Specification for

Low Voltage Smart Power Factor Correction Capacitor Bank

380/400/415V, 50/60 Hz

1. GENERAL

This article specifies the requirements for the design, manufacturing, testing of low voltage power factor correction banks with all necessary auxiliary equipment.

The three-phase automatic power factor correction equipment shall be installed indoor. Installation will be carried out by a qualified contractor and all relative information to enable proper installation shall be provided by the manufacturer.

2. APPLICABLE STANDARDS

The design of the low voltage capacitor bank and accessories shall comply with the requirements of the latest current edition of following IEC standards and with the specific requirements of this specification.

IEC 60831: Parts 1&2- Shunt power capacitors of the self-healing type for a.c systems having rated voltage up to and including 1 kV.

IEC 61921: Power factor capacitors. Low voltage capacitor banks.

IEC 61439-1/2: Low Voltage Switchgear and Control gear Assemblies.

IEC 60947: Low Voltage Switchgear

Part 2: Circuit Breakers

Part 4: Control gear for voltages up to and including 1000 V a.c.

IEC 60076-6: Detuned Reactors

IEC 60529: Degree of protection provided by enclosures (IP code).

IEC 60950 Basic requirements for the safety of information technology equipment

IEC61010-1 Safety requirement for electrical equipment for Measurement, Control & Lab use

3. HANDLING

The handling will be done with lifting eyes (already installed on the bank) or with a forklift truck (the capacitor bank base will allow safe handling with a fork lift truck).

4. PFC Bank Environnent & Installation Conditions

4-1 Ambient temperature

The LV capacitor banks shall be designed for the following ambient temperature inside the electrical room:

Maximum temperature: 45°C

Average temperature over 24 hours period: 35°C

Minimum temperature: -5°C

For different environmental conditions, overrated components can be prescribed.

4-2 Altitude

The LV capacitor bank shall be designed to be installed at a maximum of 2000m.

4-3 Humidity

The humidity withstand by the equipment shall be 95% of humidity.

4-4 Site pollution conditions

The site pollution conditions shall be maximum class 2 according to IEC 61010-1

4-5 Free space around the equipment

It should be possible to install the equipment directly against a wall.(Left side, right side and rear side musn't present any fans or air outlets)

5. ELECTRICAL SYSTEM CHARACTERISTICS

5-1 Low voltage network system

Nominal system voltage / rated frequency:	380, 400 or 415 V/50Hz
	400V/60Hz
Voltage tolerance at 400 V:	+/-10 %

5-2 Harmonic pollution

The capacitor bank shall be designed to withstand harmonic pollution in network with a Gh / Sn ratio below 25% (Gh: Capacitor bank kvar rating, Sn: Supply transformer kVA rating).

Low voltage capacitors banks equipped with detuning reactors shall be installed in harmonic rich network, electrical network with a Gh / Sn ratio between 25% to 50%.

6. POWER SUPPLIES

Power supplies for LV capacitor bank shall be: 380, 400, or 415V, 3 phases, 3 or 4 wires, 50/60 Hz,

230 V single phase 50/60 Hz for control circuits, fans. This auxiliary voltage shall be provided inside the bank from main power supply. Auxiliary circuits shall be protected by circuit-breaker.

7. CABLE CONNECTIONS

It should be possible to connect the power cables either from the top or bottom of the enclosure (customer to specify cable entry location). Removable gland plate shall be provided with the equipment.

8. CAPACITORS

8.1 Standards

The capacitor units shall comply with IEC60831 Part 1& Part 2 for self-healing type power capacitors

8.2 General technical requirement

The capacitor element used in unit shall have metalized polypropylene film (MPP) having low dielectric loss and impregnated with such impregnate, which shall have high dielectric constant, low viscosity and high chemical stability. The impregnate should be polyurethane base dry resin. The dielectric material should have wave cut design with slope metallization, so that higher current carrying capabilities can be achieved. Also the wound elements need to be treated with **inert gas** during impregnation to ensure all the moisture and air gaps are removed to ensure better winding stability and hence better life. Manufacturer should adopt the stacked design of wound elements for better heat dissipation and longer life. Stacked design ensures 3 phases separated in 3 elements and delta connected. The contract area must be carefully prepared so as to achieve high in rush current and long life.

