

JOHANNESBURG WATER (SOC) Ltd.

BULK WASTEWATER

PARTICULAR SPECIFICATION

**E23 : ELECTRICAL POWER FACTOR
CORRECTION**



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E23.1 SCOPE

This section covers the requirements applicable to low-voltage AC shunt capacitor banks intended to be used for power factor correction purposes, equipped with a built-in switchgear and controlgear apparatus capable of connecting to or disconnecting from the Main Distribution Board part(s) of the bank with the aim to correct its power factor.

E23.2 STANDARDS

The latest edition, including all amendments up to date of tender of the following particular national specifications, publications and codes of practice shall be read in conjunction with this specification and shall be deemed to form part thereof:

- (a) SANS 10142-1 : The wiring of premises Part 1 Low-voltage installations
- (b) SANS 60831-1 : Shunt power capacitors of the self-healing type for a.c. systems having a rated voltage up to and including 1 000 V - Part 1: General - Performance, testing and rating - Safety requirements - Guide for installation and operation
- (c) SANS 60931-1 : Shunt power capacitors of the non-self-healing type for a.c. systems having a rated voltage up to and including 1000 V - Part 1: General - Performance, testing and rating - Safety requirements - Guide for installation and operation
- (d) SANS 61439-1 : Low-voltage switchgear and controlgear assemblies Part 1: General rules
- (e) SANS 60947-2 : Low-voltage switchgear and controlgear Part 2: Circuit-breakers
- (f) SANS 60947-4 : Low-voltage switchgear and controlgear Part 4: Contactors
- (g) SANS 60076-6 : Power transformers Part 6: Reactors
- (h) SANS 61439-2 : Low-voltage switchgear and controlgear assemblies Part 2: Power switchgear and controlgear assemblies
- (i) SANS 61921 : Power capacitors - Low-voltage power factor correction banks

E23.2.1 Particular specifications to be read in conjunction with this specification

This specification shall be read in conjunction with the following specifications:

- (a) E08 : WIRING
- (b) E26 : ELECTRICAL SPECIFICATION FOR COLOUR CODES

E23.3 GENERAL REQUIREMENTS

Power Factor Correction (PFC) will only be applied at Low Voltage level. Medium Voltage PFC will only be accepted on MV motors.

All PFC equipment will be installed in separate enclosures to minimise secondary damage to adjacent equipment in the event of PFC failure. The electrical connection to the PFC enclosure will be cable or busbar trunking. Installation of PFC equipment in a MCC, DB or motor terminal box is not acceptable. PFC enclosures will not be positioned within 2m from MCC or DB's.

E23.4 METHODS FOR POWER FACTOR CORRECTION

On selecting a method of power factor correction, the following steps must be followed:

- a) Determine the required reactive energy (calculation or physical measurement)
- b) Selection of the compensation mode:

- i. Central, for the complete installation;
 - ii. By sector;
 - iii. For individual loads, such as large motors.
- c) Selection of the compensation type:
- i. Fixed, by connection of a fixed-value capacitor bank;
 - ii. Automatic, by connection of a different number of steps, allowing adjustment of the reactive energy to the required value;
- d) Allowance for operating conditions and harmonics.

Note: As a guideline: where the kvar rating of the capacitors is less than or equal to 15 % of the power supply transformer rating, a fixed compensation system will be installed. Above the 15 % level, an automatic compensation system will be installed.

E23.4.1 Fixed compensation

This arrangement uses one or more capacitor(s) to provide a constant level of compensation.

The capacitors shall be installed at the terminals of large inductive loads (mainly induction motors) where the load factor is reasonably constant. No control is possible as this is a direct connection to a load and switched with it. The contractor will adjust the protection settings to the equipment after the installation of fixed compensation capacitors.

Motors with Forward/Reverse control will not be compensated. Motors on VSD control will not be compensated.

E23.4.2 Automatic compensation

This kind of compensation provides automatic control and adapts the quantity of reactive power to the variations of the installation in order to maintain the targeted $\cos \phi$ by switching capacitor banks in and out.

The PFC equipment shall be installed at points in an installation where the active-power and/or reactive-power variations are relatively large, for example: on the busbars of main distribution switchboards.

Control will be provided by an electronic device (Power Factor Controller) which monitors the actual power factor and controls the connection or disconnection of capacitor banks in order to obtain the targeted power factor. Accurate PF control must be provided by designing the individual capacitor banks in a combination of larger and smaller kvar sizes. Capacitor bank connection is provided by contactors.

E23.4.3 Dynamic compensation

Dynamic compensation is achieved by the combination of a fixed capacitor bank and an electronic var compensator, providing either leading or lagging reactive currents. The result is a continuously varying and fast compensation.

Dynamic power factor compensation will not be acceptable.

E23.5 **OPERATING CONDITIONS AND HARMONICS**

E23.5.1 Operating conditions

The operating conditions have a great influence on the life expectancy of capacitors. The following parameters should be taken into account:

- a) Ambient temperature (°C);
- b) Expected current and voltage fluctuations.

