2.4-35 KV Medium Voltage Fixed & Automatic Metal-Enclosed Harmonic Filter Banks

Specification Guide

1. GENERAL: To define the requirements for metal enclosed capacitor banks comprised of interconnected capacitor assemblies or equipment, and used for power factor improvement.

1.1 This specification is for a medium voltage three phase metal-enclosed automatic capacitor bank consisting of, _____steps of _____kvar at _____KV. The bank shall be automatically switched based on power factor ***(other optional methods include, include, current, voltage, KW, KVAR, temperature, time, SCADA, KYZ Pulse).*** All controls, switching devices, and protection features are enclosed in an all-welded compartmentalized steel enclosure. The bank shall come fully assembled and ready for interconnection. All exceptions to this specification shall be clearly stated with your bid. **If** no exceptions are taken, the bid should include the phrase "no exceptions have been taken".

1.2 The electrical ratings of the bank and associated switchgear, switching devices, capacitors, fuses, and all other applicable components shall have ratings designed for application on the following system.

Basic Lightning Impulse Insulation Level [BIL] _____ kV Crest

Maximum System Voltage _____ kV RMS

Nominal System Voltage _____ kV RMS

Available SSC KVA at the Capacitor Bank

Line to Line _____ kA RMS

Line to Ground _____ kA RMS

2. REFERENCES CODES & STANDARDS

The power capacitor bank shall meet or exceed the applicable requirements of the latest editions of the following codes and standards.

- ANSI/IEEE STD 18----------Shunt Power Capacitors
- CP-1 NEMA ----------Standards on Shunt Capacitors
- ANSI C37.20.2----------IEEE Standard for Metal-Clad and Station-Type Cubicle Switchgear
- ANSI C37.20.3----------IEEE Standard for Metal-Enclosed Interrupter Switchgear
- ANSI/IEEE C37.99----------Guide for Protection of Shunt Capacitor Banks
- ANSI C57.16----------Requirements, Terminology and Test Code for Current Limiting Reactors
- NFPA 70----------National Electric Code (NEC)
- ANSI C2----------National Electric Safety Code
- IEEE Std. 1036----------Guide for Application of Shunt Power Capacitors
- ANSI Std. Z535.4 ----------Product Safety Label Standard
- UL-347----------High Voltage Industrial Control Equipment
- UL-508----------Industrial Control Panels
- UL-50----------Standard for Enclosures for Electrical Equipment

3. DEFINITIONS

Capacitor Equipment - an assembly of power capacitor units, complete with required accessories such as fuses, main disconnect switch, insulators, capacitors, reactors, vacuum switches, ground switch etc., all mounted on a common mounting frame, and designed to operate as a single unit. This may also be referred to as a “step”, “Bank”, or “assembly”.

4. REQUIREMENTS

Customer will provide short-circuit, load flow, and protective device coordination information, together with details of the electrical distribution system, and any other pertinent information required by the vendor.

The vendor will perform a post-installation harmonic analysis at the site to verify that harmonic resonance conditions were not created as a result of adding capacitors.

Capacitor banks supplied in accordance with this specification shall be new, containing no previously used or re-manufactured parts, and shall be designed and constructed in accordance with the requirements of all applicable manufacturing standards and code requirements.

Each capacitor assembly shall be supplied as a three-phase arrangement of capacitor units, including, but not limited to, current-limiting fuses, line reactors, interconnecting bus work, bus support insulators, grounding switch (optional), main fused disconnect switch, and associated control equipment.

The installation shall be capable of continuous operation in an ambient temperature range of -40 °C. to +46 °C, without exceeding the capabilities of any component.

The final installation shall conform to the requirements of the National Electric Code (NEC) as well as any local codes and ordinances applicable to the locality of installation.

5. ENCLOSURE CONSTRUCTION

5.1 The capacitor bank shall consist of a single compartmentalized enclosure with NEMA 1 indoor or NEMA 3R outdoor construction that will house all components, including fuses, capacitors, switches and associated controls. All components shall be accessible and removable from the front of the enclosure. Bolted panel construction, and switchgear cubicle style enclosures will not be allowed and will be rejected.

5.2 The enclosure shall be fabricated from 11-gauge cold rolled galvaneal or hot-rolled pickled and oiled ASTM A569 Type 1010 steel. All seams shall be welded and ground smooth to present an attractive appearance. The roof shall be cross-kinked or gabled to allow for watershed.

5.3 The doors shall be flush with the skin of the enclosure. Each door shall be equipped with stainless steel hinges and hinge pins, and 3-point latching handles. The handles shall be pad lockable. All doors providing access to high voltage compartments shall be equipped with door stays to hold doors in the open position.