8.3 Safety Requirements

8.3.1 Pressure Sensitive disconnector :

The capacitor unit shall have **pressure sensitive disconnector mechanism in all three phases.** Pressure sensitive disconnector has to be independent from internal assembly for safe disconnection. For easy identification of failed units with naked eye all the three phases should be simultaneously disconnected to ensure complete electrical isolation and enough lid deflection.

8.3.2 Discharge Device:

Every capacitor shall be provided with a tamper proof , non accessible in build discharge device to ensure the capacitor discharge with in 1 minute. Discharge resistance shall reduce the residual voltage to less than 50 volts within one minute as required by IEC60831.

8.4 Construction

The capacitors assembly should have 3 elements arranged in stack design and internally delta connected. This capacitor assembly housed in cylindrical aluminum container and seamed to ensure leak proof. Capacitors shall be filled with the suitable impregnant material to ensure insulation and faster cooling so that the windings are kept cool. At the base of capacitors unit suitable arrangement for earthing preferably in form of M-12 size stud bolt having 16mm outer(projected) length with toothed washer hexagonal nut .

There should be an in built protection devices(s) /pressure sensitive in the event of any fault/ abnormal condition inside the capacitor unit. Occurrence of such condition must be indicated by any mechanism/symbol in the capacitor unit

The resin filled capacitor units must be inert and absolutely harmless to environment. The operation and disposal of capacitor units must be environmental friendly. The constructional features necessary to prevent leakage and to ensure safety during operation must be adopted.

Mounting of capacitors: Capacitors need to be mounted both vertically and horizontally depending up on the requirements. None of the material used inside the capacitor should be liquid or semi liquid in nature so that it can prevent leakage in the case of horizontal mounting.

All the materials used to construct the capacitor need to be environment friendly i.e RoHS & REACH compliance.

8.5 Technical Specifications

8.5.1 Permissible overloads

8.5.1.1 Voltage:- The permissible over loads shall not exceed limits set by IEC 60831 for self healing type capacitors. Capacitors shall be suitable for prolonged operation at RMS voltage between terminals not exceeding 1.1 times the rated voltage.

8.5.1.2 Capacitors units shall be suitable for continues operation at r.m.s. line current 1.8 times the current occurs at rated sinusoidal voltage and rated frequency excluding transients

8.5.1.3 Inrush Current: **-** Should be 200 times rated current.

8.5.2 Capacitor Losses

The dielectric loss shall not be more than 0.20 W/kvar. The total capacitor loss after stabilization **including discharge resistor** should not be more than 0.5 watt/kvar for self-healing type capacitors using metalized polypropylene.

Each element is to be of a dry self-healing metallised polypropylene film and to be housed in a three phases assembly in one aluminium casing.

A double protection system shall be fitted to each three phases assembly which shall comprise an integral discharge resistor and an overpressure disconnect device. This over pressure device must disconnect the 3 phases

Each element forming the three phases capacitor shall be fitted with an internal discharge resistor to ensure that the capacitor is discharged to a voltage not exceeding 50 V measured at the capacitors terminals, one minute after disconnection from the power supply.

The use of polychlorinated biphenols (PCB) and oil as capacitor impregnation is not acceptable.

The capacitor losses in Watts shall not exceed 0.5 W / kvar, discharge resistor included.

8.5.3 Temperature class

Temperature class shall be -25°C/55°C (class D) as per IEC 60831.

8.5.4 Rated impulse withstand voltage

It shall withstand to the levl 6 or 8 KV.

8-6 **Certification**

The three phase capacitor shall be designed and manufactured in an ISO 9001 and ISO 14001 certified manufacturing plant. Certificates shall be available on request.

9. POWER FACTOR CONTROLLER

9. 1. Input & Control supplies

The Power factor controller has to be made suitable for direct connection in low voltage system up to 480V and through a PT for above 480V. There should be a provision for inputting either 1A or 5A secondary CT to the PFC controller.