E23.5.2 Harmonics

Harmonic rated capacitors must be used with detuned reactors. Reactors are necessary in order to prevent the amplification of harmonic currents and avoid resonance.

E23.6 SELECTION OF PFC COMPONENTS

The contractor must supply a safe, reliable and high-performance solution for power factor correction in the most severe application conditions.

E23.6.1 Capacitors with detuned reactors

The use of detuned reactors prevents harmonic resonance problems, avoids the risk of overloading the capacitors and helps reduce voltage harmonic distortion in the network. Capacitors banks must be configured with reactors in a series resonant circuit, tuned so that the series resonant frequency is below the lowest harmonic frequency present in the system.

a) Detuned Capacitor Banks

The tuning frequency for a capacitor bank with detuned reactors can be expressed by the relative impedance of the reactor (in %), or by the tuning order, or directly in Hz. The value of relative impedance must be designed to filter the highest harmonic voltage at the specific installation. Standard tuned reactors are available for the following harmonic current spectrum:

- i. Impedance 5.5 % (3rd Harmonic)
- ii. Impedance 10.7 % (5th Harmonic)
- iii. Impedance 5.3 % (7th Harmonic)
- iv. Impedance 2.1 % (11th Harmonic)

b) Capacitors

Capacitors must be supplied with the following as the minimum requirement:

- a) Self-healing, which is a process by which the capacitor restores itself in the event of a fault in the dielectric, which can happen during high overloads, voltage transients etc.;
- b) Pressure-sensitive disconnecter (also called 'tear-off fuse') in each phase of the capacitor to enable safe disconnection and electrical isolation at the end of the life of the capacitor;
- c) Discharge resistors fitted.

The rated voltage (U_N) of a capacitor is defined as the continuously allowable operating voltage. In order to accept system voltage fluctuations, capacitors must be selected to sustain over-voltages equal to 1.1 times U_N for a period of 8 hours per 24 hours. (SANS 60681-1). In a detuned filter application, the voltage across the capacitors is higher than the network service voltage (U_S). Then, capacitors must be designed to withstand higher voltages.

The rated current (I_N) of a capacitor is the current flowing through the capacitor when the rated voltage (U_N) is applied at its terminals, supposing a purely sinusoidal voltage and the exact value of reactive power (kvar) generated. Capacitor units shall be suitable for continuous operation at a rms current of ($1.3 \times I_N$) (SANS 60681-1). Depending on the selected tuning frequency, part of the harmonic currents are absorbed by the detuned capacitor bank. Then, capacitors must be designed to withstand higher currents, combining fundamental and harmonic currents.

c) Detuned reactors

Detuned reactors must be supplied with thermal protection (a normally closed dry contact). The thermal protection contact must be connected to trip the supply circuit breaker in case of overheating.

Force ventilation is mandatory when installing detuned reactors. The operating temperature of the panel should be maintained < 50 degrees through proper ventilation. The sizing must consider ambient conditions.

Power Factor controllers

Control will be provided by an electronic device (Power Factor Controller) which monitors the actual power factor and controls the connection or disconnection of capacitor banks in order to obtain the targeted power factor.

The Power Factor Controller must

- a) Permanently monitoring the network and equipment;
- b) Equipped with a large on-board display;
- c) Allows controller self-configuration;
- d) Provide information about equipment status;
- e) Activate Alarm signals in case of PFC malfunction.

d) Contactors

Special contactors designed for switching 3-phase, single or multiple-step capacitor banks shall be supplied. The contactors must be fitted with a block of early make poles and damping resistors, limiting the value of the current on closing to $60 I_n$ max. This current limitation increases the life of all the components of the installation, in particular that of the fuses and capacitors. The contactors must conform to SANS 60070 and 60831.

Short-circuit protection must be provided by gl type fuses rated at $1.7...2 I_n$.

E23.7 FIXED COMPENSATION PFC PANELS

E23.7.1 Enclosure

Fixed Compensation PFC enclosures will be:

- a) Manufactured from 3CR12 stainless steel (min 2.0mm thickness);
- b) Painted electric orange (B26);
- c) Rated IP65 to SANS 60529 and shall be fitted with a canopy when installed outdoors;
- d) Wall mounted or pedestal mounted at least 1000mm above floor level. The pedestal base plate shall be installed on 10mm of epoxy grout to prevent crack corrosion. The pedestal material shall be stainless steel (3CR12) and have minimum thickness of 6mm. The pedestal shall be painted electric orange (B26);
- e) Mounted as close as possible within a radius of 1000mm from the supply terminals of the main equipment (motor);
- f) Clearly labelled with an identity label. The label will be engraved with 30mm high black on white characters, and shall be mounted on the top of the enclosure. The name of the associated drive will be shown.

E23.7.2 Equipment

The PFC circuit will consist of:

- a) Incomer CB (MCCB) with overload and thermal protection;
- b) Capacitors with detuned reactors. The kvar rating of the capacitor bank will be in the order of 25% of the kW rating of the motor.

