KBR compensation system
Commissioning – Maintenance – Safety

1. General installation and connection conditions / Safety instructions

1.1 General technical installation conditions

- The installation site must comply with requirements in respect of protection class and ambient conditions.
- Ambient temperatures:
  The T40 temperature class applies for use
  (temperature of the ambient air)
- maximum briefly: 40 °C
- highest average over 24 hours: 35 °C
- highest average over 1 year: 25 °C
- Ventilation: Ensure sufficient air exchange at the installation site.
- Contamination: Degree of contamination 3 (IEC 61439).
- Relative air humidity: max. 95 %
- Installation height: max. 2,000 m
- Danger if installed in escape areas.
- Distances specified in the applicable regulations must be complied with when installing in escape areas.

1.2 Electrical connection conditions

- Connection and maintenance according requirements from design verification to Standard DIN EN 61439-0/-1/-2; IEC 61921.
- Suitable for indoor installation.
- Voltage fluctuations of the rated voltage, max. -10 % / +10 % of rated voltage is permissible.
- Harmonic load of mains connection: suitable for Class 2 as per EN 61000-2-4.
- Voltage distortions and harmonic loads:
  Detuning must be selected according to the harmonic loads at the connection site. The resonance frequency of the detuning must lie below the lowest occurring harmonic.
  It must be ensured that there is no ripple-control signal in the vicinity of the resonance frequency as otherwise this will be short-circuited.
- Detuned systems may not be operated with non-detuned capacitors on the same busbar, as there is a danger here of a parallel resonance.
- Detuned systems need to be regularly checked, as overloads could occur through changes in capacitance.

1.3 CAUTION! Danger of electric shocks and arcing faults

- Do not mount near pipes.
- Do not mount in areas where ATEX regulations must be complied with.
- Non-compliance with this information can lead to failure or destruction of the system.

1.4 Ventilation
CAUTION! Danger of overheating in the housing

- Do not install in areas with high levels of dirt and dust (note protection class).
- Do not mount in areas that are heated (floor heating, heating pipes, etc.).
- Please ensure sufficient heat dissipation when installing modules and assemblies in third-party cabinets.
- Minimum distances between ventilation openings and other objects must be complied with.
- Additional heat sources in the vicinity of the ventilation openings must be avoided.
- For existing systems, clean the filter mats at regular intervals dependent on the degree of contamination.
- Non-compliance with this information can lead to failure or destruction of the system.

1.5 Discharging device

- A discharge resistor or maintenance-free discharge reactor (optional) is used as a discharging device.
- Check the condition of the discharge device before commissioning and during installation/maintenance work.
- The discharge time depends on the discharging device used.
- **Caution! The discharge time of 3 minutes after all capacitors are switched off must be complied with.**

1.6 Other operating conditions

- Please contact your KBR contact person for operating conditions outside the specifications.

