

Specification for Low Voltage Smart Power Factor Correction Capacitor Bank NEMA 480/600V, 60Hz

Chapter 1 General

- This article specifies the requirements for the design, manufacturing, testing of low voltage power 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.

1. Applicable References

- The publication listed below form a part of this Specification to the extent reference. The publications are referred to in the text by the basic designation only. The edition/ revision of the referenced publications shall be the latest date as of the date of the Contract documents, unless otherwise specified.
 - **American National Standards Institute (ANSI)**
 - ANSI C37.51 “Switchgear Metal Enclosed Low Voltage AC Power Circuit Breaker Switchgear Assemblies Conformance Test procedures.”
 - **American Society for Testing and Materials (ASTM)**
 - ASTM E 329, “Standard Specification for Agencies Engaged in the Testing and/or Inspection of Materials Used in Construction.”
 - **Canadian Standards Association (CSA)**
 - C.22.2 No. 190, “Capacitors for Power Factor Correction”
 - C22.1, “Canadian Electrical Code Part I” (CEC)
 - Z462, “Workplace Electrical Safety”
 - **National Electrical Manufacturers Association (NEMA)**
 - NEMA 250, “Enclosures for Electrical Equipment (1000 Volts Maximum)”
 - **National Fire Protection Association (NFPA)**
 - NFPA 70, “National Electrical Code” hereinafter referred to as NEC.
 - NFPA 70E, “Standard for Electrical Safety Requirements for Employee Workplaces”
 - **Underwriters Laboratories, Inc. (UL)**
 - UL 508a, “Industrial Control Panels”
 - UL 810, “Standard for Capacitors.”
 - **Prop65 Regulation**
 - Warning to the significant exposure to chemicals that cause cancer, birth defects or other reproductive harm as per California law.

2. Marking and Labeling

- All identification and warning labels and nameplates exterior to the Capacitor Bank shall be resistant to weather, UV, and their intended installation environment.
- Each Capacitor bank shall be provided with a nameplate identifying the project specific equipment serial no and service description.
- Warning labels and nameplates shall be present at access locations to advise personnel of possible hazards. The Capacitor bank shall be marked in accordance with UL, CSA, NFPA 70 NEC, NFPA 70E and other applicable standards.

3. Delivery, Storage and Handling

- Prior to delivery to the project site, ensure that suitable storage space is available to store materials in a well-ventilated area protected from weather, moisture, soiling, extreme temperatures, humidity, and corrosive atmospheres. Materials shall be protected during delivery and storage and shall not exceed the manufacture stated storage requirements. As a minimum, store indoors in clean, dry space with uniform temperature to prevent condensation. In addition, protect electronics from all forms of electrical and magnetic energy that could cause damage.
- Deliver materials to the project site in supplier's or manufacturer's original wrappings and containers, labelled with supplier's or manufacturer's name, material or product brand name, and equipment tag number or service name as identified within the contract Documents.
- Inspect and report any concealed damage or violation of delivery storage, and handling requirements to the Engineer.

4. Environmental and Installation conditions

Ambient Temperature

- The LV Capacitor Bank shall be designed for the following ambient temperature inside the Electrical Room
 - Operating ambient temperature shall be 15°F (-10°C) to 104 °F (40 °C) maximum.
 - Highest mean over any period of 24 hours shall be 104 °F (40 °C).
 - Highest mean over one year shall be 95 °F (35 °C).

Altitude

- The LV Capacitor Bank shall be designed to work at an altitude of 2000 metres/6500Ft above Sea level.

Humidity

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

Free Space around the Capacitor Bank

- It should be possible to install the equipment directly against a wall. (Left side, Right side, and Rear side must not present any fans or air outlets), further there should be minimum 300mm free space for the air exhaust vent at the top of capacitor bank.

5. Electrical System Characteristics

Low Voltage Network System

Nominal system voltage (line to line)/ rated frequency

- 480 V/60 Hz
- 600 V/ 60 Hz
- +/- 10 %

Other Characteristics at 480 and 600 V

- Rated capacitor cell voltage shall be minimum of 575 volts for 480V networks while 690 V for 600V network.
- If the incomer has terminal lugs, then the same shall be of copper and copper bus shall be braced to withstand fault level at either 65kA symmetrical plus 10%.
- If the incomer is a circuit breaker, then the same shall be rated to withstand a fault level of 65 kA at 480V and 50kA at 600 V. The main circuit breaker shall be rated for a minimum of 135 percent of the capacitor system full load current at operating voltage.