The controller has to be self powered. There should not be any dedicated control supply needed for the operation of controller.

9.2. Communication

The Controller must have a inbuilt RS485 port in Modbus Protocol. Manufacturer has to provide the detail registry map of the Modbus device for the future reference. There should not be any dedicated power supply or wiring to be done for the RS485 communication except the normal communication cable wiring.

9.3 Power Factor Correction intelligence

9.3.1 Input connection correction

The controller should be able to detect and correct abnormalities in wirings such as reversed CT, PT on a wrong phase etc.

9.3.2 Automatic step size detection

The PFC controller should be able to detect the step sizes by automatic recognition. It should detect the connected step and the power factor correction should not be affected if one or more steps failed, provided there is enough remaining steps in PFC bank to do operations.

The PFC controller should detect the capacitor bank size if in case the present capacitor is replaced by a new capacitor of different rating. ??

9.3.3 No Step sequence

The controller should not have any specific sequences to follow for successful operation. It should be also possible to connect smaller or bigger capacitors after the first step in the controller. There should not be any restriction in replacing the failed capacitor with any new rating and detecting the new capacitor which replaced the failed one. ??

9.3.4 Switching program intelligence

The PFC controller programming intelligence should make sure the minimum switching of steps while maintaining the target power factor.

There has to be provisions in configuration of the controller to program the individual steps for Fixed ON, Fixed Off or Automatic.

The Controller should be able to detect the number of steps connected automatically with out any programming.

9.3.5 Dual Cos Phi – The Controller should have programmable dual cos phi to differentiate the need in compensation (Cos Phi) when the operating condition changes. Like Power factor correction needs with a utility supply changes when the input power is from a in house Generator. There should be dedicated connecting terminal for providing this input.

9.3.6 Power Factor correction range

0.7 Lag to 0.7 Lead

9.4 Measurement & Display

9.4.1 Measurement of Power

The controller should be able to measurement and display of Active, reactive and apparent power

The controller should be able to project the reactive power required to attain the target power factor in the display

9.4.2 Measurement of Power and Harmonics

The controller should be able to measure and display the following

1. Active, reactive and apparent power
2. Reactive power required to attain the target power factor in the display
3. Network voltage, Current
4. Total Harmonic distortion of Voltage
5. Individual voltage harmonic distortion up to 19th harmonic.

9.4.3 Temperature measurement

The controller should have a inbuilt temperature sensor with programmable offset limits to measure and display the cabinet temperature.

The controller should display the maximum temperature recorded from the last reset.

9.4.4 Connected Step Database.

The controller should be able to measure and display the following

1. Step Status – Step is Connected or Not
2. Step power in Kvar for all the connected steps
3. Number of switching operation for every step
4. Available power per step as a % of initial power.

9.4.5 Type of Display has to be LCD with backlit with a minimum screen size of 50X20

9.4.6 The Controller should be enabled for doing Measurement and power factor correction in four quadrant operations

9.5 Manual Switching of steps

The controller has to have a provision of connecting the steps manually also for testing purpose. User must be able to connect or disconnect the steps manually.

9.6. Safety features

9.6.1 Step re connection delay

The default configuration of the controller must be in such a way that it should not connect a step before 50sec after it got disconnected. This parameter can be programmable for the user to configure the controller for special applications.

9.6.2 Safety certification –

The controller need to complied with IEC 61010-1 (2010) ed.3 / UL61010-1(2012) ed 3 / CAN/CSA C22.2 N°61010-1 (2012) ed 3
(Safety requirements for electrical equipment for measurement, control, and laboratory use - Part 1: General requirements)

And with IEC61010-2-30 (2010) ed.1 / UL61010-2-30 (2012) ed 1 / CAN/CSA C22.2 N° 61010-2-30 (2012) ed 1
(Safety requirements for electrical equipment for measurement, control, and laboratory use - Part 2-030: Particular requirements for testing and measuring circuits)

9.6.3 Thermal safety

The Controller should have a dedicated Fan control contact to switch on the fan when the cabinet temperature exceeds 30 degrees. The controller also should operate alarm contact when the temperature exceeds 50 degrees. These limits have to be programmable and user should be able to program an offset temperature if required.

