ZVEI: Die Elektroindustrie

General Safety Recommendations for Power Capacitors

General safety recommendations and requirements of power capacitor manufacturers who are members of ZVEI

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German Electrical and Electronic Manufacturers´ Association

I. Scope

These safety recommendations and requirements apply to the following power capacitors and standards. Their purpose is to describe the state of technology which must as a rule be adhered to in all relevant contracts for goods and services.

Power capacitors for power factor correction (PFC) up to 1000 V	IEC / DIN EN 60831 and 60931
Power capacitors for power factor correction (PFC) above 1000 V	IEC / DIN EN 60871
Power capacitors for induction heating installations (PFC)	IEC / DIN EN 60110
Capacitors for power electronics (PEC)	IEC / DIN EN 61071
Capacitors for railway applications (PEC)	IEC / DIN EN 61881
Lighting capacitors (AC)	IEC / DIN EN 61048/49
Motor capacitors (AC)	IEC / DIN EN 60252
Surge capacitors	DIN VDE / 0560-3 (currently no IEC rule available)

II. General safety rules

Since power capacitors are electrical energy storage devices, they must always be handled with caution. Even after being turned off for a relatively long period of time, they can still be charged with potentially lethal high voltages. The same applies to all system components and devices which have an electrically conductive connection to the capacitor. The general rules of good electrical engineering practice must always be complied with when handling live components in electrical systems.

III. General conditions for storage and use

1. The manufacturer's installation, application and maintenance instructions and the relevant standards must always be complied with.

2. Capacitors must never be stored or used outside the specified temperature ranges.

3. Capacitors may not be stored or operated in corrosive atmospheres, particularly not when chlorides, sulfides, acids, alkalis, salts, organic solvents or similar substances are present.

4. In dust and dirt-prone environments, regular checks and maintenance (particularly of the terminals and insulators) are absolutely necessary to prevent creation of creepage distances between live parts and/or to the protective conductor/ground.

5. The maximum temperatures (including inherent heat), voltages, currents, power, thermal resistances, frequencies, discharge times and switching frequencies specified in the data sheet must be adhered to.

6. A means of sufficient dissipation of heat loss (fan, cooling) or escaping gases and liquids in case of malfunction must be provided. Required minimum distances (e.g. to sources of heat) must be maintained.

7. Specified torques for electrical connections and fasteners must be adhered to.

8. Mechanically or electrically damaged, leaky or otherwise damaged capacitors may not be used or continue to be used.

9. Existing protective devices of the capacitors may not be manipulated, removed or impaired in their function.

IV. Protective devices

1. The following table gives an overview of the known internal protective devices:

Protective Device/ Protective Mechanism	Application Area		
	PEC	PFC	AC
Without protective devices	x		
Exclusively self-healing[1)]	x	x	x
Singly or in combination:			
Improved self-healing[2)]	x		
Overpressure interrupter	x	x	x
Overpressure switch	x	x	x
Overpressure valve	x	x	
Reinforced housing	x	x	
Segmented film	x	x	x
Winding fuse		x	x
Thermal fuse			x

1) Self-healing defines the capacitor technology. Self-healing capability is not a safety system!
2) Improved self-healing classified as a safety system means that the protective function was tested using special methods. However, the effectiveness of an improved self-healing system cannot be compared with traditional safety devices such as overpressure switches or overpressure interrupter. Improved self-healing can significantly reduce the failure probability though.

2. Internal protective devices offer basic protection against certain internal faults, aging and overload.

3. Internal protective devices alone are not sufficient to prevent all conceivable dangers in case of malfunction. The so-called self-healing capability is not the same as fail safe system stability.

4. Most internal protective devices can interrupt the voltage only within the capacitor. They are not fuses in the classical sense such as cable or device fuses which interrupt the voltage upstream from the faulty system component.

