	200	0,00912	10.967.593
LKI 1992	300	0,01369	7.304.471
LKI 1993	87	0,00397	25.199.600
LKI 1994	358	0,01635	6.114.480
LKI 1995	256	0,01169	8.557.955
LKI 1996	185	0,00843	11.858.452
LKI 1997	41	0,00188	53.204.590
total	200	0,00229	43.738.030

* at 4380 operating hours per year

The FRAKO LKI power capacitors produced between 1983 and 1985 have shown no increase in failure rate up to now, 13 to 15 years later, and thus are far from the end of their expected operating life. In the meantime, the fourth generation of LKI capacitors has now been produced - with a significant increase in load capacity when compared with the first generation in 1983. The FRAKO Quality Management Group is collecting and analysing all failed components which have been returned or else reported in the field. All the results since 1991 (when this documentation first began) to the present have shown a failure rate of only 200 ppm (parts per million). Assuming that 1/3 of all failures have been reported to FRAKO, these power capacitors show **a failure rate of just 1% in 15 years**.

Safety first

Even with the highest quality and expected service life, individual capacitors are still capable of failing. These should, however, not affect the environment - by exploding, burning or giving off flammable gases, regardless the capacitor has been in operation for many years and the guarantee is no longer valid.

Right from the start, construction and internal capacitor design must take into account any possible failure. Therefore FRAKO power capacitors have two integrated features of safety: Self-healing metallisation and internal overpressure disconnector.

FRAKO power capacitors are metalised with a self-healing property so that no failure occurs due to transient surges. Any breakdown in the dielectric is isolated by this self-healing characteristic. The resulting loss in capacity with a self-healing breakdown is only about one ten-millionth (10^{-7}) of the nominal rating.

FRAKO power capacitors are equipped with an internal overpressure disconnector which is well established and has been available for more than 15 years. FRAKO overpressure disconnectors are continuously being improved upon so that they isolate the power network with maximum reliability.

FRAKO capacitors are, therefore, not filled with gas as the necessary pressures to activate the disconnector will only be build up once there is advanced damage to the dielectric. Consequently, FRAKO does not produce capacitors filled with gel or jelly-type filling as any gas produced due to damage in the lower part of the capacitor would not activate the overpressure switch.

The most costly, but effective, overpressure disconnector device is the diaphragm cover. An aluminium can and the cover are rolled and then secured together using an elastic sealant. The rate of return for leaking power capacitors has been neglectible over the years.

The diaphragm cover keeps the connecting terminal fixed during normal operation. The cover curves outwards with a displacement of approx. 10 mm when the pressure builds up inside the capacitor. In most cases, the connecting wires are disconnected with a displacement of just 5 mm and isolated from the network. The reliability of this function during production is monitored in type tests and also regular random sampling tests. These test procedures conform to EN 60831 and IEC 831. The capacitors, therefore, provide the highest possible level of safety on overload right to the end of their operating life. (Fig. 1).

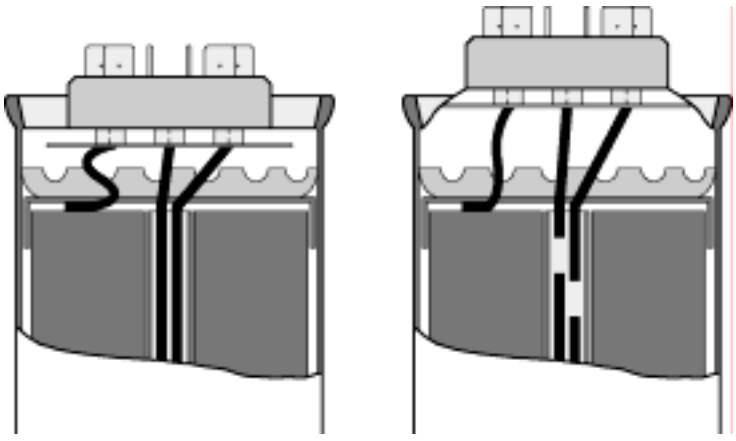

Fig. 1 FRAKO overpressure disconnector

Load capacity is a feature of quality...

Resonances with overvoltages and very high actual currents can be expected with harmonic loads of the power network. If, for example, approx. 8% of the 11th harmonic occurs, then the effective value of the RMS voltage is about 0,3% higher but the capacitor current is 1.33 times that of the capacitor current rating (Fig. 2). Thus a higher current load capacity is much more important than the

voltage load capacity. Consequently, with 400 V power networks, power capacitors with a nominal voltage of at least 440 V are used by FRAKO. But their current load limit is

- **at least 2.0 times the nominal current at 400 V continuous load and**
- **at least 300 times the nominal current for transient current peaks.**

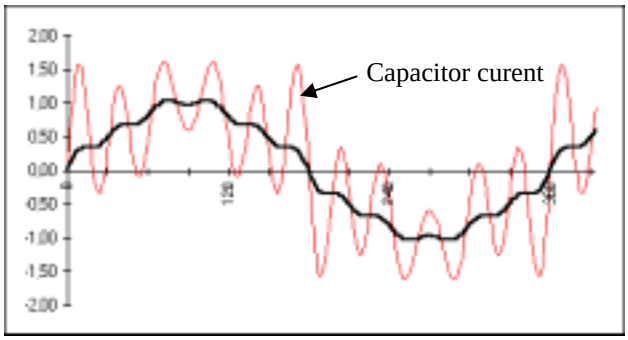

Fig. 2 Voltage and capacitor current with high harmonic content

....just as a highly rated acceptable case temperature.