E23.8 AUTOMATIC COMPENSATION PFC PANEL

E23.8.1 Enclosure

Automatic Compensation PFC enclosures will be:

- a) Manufactured from 3CR12 stainless steel (min 2.0mm thickness);
- b) Painted electric orange (B26);
- c) A freestanding panel, floor standing with front access doors. Cable entry will be from a cable trench below the panel;
- d) Installed in an electrical substation building 2m away from the main MCC or DB;
- e) Clearly labelled with an identity label. The label will be engraved with 30mm high black on white characters, and shall be mounted on the top of the enclosure. The name of the associated MCC or DB will be shown.

E23.8.2 Equipment

- a) Incomer CB (ACB or MCCB) with overload and thermal protection;
- b) Capacitors banks with detuned reactors complete with CB's or fuses and contactors. The kvar rating of the capacitor banks will be based on the transformer size feeding the MCC or DB;
- c) Power Factor controller.

E23.8.3 Protection Devices

The following protection devices must be included in the PFC system as a minimum:

- a) **Over voltage**
In the event of an over voltage, electrical stress on the capacitor dielectric and the current drawn by the capacitors will increase. The PFC equipment must be switched off in the event of over voltage with a suitable over voltage relay / surge suppressor.
- b) **Over Current**
Over current condition is harmful to all current carrying components. The capacitor bank components must be rated based on the maximum current capacity. A suitable over current relay with an alarm function must be used for over current protection.
- c) **Short circuit protection**
Short circuit protection at the incomer of the capacitor bank must be provided by devices such as MCCB's and ACB's. MCB or MCCB must be installed at every step for short circuit protection.
- d) **Thermal Overload**
A thermal overload relay must be used for over load protection and must be set at 1.3 times the rated current of capacitors (as per SANS 60831).
In case of de tuned capacitor banks, the over load setting is determined by the maximum over load capacity of the detuning reactor (kvar rating).
- e) **Over Temperature protection**
The PFC controller must be tripped with the help of thermostats in cases the internal ambient temperature of the capacitor bank exceeds the temperature withstand characteristics of the capacitor bank components. Reactors are provided with thermal switches and can be isolated in the case of over temperature conditions.

E23.9 **TESTS**

At the end of the manufacturing process, the LV PFC switchboard must undergo various routine inspections and tests in the factory, following an established programme.

The switchboard must comply with :

- a) The appropriate standards (listed above);
- b) The design file (drawings, diagrams and specific requirements);
- c) Manufacturer mounting instructions;
- d) Joburg Water In-house instructions (this specification).

E23.10 **MAINTENANCE**

For the first year after commissioning (defects liability period), the contractor is responsible to maintain and test the PFC installation. Thereafter, maintenance must be done every year. The following annual checks must be performed:

- a) General cleanliness of the equipment;
- b) Filters and ventilation system;
- c) Terminal tightening torques;
- d) Proper working order of switching and protective devices;

- e) Temperature in the premises: -5 °C to +40 °C max - for normal designs;
- f) Capacitance: It is recommended to change the capacitor if the capacitance value has reduced more than 10%.

E23.11

MEASUREMENT AND PAYMENT

<u>Item</u>	<u>Unit</u>
Supply and delivery of Fixed Compensation PFC Panels	No

The unit of measure shall be the number of Fixed Compensation PFC panels supplied and delivered.

The tendered rate shall include all costs related to the manufacture, supply and delivery of the Fixed Compensation PFC panels (as detailed in the schedule of quantities), including support pedestal in accordance with this specification and the additional requirements detailed in the detail specification complete with all mounting brackets.

Separate items will be scheduled in the schedule of quantities for different types and sizes, defined by the kvar rating of the Fixed Compensation PFC panels.

<u>Item</u>	<u>Unit</u>
Install Fixed Compensation PFC Panels	No

The unit of measure shall be the number of Fixed Compensation PFC Panels installed.

The tendered rate shall include full compensation for installing, testing and commissioning of the Fixed Compensation PFC Panels as specified. The rate shall further include for pedestal support securing and sealing preventing crevice corrosion.

Separate items will be scheduled in the schedule of quantities for different types and sizes, defined by the kvar rating of the Fixed Compensation PFC panels.

<u>Item</u>	<u>Unit</u>
Supply and delivery of Automatic Compensation PFC Panels	No

The unit of measure shall be the number of Automatic Compensation PFC panels supplied and delivered.

The tendered rate shall include all costs related to the manufacture, supply and delivery of the Automatic Compensation PFC panels (as detailed in the schedule of quantities), including additional requirements detailed in the detail specification.

Separate items will be scheduled in the schedule of quantities for different types and sizes, defined by the kvar rating of the Automatic Compensation PFC panels.

<u>Item</u>	<u>Unit</u>
Install Automatic Compensation PFC Panels	No

The unit of measure shall be the number of Automatic Compensation PFC Panels installed.

The tendered rate shall include full compensation for installing, testing and commissioning of the Automatic Compensation PFC Panels as specified.

Separate items will be scheduled in the schedule of quantities for different types and sizes, defined by the kvar rating of the Automatic Compensation PFC panels.