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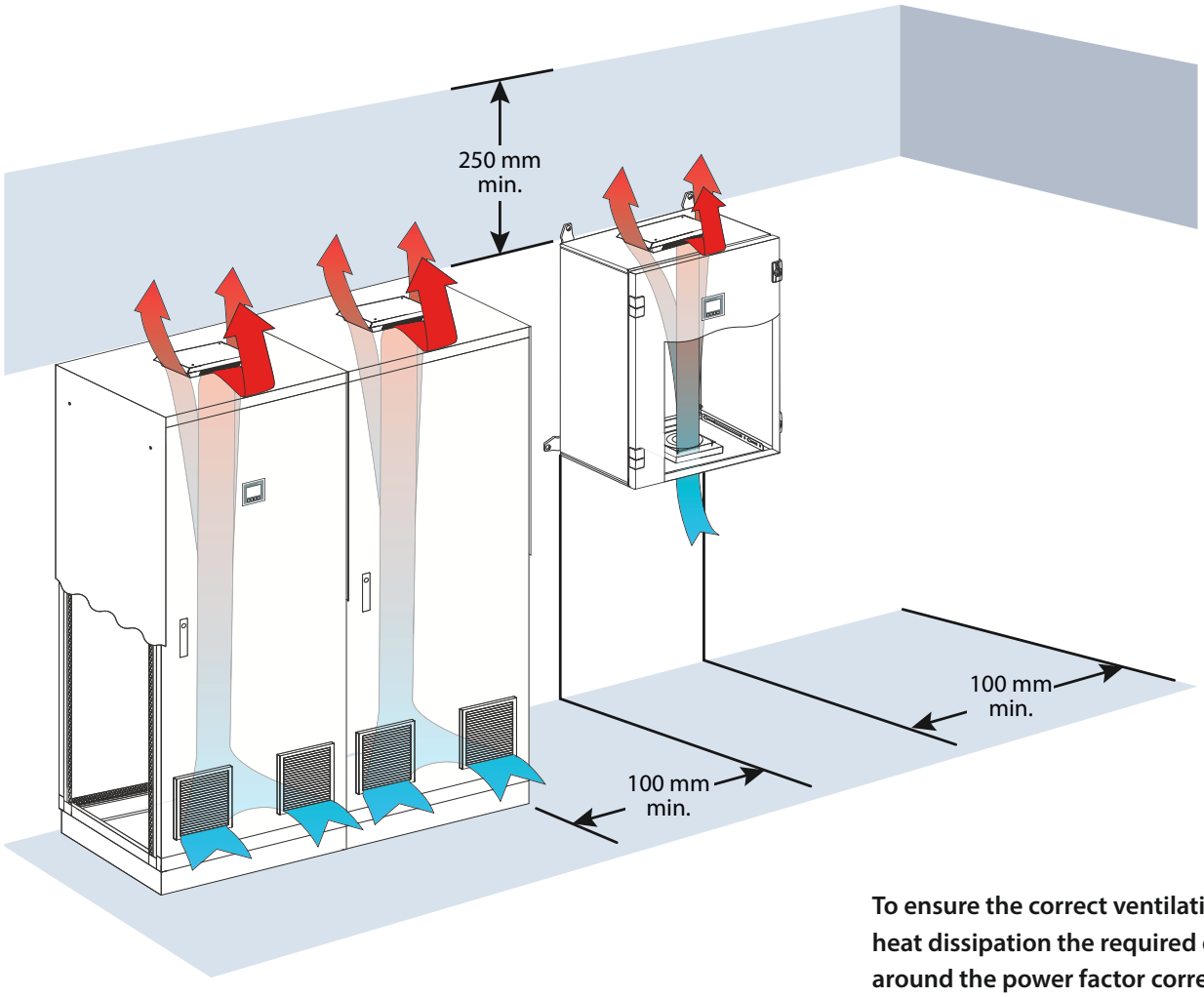

To ensure the correct ventilation and heat dissipation the required distances around the power factor correction unit need to be kept free.

2. Commissioning

2.1 Before commissioning

- Please check the system for any connections or components that have become loose due to transportation.
- Check the correct connection of the supply lines and the current transformer.
- Comply with the safety instructions.

2.2 Commissioning

- Commissioning can only be carried out by authorized electricians.
- The procedure for commissioning the system can be found in the operating instructions of the reactive power controller.
- KBR compensation systems can be pre-parameterized (see note on controller)
  Nevertheless, the correct programming of the installed current transformer is still essential in this case.
- Check the discharge devices on the capacitors.
- Please check the system in the case of malfunctions or error messages at the controller using Point 6.3 „Notes on detecting errors" in the operating instructions.

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3. Maintenance

3.1 Before maintenance

- **Caution! The discharge time of 3 minutes after all capacitors are switched off must be complied with.**
- Only then may the main fuses be removed and the maintenance work be carried out.
  The „Five safety rules" (DIN VDE 0105) and the general rules of technology must be observed and applied!

3.2 Maintenance

- 4 weeks after initial commissioning and annually thereafter, all mechanical and electrical bolted connections must be adjusted with the corresponding torque (see Point 4 Tightening torques).

The following points must be checked:

- The correct torque for all mechanical and electrical bolted connections.
- The condition and correct function of all mechanical protective equipment (protection against accidental contact and fuse covers).
- The condition of all electrical fuses.
- The rated current of the power consumption in all individual stages.
- The condition and correct function of all discharging devices. (<75 V within 180 s).
- The condition and correct function of all contactors. (Contactors are parts subject to wear; replace after 80,000 switching operations).
- The condition and function of all fans and filter mats.
- **Clean or replace filter mats**
  (Intervals can be shorter, depending on the degree of contamination).
- Heavy dust deposits on components impair cooling and may became conductive (if necessary also clean the components).
- Maintenance intervals must be adapted to the repective operating conditions as required.