It is generally true, that power capacitors have a higher service life when operating at lower temperatures. Chemical changes in the dielectric as well as corrosion proceed only half as fast at about 10 °C lower temperatures (Fig. 3)

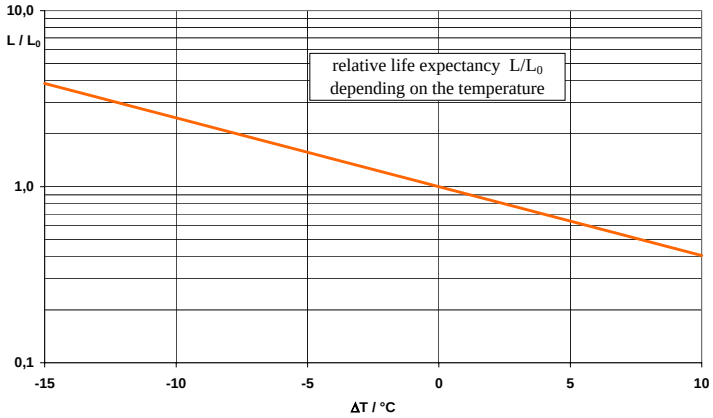

Fig. 3 Life expectancy depending on temperature

FRAKO power capacitors have low intrinsic warming. The case temperature is mostly affected by the ambient temperature as well by as the heat of other components with high levels of heat dissipation (harmonic filter chokes, fuses, etc.). Especially harmonic filter chokes should always be installed in such a way to ensure that their heat does not significantly affect the power capacitors. This is always taken into account with FRAKO Power Factor Correction Systems.

FRAKO Power capacitors are specified to withstand **case temperatures of up to 75 °C**. Therefore FRAKO Power Factor Correction Systems are designed, that with natural cooling in the control cabinet a maximum permissible ambient temperature of 60 °C is provided..

Measurable quality

Load capacity and quality are measurable variables which can be validated:

- by trained production personnel who are totally familiar with working procedures.
- by monitoring consistent sample testing during the production phase (capacitor coils are checked on a daily basis to see if the sample withstands a current surge of 500 times nominal current).

- by regular and repeated checks to indicate approximately what the capacitor actually withstands, e.g. a current load test with 2.5 nominal current, a voltage test at 600V to 700V for at least 1000 h at capacitors with 440 V nominal voltage.
- or by 100% final testing which goes far beyond what is specified in the EN 60831 or IEC 831 standards.
- The dissipation factor of the polypropylene dielectric of the MKP capacitors is about $2*10^{-4}$ or 0.2 W / kvar. The metalisation, contacts and current paths in the capacitor increase the dissipation factor - measured at the capacitor connection terminal - to a maximum $5*10^{-4}$ or 0.5 W / kvar.
  (Fig. 4). With routine check testing, the dissipation factor is monitored at a measuring frequency of
  1 kHz. This value represents the ohmic resistors in the capacitor which, for a maximum effective current load, is as low as possible.

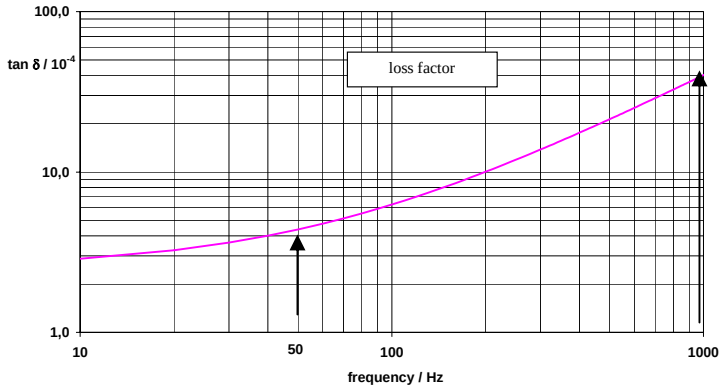

Fig. 4 Loss factor depending on frequency

In its quality policy FRAKO always **focuses on the value of the complete Power Factor Correction System** and not just on the value of the Power Capacitors. The FRAKO LKI and LKT type capacitors are used in FRAKO's own Power Factor Correction Systems. This ensures the user of FRAKO LKI and LKT that they have an extreme long operating life while being operationally safe and withstanding high overloads.

FRAKO power capacitors:

	Power at 400 V	Nominal voltage of capacitor	Capacitor current at 400V / 50 Hz	permissable continuous current		permissable peak current	
	Q_{400} / kvar	U_N / V	I_N / A	I_{max} / A	I_{max} / I_N	I_S / A	I_S / I_N
LKI 7.6-440-D50	6,25	440	9,0	18,0	2,0	2.990	331
LKI 9.1-440-D50	7,5	440	10,9	21,5	2,0	3.580	330
LKI 12.1-440-D52	10,0	440	14,4	28,5	2,0	4.760	330
LKI 15.1-440-D52	12,5	440	18,0	35,5	2,0	5.940	330
LKT 13.8-470-D52	10,0	470	14,4	28,5	2,0	4.760	330
LKT 17.3-470-D52	12,5	470	18,0	35,5	2,0	5.940	330
LKI 4,3-525-D50	2,5	525	3,6	8,8	2,4	1.420	394
LKI 8,6-525-D50	5,0	525	7,2	18,0	2,5	2.840	394

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