Harmonic Pollution

- Standard capacitor bank shall be designed to withstand harmonic pollution in network with a Gh/ Sn ratio below 25% (Gh: Apparent power of harmonic generating loads, Sn: Supply transformer kVA rating).
- Low voltage capacitors bank 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
 - 480 V or 600 V
 - 3 phases
 - 3 or 4 wires
 - 60 Hz
- 120-volt AC control circuit transformer shall be provided within the enclosure

7. External Current Transformer (CT)

- A current transformer to be installed upstream of where the automatic capacitor is attached to the electrical distribution system, shall be provided with a secondary of 1 or 5 amperes.
- A shorting terminal shall be provided for incoming current transformer wires.

8. Cable Connections

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

9. Capacitors

Standards

- Internal capacitor cells shall be UL and CSA certified in compliance with UL 810 and CSA22.2 No. 190.

General technical requirement

- The capacitor element used in unit shall have metalized polypropylene film (MPP) having low dielectric loss and impregnated with a high 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 better heat dissipation and longer life. Stacked design ensures 3 phases separated in 3 elements and delta connected. The contact area must be carefully prepared so as to achieve high performance with inrush current and long life.

Safety Requirements

- Pressure Sensitive Disconnecter
 - The capacitor unit shall have pressure sensitive disconnecter mechanism in all three phases must have Pressure sensitive disconnecter must 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.
- Discharge Device
 - Every capacitor shall be provided with a tamper proof, non-accessible in build discharge device to ensure the capacitor discharge within 1 minute. Discharge resistance shall reduce the residual voltage to less than 50 volts within 1 minute as per UL/CSA requirement.

Construction

- The capacitor assembly should have 3 elements arranged in stack design and internally delta connected. This capacitor assembly must be housed in cylindrical AL(aluminium) hermitically sealed. Capacitor 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 length with Star washer and hexagonal nut.

- There should be an in-built protection device/ 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 on the capacitor unit.
- The resin used in the capacitor units must be inert and absolutely harmless to the environment, the operation and disposal of capacitor units must be environmentally friendly. Constructional features necessary to prevent leakage and to ensure safety during operation must be adopted.

Mounting of capacitors

- Capacitor can be mounted vertically or 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 at a minimum meeting the requirement of RoHS and Reach.

Technical Specifications

Permissible Overloads

- The Permissible overloads 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.
- Capacitors units shall be suitable for continued operation at $1.8 \times I_n$ (I_n = capacitor effective nominal current) at rated sinusoidal voltage and rated frequency excluding transients.
- The capacitor cells must be able to withstand an inrush current equal to 200 times I_n .

Capacitors 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 W/kVAr for self-healing type capacitor using metallized polypropylene.
- Each element is to be of a dry self- healing metallized polypropylene film and to be housed in a three-phase assembly in one aluminium casing.
- A double protection system shall be fitted to each 3 phases assembly which shall comprise an integral discharge resistor and an over pressure disconnect device. This over pressure device must disconnect the 3 phases.
- Each element forming the 3 phases capacitor shall be fitted with an internal discharge resistor to ensure that capacitor is discharged to a voltage not exceeding 50V measured at the capacitor's terminals, one minute after disconnection from the power supply. The use of polychlorinated bisphenols (PCB) and oil as capacitor impregnation is not acceptable. The capacitor losses in Watts shall not exceed 0.5 W/kVAr , discharge resistor included.

Temperature Class

- Temperature class shall be $-25\text{ }^{\circ}\text{C}/55\text{ }^{\circ}\text{C}$ (class D) as per IEC 60831.

Rated Impulse Withstand Voltage

- It shall withstand to the level 8 KV.

Certification

- The 3 phases capacitor shall be designed and manufactured in an ISO 9001 and ISO 14001 certified plant. Certificates shall be available on request.

10. Power Factor Controller

Input and Control Supplies

- The power factor controller has to be made suitable to work with 480V or 600V with a PT. There should be a provision for inputting either 1A or 5A secondary CT to the PFC controller.

Communication

- The controller must have an inbuilt RS485 port in Modbus Protocol. Manufacturer must provide the controller Modbus register mapping to allow for communication with third party Building Management System (BMS). There are not be any dedicated power supply or wiring to be done for the RS485 communication except the normal communication cable wiring.

Power Factor Correction Intelligence

Input Connection Correction

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

Automatic Step Size Detection

- The PFC controller should be able to detect the step sizes by the automatic recognition. It should detect 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 in case the present capacitor is replaced by a new capacitor of different rating.

No Step Sequence

- The controller should not have any specific sequence 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.

Switching Program Intelligence

- The PFC controller programming intelligence should make sure the minimum switching of steps while maintaining the target power factor.
- There must 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 without any programming.

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 or a back up Generator. There should be dedicated connecting terminal for providing this input.

Power Factor Correction Range

- 0.7 Lag to 0.7 Lead

Measurement and Display

Measurement of Power

- The controller should be able to measure and display active, reactive, and apparent power.
- The controller should be able to project the reactive power required to attain the target power factor set by the end user.