We are happy to support you with regards to the professional and reliable implementation of commissioning and maintenance of your system. Please contact our KBR Service for this purpose.

4. Tightening torques

Capacitor contactors

Protection type	Main terminal set value (Nm)	Control terminal set value (Nm)
BJ K3-18	1,3	1,0
BJ K3-32	2,5	1,0
BJ K3-62 / BJ K3-74	4,0	1,0
BJ K3-90	6,5	1,0

Power capacitors

Capacitor	Set value (Nm)
Terminals up to 16 mm^2	2,0
Terminals 25 mm^2	2,5
Grounding bolt	10,0

Connection fuse unit

Fuse unit	Set value (Nm)
NH-00 – Clamp lower section M5	3,0
NH-00 – Clamp isolator M5	3,0
NH-00 – Screw lower section M6	5,0
NH-00 – Screw isolator M6	5,0
NH-00 – Screw lower section M8	12,0
NH-00 – Screw isolator M8	12,0

Clamping copper bars	Set value (Nm)
NH-00 – Screw isolator M6	5,0
NH-00 – Screw lower section M6	5,0

Terminal strips

Terminal strip	Set value (Nm)
Terminal 16 mm^2 screw	1,6
Terminal 35 mm^2 screw	3,0

Busbar / PEN busbar

Busbar / PEN busbar	Set value (Nm)
Screw M8	25,0
Screw M10	49,0
Screw M12	85,0

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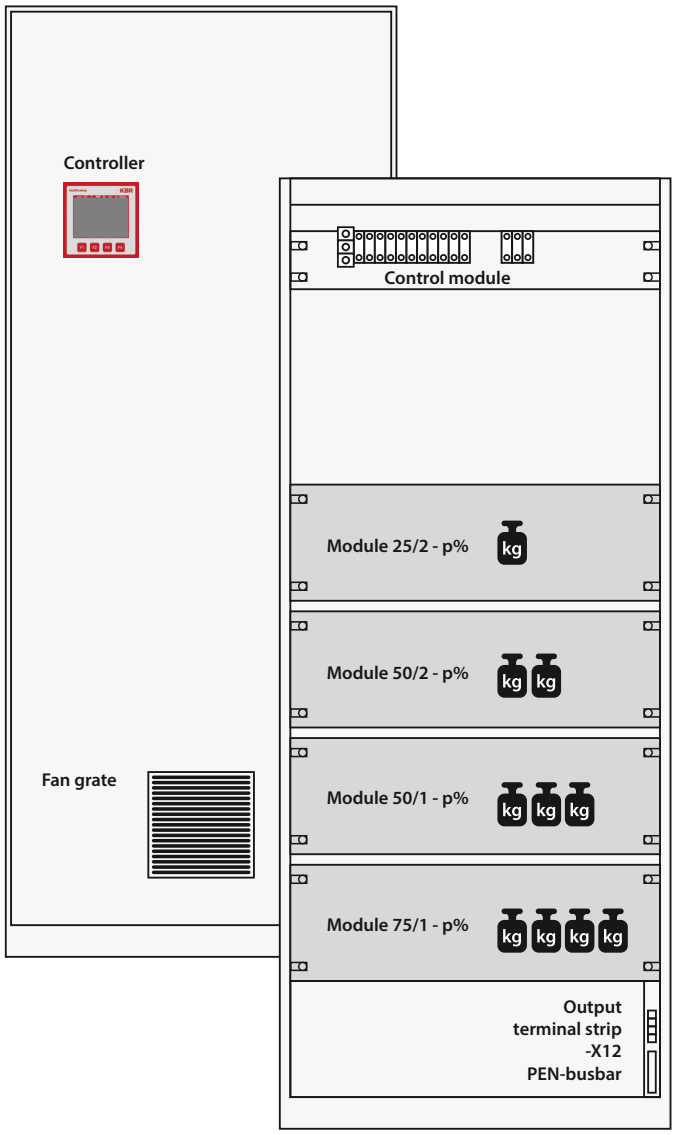
5. Layout proposal

Universal layout proposal
For a module layout based on the example of a detuned 200 kvar compensation system with 4 modules in a KBR standard cabinet (plug-in design).

Heavier and more powerful modules should preferably be installed in the lower section.