5. It is advisable to supplement internal protective devices with external protective devices, for example:
   - short-circuit protection by fuses or circuit breakers/protective relays
   - overload protection for fundamental frequency and harmonics using current measurement
   - load unbalance protection
   - temperature control

6. Depending on their protective mechanism, protective devices are subject to technical and functional limits which, when exceeded, will inevitably cause malfunctions. Such violations include excess temperature, overvoltage, incorrect application, incorrect installation, faulty maintenance, mechanical damage, or operation outside the technical limits of the specification.

V. Risk factors for the capacitor

The most frequent risk factors which cause capacitor damage and possibly also the failure of the internal protective devices are:

1. Exceeding the permissible temperature on the capacitor surface (every increase in operating temperature of 7 K cuts life expectancy in half).

2. Overvoltages, overcurrents and high inrush currents even if they only occur briefly or cyclically (a continuous increase in the operating voltage of the capacitor of 8 % cuts life expectancy in half).

3. Network harmonics, resonances created by harmonics or flicker even when they occur only briefly or cyclically.

4. Aging of the lighting equipment and consequential excess temperature or high UV stress.

5. Failure of other components in a common circuit and consequential overvoltages or overcurrents.

6. Interaction with other reactive power components, and also parasitic capacitances (cable) or inductivities in common circuits.

7. Even if the test based on the capacitor standard is passed, this does not ensure comprehensive protection against all possible overloading.

   Currently, a number of customers are requesting special tests on unprotected capacitors with extreme overvoltages and temperatures to prove safe capacitor performance.

   These additional tests on self-healing PEC capacitors without a safety system (unprotected) are often referred to as "destruction tests" and are not IEC compliant. Furthermore, such tests are unsuitable for evaluating potential risks posed by PEC capacitors or their behavior in the event of a fault.

Instead of these tests, critical operating conditions which could lead to the failure of a PEC capacitor (voltage/current/temperature) should be monitored within the application.

8. During the operation of thyristor-switched capacitor systems, high DC voltages can occur continuously on the capacitors of compensation systems which are not switched on. These DC voltages must be considered when designing the capacitors and their discharge devices.

VI. Risks when a fault occurs

1. Power capacitators can be a significant risk in the case of failure due to their stored energy and/or their properties during operation in networks with high short-circuit power.

   The use of ever larger capacitors, for example in multi-level high-voltage direct current (HVDC) transmission systems, which are notable for the size, arrangement and number of capacitors, poses particular risks.

   If energy values exceed 30 kJ per capacitor unit, it is assumed that, in the event of failure, the risk will increase if there is an uncontrolled release of this energy. This poses an additional hazard potential in systems containing several capacitor units due to possible avalanche effects.

2. Power capacitors can actively fail when internal or external protective devices are missing, incorrectly dimensioned or have failed. They can burst, burn or, in extre-me cases, explode. This also applies to ga-ses escaping from internal protective de-vices (overpressure valve).

3. The gases (e.g., hydrocarbons as decomposition products of the organic insulating materials used) released in case of damage are flammable and can create explosive mixtures. The fire load of a power capacitor is approx. 40 MJ/kg. It is to be noted in this context that – depending on size – combustible materials make up around 55 % of the total mass of small capacitors and max.75 % of large capacitors.

VII. Risk minimisation

1. The capacitor manufacturer cannot predict all possible stresses which a power capacitor can be subjected to and which must be taken into account in the design. This means that the user bears crucial co-responsibility here. For this reason alone, safety and quality should be the top priorities when a capacitor is selected. This is why we urgently recommend the use of capacitors with appropriate internal protective devices.

2. Before designing the application, capacitors must be checked for their suitability for this particular application. All influences (parameters) must be considered. Unexamined use in an application may have serious consequences.

3. Particularly with sensitive applications, the internal protective devices of the capacitors must be supplemented by the user with suitable external protective measures. External protective measures are even mandatory when capacitors are used without internal protective devices.

4. When power capacitors are used, suitable measures must always be taken to eliminate possible danger to humans, animals and property both during operation and when a failure occurs. This applies to capacitors both with and without protective devices. Regular inspection and maintenance by a competent person is therefore essential.

5. Power capacitor manufacturers who are members of the ZVEI will gladly advise users who are planning an application, provide firm recommendations and offer their services.

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