Measurement of Power and Harmonics

- The controller should be able to measure and display the following
 - Active, reactive and apparent power.
 - Reactive power required to attain the target power factor.
 - Network voltage and current.
 - Total harmonic distortion in voltage.
 - Individual voltage harmonic distortion up to 19TH harmonic.

Temperature Measurement

- The controller should be having an inbuilt temperature sensor with programming offset limits to measure and display the cabinet temperature.
- The controller should display the maximum temperature recorded from the last reset.

Connected Step Database

- The controller should be able to measure and display the following
 - Step Status - Step is connected or not.
 - Step power in kVAr for all the connected steps.
 - Number of switching operation for every step.
 - Available power per step as a % of initial power.
- Type of display must be LCD with backlit with a minimum screen size of 50x20mm.

- The controller should be enabled for doing Measurement and Power Factor Correction in 4 quadrant operations.

Manual Switching of Steps

- The controller must have a provision of connecting the steps manually.

Safety Features

Step Re- Connection Delay

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

Safety Certification

- The controller needs to comply with IEC 61010-1 (2010) ed.3/ UL61010-(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: Particular requirements for testing and measuring circuits).

Thermal Safety

- The controller should have a dedicated Fan control 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 must be programmable, and user should be able to program an offset temperature required.

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.

Alarms

Alarm Contact

- The controller should have a dedicated alarm contact which indicate that an alarm condition has been reached.

Alarms

- Following alarms must be incorporated in the PFC Controller
 - Over/ Under Voltage alarm.
 - Low Current alarm.
 - Under/ Overcompensation alarm.
 - Faulty Step alarm - Indication of faulty step with step number.

- Derating alarm - Individual step de rating of capacitor indicator.
- High temperature alarm - Through the internal thermal sensor. User need not have to connect any external sensor to enable this alarm.
- Total harmonic distortion alarm at 7 % THDu.

Alarm Logs

- The controller must be able to display at least the last 5 alarms.

Types 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.
 - IEC 61010-2-30 (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 (2010)
 - Electrical equipment for measurement, control and laboratory use - EMC requirements –
 - (1) **Part 1: General requirements.**
 - IEC 61000 6-2 (2005) ed 2
 - (2) **Electromagnetic compatibility (EMC) –**
 - Part 6-2: Generic standards - Immunity for industrial environments IEC 61000 6-4 (2006) ed. 2
 - (3) **Electromagnetic compatibility (EMC) –**
 - Part 6-4: Generic standards - Emission standard for industrial environments.

11. Contactors

- For applications with gradual load variation, electromagnetic contactors shall be used. The electromagnetic contactors shall be 3 poles; rated for the repetitive high inrush switching duty in the capacitor application. Contactors shall be designed for capacitor switching duty, UL/ CSA listed and rated 600 volts AC with 120 volts AC operating coils.

12. Reactors

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 over current generated of a minimum of 1.35 x In (In = Stage nominal current).
 - Tuning reactors for each capacitive stage shall be selected such that filter tuning of each stage shall be equal to 4.2x 60 Hz equivalent to a 252 Hz tuning.
 - Reactor shall be construction of EI laminated low hysteresis core with a controlled air gap and 3 aluminium windings.
 - Reactors insulation shall be rated for 180 ° C, class H.
 - The detuning reactor shall be equipped with thermal protection device used for step disconnection under overload or over heating condition.
- The Detuned reactor shall be 3 phase iron core aluminium winding. All the parts of the reactor protected against corrosion with varnish.
- The Detuned reactor shall be equipped with thermal protection device used for step dis- connection under overload condition.

Standard

- The reactor shall comply with IEC 60076-6, UL 5085-2, Low Voltage Transformers - Part 2: General Purpose Transformers and CSA-C22.2 No. 66.2, Low Voltage Transformers - Part 2: General Purpose Transformers.

Technical Specifications

- Tolerance: +/- 5 %
- 4.2 (relative impedance 5.67 %)
- Test voltage (coil to core and coil to earth) 4 kV for 1 minute

13. Cables

Control Cables

- Small wiring cables shall be insulated 600 V 105 °C, ROHS compliant. The cross section shall be minimum 1mm²

Power Cables

- The power cable used shall be insulated 600V 105°C, ROHS compliant, 10V2-K type.

14. Enclosure or Cubicle Features

- Enclosure(s) shall be free standing or wall mounted, and shall be constructed of sheet steel including, but not limited to a hinged door, ground lug, and removable lifting eyes, finished with standard RAL 7035 paint.

- Enclosure(s) shall meet NEMA 250 type 1 for indoor application, further the Enclosure shall provide an option with a gasketed control door.
- Enclosure door(s) shall be full height, key lockable with door mounted controller, to comply with NFPA70E requirements.