6. Recommendations for selection of lines and fuses

The recommendation for the supply lines (NYY; four-core; Cu) is in accordance with DIN VDE 0298-4 (Table 3, laying type C, without bundling). Ambient temperature +35 °C.
The recommendation of the fuse strengths are for short-circuit protection. If conditions are different (including harmonics), appropriate reduction factors must be taken into account.

The system installer is responsible for measuring and selecting cables and fuses.

CAPACITOR POWER (400 V / 50 Hz) in kvar	CURRENT CONSUMPTION I (A) per phase	SUPPLY LINE Cu mm²	FUSE NH-System gL je Phase
1	1,44	4 x 1,5	10
1,5	2,16	4 x 1,5	10
2	2,88	4 x 1,5	10
2,5	3,60	4 x 1,5	10
3	4,32	4 x 1,5	10
4	5,76	4 x 1,5	10
5	7,20	4 x 2,5	16
6	8,64	4 x 2,5	16
7,5	10,80	4 x 2,5	20
10	14,40	4 x 4	25
12,5	18,00	4 x 6	35
15	21,60	4 x 6	35
17,5	25,20	4 x 10	35
20	28,80	4 x 10	50
25	36,00	4 x 16	63
30	43,20	4 x 25	80
35	50,40	4 x 25	80
40	57,60	3 x 35 / 16	100
50	72,00	3 x 35 / 16	125
60	86,40	3 x 50 / 25	125
70	100,80	3 x 70 / 35	160
75	108,00	3 x 70 / 35	160
80	115,20	3 x 95 / 50	200
90	129,60	3 x 95 / 50	200
100	144,00	3 x 120 / 70	250
120	172,80	3 x 120 / 70	250
125	180,00	3 x 150 / 70	315
150	216,00	3 x 185 / 95	315
175	252,00	3 x 240 / 120	400
200	288,00	3 x 240 / 120	400
250	360,00	2 x 3 x 150 / 70	500
300	432,00	2 x 3 x 185 / 95	630
350	504,00	2 x 3 x 240 / 120	2 x 400
400	576,00	2 x 3 x 240 / 120	2 x 400
450	648,00	4 x 3 x 120 / 70	2 x 500
500	720,00	4 x 3 x 150 / 70	2 x 500

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Safety Recommendations

General Safety Recommendations and Requirements for the Usage of Power Capacitors

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

- The manufacturer’s installation, application and maintenance instructions and the relevant standards must always be complied with.
- Capacitors must never be stored or used outside the specified temperature ranges.
- 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.

- 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.
- 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.
- 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.
- Specified torques for electrical connections and fasteners must be adhered to.
- Mechanically or electrically damaged, leaky or otherwise damaged capacitors may not be used or continue to be used.
- Existing protective devices of the capacitors may not be manipulated, removed or impaired in their function.

IV. Protective devices

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

Protective Device/ Protective Mechanism	Application		
	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

Table: overview of the known internal protective devices and areas of application
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.

- Internal protective devices offer basic protection against certain internal faults, aging and overload.
- 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.
- Most internal protective devices can interrupt the voltage only within the capacitor.
- They are not used in the classical sense such as cable or device fuses which interrupt the voltage upstream from the faulty system component.
- 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
- 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:

- Exceeding the permissible temperature on the capacitor surface (every increase in operating temperature of 7 K cuts life expectancy in half).
- 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).
- Network harmonics, resonances created by harmonics or flicker even when they occur only briefly or cyclically.
- Aging of the lighting equipment and consequential excess temperature or high UV stress.
- Failure of other components in a common circuit and consequential overvoltages or overcurrents.
- Interaction with other reactive power components, and also parasitic capacitances (cable) or inductivities in common circuits.
- Even if the test based on the capacitor standard is passed, this does not ensure comprehensive protection against all possible overloading.
  - In some cases, there is a customer request for special tests with extreme overvoltages and temperatures for capacitors without protective devices to prove safety.
  - 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.
- 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

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

- 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 coresponsibility 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.

- Capacitors must be checked prior to use to ensure they are suitable for the intended application. This applies in particular if the capacitor has a particular hazard potential due to its proximity to people, as is always the case with traction applications, for example. In this case it is always preferable to use capacitors with protective devices. All influences (parameters) must be taken into account in the risk assessment / suitability test. This also includes possible production errors in the capacitor and their effects on safety in the application. The unhesitating acceptance of the capacitor in an application without a concrete risk assessment can have serious consequences for the safety of the system.
- 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.
- 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.
- 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.

Contact

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