9.6.4 Safety against harmonic amplification

The controller should have a voltage harmonic distortion alarm and it should automatically disconnect connected steps to reduce the harmonic which is generated due to parallel resonance due to capacitors. This harmonics limits has to be programmable and by default value can be 7%.

9.7. Alarms

9.7.1 Alarm contact

The Controller should have a dedicated alarm contact which will make users to wire it to trip the PFC bank.

9.7.2 Alarms

Following alarms has to be incorporated in the PFC Controller

1, Over /Under Voltage alarm

2. Low Current Alarm

3. Under/Over compensation alarm

4. Faulty Step alarm – Indication of faulty step with step number

5. Derating alarm – Individual step de rating of capacitor indicator.

6. High temperature alarm – Through the internal thermal sensor. User need not have to connect any external sensor to enable this alarm.

7. Total Harmonic distortion alarm at 7% THDu.

9.7.3 Alarm Logs

The Controller must be able to display at least last 5 alarm logs.

9.8. Type Tests

The type tests of PFC Controller should be done in compliance with

IEC 61010-1 (2010) ed.3
UL61010-1(2012) ed 3
CAN/CSA C22.2 N°61010-1 (2012) ed 3
Safety requirements for electrical equipment for measurement, control, and laboratory use - Part 1: General requirements

IEC61010-2-30 (2010) ed.1
UL61010-2-30 (2012) ed 1
CAN/CSA C22.2 N° 61010-2-30 (2012) ed 1
Safety requirements for electrical equipment for measurement, control, and laboratory use - Part 2-030: Particular requirements for testing and measuring circuits

IEC 61326-1 (2012)
Electrical equipment for measurement, control and laboratory use - EMC requirements - Part 1: General requirements

IEC 61000 6-2 (2005) ed 2
Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity for industrial environments

IEC 61000 6-4(2006) ed.2
Electromagnetic compatibility (EMC) – Part 6-4: Generic standards – Emission standard for industrial environments

10. CONTACTORS

Contactors shall be used to switch capacitors in or out of service. They shall comply with IEC 60947-4 and shall have a rating suitable for the service required.

Contactor must be specially designed for capacitor switching purpose and must be able to reduce the transient voltage surges .

They must be fitted with early make poles and damping resistors to limit the value of inrush currents to a maximum of 60 In (banks without detuned reactors).

11. REACTORS

11.1 Harmonic profile

Detuning reactors shall be used when the capacitor bank is installed in harmonic rich network (25% < Gh / Sn < 50%).

Detuned reactors must be designed to support overcurrent generated by the following harmonic profile according to the relative impedance.

(%)	*Harmonic currents*			
Tuning order / Relative Impedance	i_3	i_5	i_7	i_{11}
2.7 / 14%	5	15	5	2
3.8 / 7%	3	40	12	5
4.2 / 5.7%	2	63	17	5

11.2 Construction

The detuning reactor shall be three phase iron core with copper or aluminium winding.

All the parts of the reactor protected against corrosion with varnish.

The detuning reactor shall be equipped with thermal protection device used for step disconnection under over load condition.

11.3 Standard

The reactor shall comply with IEC 60076-6

11.4 Technical specifications

Tolerance: +/- 5 %

Tuning order: 2.7 (relative impedance : 13.7%); 3.8 (relative impedance 6.94%); 4.2 (relative impedance : 5.67 %)

Permissible overload fundamental current: 1.1 time the nominal current (I1).

Insulation level: 1.1 kV according to IEC 60076-6

Test voltage (coil to core & coil to earth): 4 kV for 1 minute

12. CABLES

12-1 Control cables

Small wiring cables shall be insulated 1000 V 105°C , ROHS compliant.

The cross section shall be minimum 1mm².

12-2 Power cable

The power cable used shall be insulated 1000 V 105°C , ROHS compliant, 10V2-K type.

13. ENCLOSURE or CUBICLE FEATURES

The equipment shall be housed in a metal enclosure with an ingress protection level of IP31.