- Design Data

- NEMA standard: NEMA 250 Type 1
- Degree of protection: NEMA 1, NEMA 1 with gasket
- Installation: Indoor
- Insulation level: 2.5 x Un for 1 min.
- Short circuit level for 4 cycle: 50, 65 or 100 kA ANSI- C37.
(65kA for MLO for Detuned Offer)
(65kA 480V Standard, 50kA 600V Standard)
- Enhanced Rating with Incoming CB: 100kA for 480V, 65kA for 600V
- Gland plate: provided for cable entry.

- 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.

- Surface Treatment/ Painting

- Surface Treatment**

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

- 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 polymerized into an oven. The colour of the capacitor bank shall be RAL 7035.

- Rating Plate

- Self-adhesive rating plate shall be fitted outside the enclosure listing the following information as per UL and CSA recommendation as below –
 - Manufacturer’s name, trademark, or other acceptable symbol of identification
 - A distinctive catalogue number or equivalent

- This equipment is Rated for(rating) kvar.
- Number of Phases and method of connection
- Rated frequency
- Rated voltage
- BIL, Basic insulation level
- Enclosure designation (e.g. CSA Type 1 enclosure (when applicable))
- For metal enclosed banks, the maximum short-circuits withstand rating of the assembly at rated input voltage in accordance with clause 7.5 of C22.2 No 31 for low voltage equipment and Clause 8.5.4 of C22.2 no 31 for high-voltage equipment and
- Serial no or date code.

15. Protection Devices

Without incoming circuit breaker (Main lug Option/ MLO)

- In case if the capacitor is with MLO, then it should be connected with a properly rated upstream circuit breaker which should be properly sized to ensure an overload and short-circuit protection.

Incoming Circuit Breaker

- An incoming circuit breaker shall be installed as the main protective device to the capacitor bank. The circuit breaker should be properly sized to ensure an overload and short circuit protection

Capacitor Step Circuit Breaker

- The capacitor step protection shall be done via a circuit breaker allowing over current and overload protection. example circuit- breakers shall be selected to ensure coordination with in-coming circuit-breaker.

16. Measurement and Control for Electrical Power Management System – Smart & Connected offer.

- The capacitor bank shall have a device for communication. It shall connect with the power factor controller and 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 and provide trending of the measured parameters. This shall help the user to plan the maintenance. It shall also log the alarms and 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.
 - The capacitor bank shall provide the necessary communication connectivity and functionality required to support the functionality of an Electrical Power Management System (EPMS). This shall include but not be limited to the following

- Communication connectivity using the specified Ethernet network and protocols of the EPMS and related EPMS connected equipment necessary to provide functionality. Equipment may be connected through a communications gateway as shown or specified: otherwise Ethernet and protocol connectivity shall be provided within the equipment.
- Compliance with cyber security requirements.
- Remote EPMS application functionality for equipment configuration and operational control electrical power monitoring, power quality monitoring, compliance and correction, and alarm monitoring with event log.
- Refer to the Electrical Power Management System specification section for additional requirements.
- Native software compatibility shall be fully factory- tested and shall include the following characteristics.
 - Capability for pre- engineered, interactive display screens to view and analyse real - time device data. Data displayed shall including the following
 - Power factor (target, measured total, measured displacement)
 - Total power values (kW, kVAr, and kVA)
 - Average current
 - Step settings and status of each step (whether closed, faulty, whether step type is automatic or fixed)
 - Step capacity for each step (initial, present and percentage remaining)
 - Device status information (line to line voltage, average current, temperature)
 - Device maintenance warnings and alarms (step broken, step power loss, hunting, over- under compensation, temperature alarms, operating hours exceeded, switching cycles exceeded etc.)
 - Device diagnostic data (operating hours, ambient temperature, overload current ratio, fan relay status etc.)
 - Device configuration settings (control sensitivity, step switch internal, discharge time etc.)
 - Pre- mapping of registers to standard measurement names without the need for additional configuration or internal device registers.
 - Automatic collection and logging of device data by EPMS software without additional configuration. Historical data logged shall include the following
 - Average Current
 - Ambient Temperature
 - Power Factor (total, apparent, reactive, real)

17. Inspection and Routine Testing

- Tests shall be performed at the manufacturer's in works in accordance with the relevant UL/CSA standards. The test shall include –
 - Routine Tests for Capacitor Bank

- Inspection for conformity with the specification, Power rating
- Dielectric tests
- Grounding continuity test
- Electrical test
- Routine Tests for Capacitor
 - Voltage withstand test between terminals
 - Capacitance measurement
 - Loss angle measurement on similar capacitor

18. Type Tests

- The type test should be done in compliance with applicable UL and CSA standards, for safety and reliability as mentioned in reference standard paragraph.
- 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 and creepage distances
 - Mechanical operation
 - Degree of protection
 - Protect people against contact with live parts
 - Protect equipment against penetration of solid objects and 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.