The doors of the capacitor bank enclosure shall be interlocked to prevent access to the bank, when energized

The protection against direct contact when the door is opened shall be IPXXB according to IEC 60529.

The ventilation will be natural or forced. In case of forced ventilation, it will be controlled by ~~a~~ temperature sensor.

13-1 Design data

IEC standard :	61439-1/2 and 61921
Degree of protection :	IP31 (IP54 can be prescribed for dusty environment)
Installation:	Indoor
Insulation level:	0,69 kV
Short circuit level for 1 second:	15 or 35 or 65 kA
Gland plate:	Un-drilled

13-2 Enclosure thickness

The thickness of the metal sheet of the enclosure shall be 1 or 1.5 mm.

However some metal parts and devices inside the enclosure may have a lower thickness.

The mechanical resistance of the enclosure shall be IK 10 according to IEC 62262

13-3 Surface treatment / Painting

13-3-1 Surface treatment :

The metallic parts of the enclosure shall be washed at 40°C minimum to remove any grease residue and rinsed in water.

13-3-2 Painting :

A powder Epoxy Polyester shall be applied with a thickness of 30 microns.

The Epoxy will protect the enclosure against chemical reaction and the polyester will protect against mechanical shocks.

The painting shall be polymerised into an oven.

The colour of the capacitor bank shall be RAL 7035.

13-4 Rating plate

Self adhesive rating plate shall be fitted inside the enclosure listing the following information:

- Reactive power
- Nominal voltage
- Frequency
- Tuning factor
- Minimum/Maximum ambient temperature
- IP
- Icc/Icw

14. PROTECTION DEVICES

14.1 Incoming Circuit Breaker

An incoming Circuit Breaker shall be installed as the main isolator to the capacitor bank.??

The Circuit Breaker should be properly sized to ensure an overload and short circuit protection.

14.2 Capacitor step circuit breaker

The capacitor step protection shall be done via a circuit breaker allowing over current and overload protection.

The step circuit-breakers shall be selected to ensure coordination with incoming circuit-breaker.

15. Measurement and Control

15.1

The Capacitor bank shall have a device for communication. It shall connect with the power factor controller & the temperature device over any communication protocol to collect the data like temperature, active steps, step data etc. It shall be possible to store this data & provide trending of the measured parameters. This shall help the user to plan the maintenance. It shall also log the alarms & immediately inform the user about the alarm conditions so that the user can take corrective action. This shall immediately alert the user of the abnormal condition to take suitable corrective action. This shall help to operate the capacitor bank to its optimum performance. The data shall be accessed by the user over the wired or wireless network in his computer / mobile.

15.2

The capacitor bank shall be equipped with a smoke detection device which should be able to detect any smoke inside the capacitor bank and should trip the incoming circuit breaker on smoke detection. Further, it should be able to send an alarm/indication to the user indicating the presence of smoke.

16. INSPECTION AND ROUTINE TESTING

Tests shall be performed at the manufacturer's works in accordance with the relevant IEC standards.

The tests shall include:

16.1 Routine tests for capacitor bank

- Inspection for conformity with the specifications
- Power rating

- Dielectric tests
- Grounding continuity test
- Electrical test

16.2 Routine tests for capacitor

- Voltage withstand test between terminals
- Capacitance measurement
- Loss angle measurement on similar capacitor

17. TYPE TESTS

The type tests should be done in compliance with IEC 61439-1&2 and IEC 61921 standards, for safety and reliability.

Type tests to be performed on the capacitor bank range:

- dielectric properties
- temperature rise limits
- short-circuit withstand strength
- effectiveness of the protection circuit
- clearances & creepage distances
- mechanical operation
- degree of protection
    - protect people against contact with live parts
    - protect equipment against penetration of solid objects &liquids (IP code defined in IEC 60529)
    - protect equipment against impact (IK code defined in IEC 62262)

Type test certificate shall be issued by independent certified laboratories.

18. CURRENT TRANSFORMERS

The current transformer shall comply with IEC 60044-1 and shall be of 5 A output, class 5P10, 5 VA minimum.

The current transformer has to be supplied by the contractor .