5.4 The compartment containing the load-interrupter switch shall be equipped with a pad-lockable, or key interlocked, to guard against inadvertent entry to the terminals of the load-interrupter switch. Access to any portion of the load-interrupter switch shall be blocked by the protective screen while allowing access to the load-interrupter main fuses and capacitor compartments.

5.5 The base of the enclosure shall be equipped with C4x5.4 structural steel channel. Removable steel lifting plates consisting of 1/2" steel shall be located as required for proper lifting. Formed

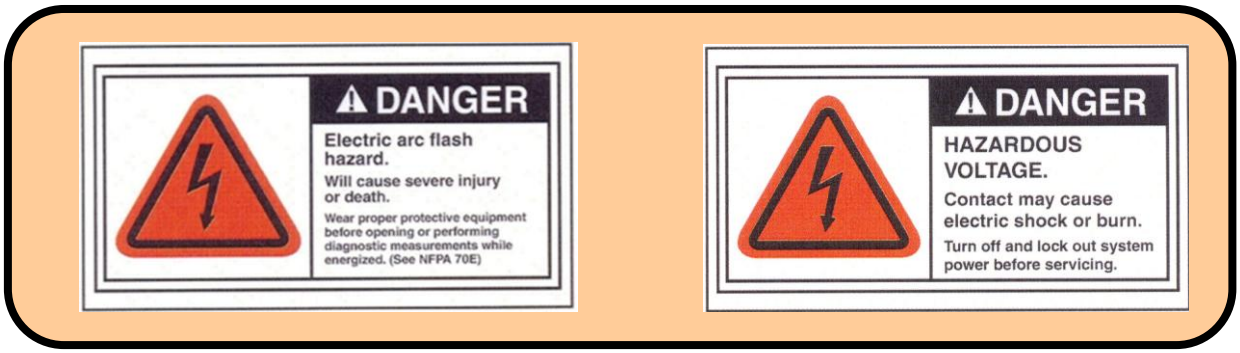
channel bases will not be accepted.

5.6 All ventilation louvers shall be located on the front of the enclosure and shall be backed with a permanently installed screen. The removable filters shall have washable, aluminum mesh elements that can be cleaned and services from the outside of the enclosure.

5.7 All fasteners and associated hardware, inside and out, shall be stainless steel. Externally accessible hardware shall not be used for support of high-voltage components or switch operating mechanisms within the capacitor bank.

5.8 Thermostatically Controlled Strip Heaters rated 500 watts @ 240 vac shall be supplied in all non-ventilated compartments. When determined by the manufacturer, a thermostatically controlled fan or ventilator shall be supplied. This fan shall be accessible from the exterior of the unit to allow for replacement without removing power from the bank.

5.9 Access doors of the enclosure shall be equipped with permanently attached warning signs that comply with ANSI Z535.4 Product Safety Label Access Doors: Access doors shall be hinged, with a neoprene rubber perimeter gasket, and three-point locking mechanisms.



5.10 The capacitor bank shall be name plated with a riveted anodized steel nameplate containing the following information:

- Project No.
- Customer Reference or PO No.
- Nominal System Voltage
- Maximum System Voltage
- Frequency
- KVAR Rating
- BIL [Basic Lightning Insulation Level]

5.11 The enclosure shall have a continuous 1/4" x2" Silver-plated Copper ground bus that spans the full width of the enclosure. Ground pads w/NEMA 2 hole pattern shall be provide at each end of the enclosure for customer connection.

5.12 The enclosure shall be prepared and painted with a high-solid epoxy coating as specified below. The paint shall, ANSI # 61 or 70 light Grey or other colors as specified by the customer are available.

Surface Preparation:
All steel surfaces shall be prepared per SSPC-SP2, 3, 6, 7, 10, 11 or the paint manufacturer's recommendations.

Inaccessible Surfaces:
Prepare and coat steel surfaces inaccessible to preparation and coating after fabrication with all coats before fabrication. Inaccessible surfaces shall be considered Zone 2A per SSPC specifications.

Primer Specification:
All surfaces, inside and out, shall be primed with a Zinc-Rich Epoxy (primer coat shall have a minimum 2 mil dry film thickness) paint. The primer shall have following minimum performance and properties:

- Salt Spray (ASTM B117) 3000 Hours with no face blistering
- Humidity (ASTM 02247) 750 Hours with no face corrosion or blistering
- Immersion (NACE TM-01-69) fresh water 1 year with no blistering
- Abrasion resistance (ASTM 04060) 1kg load/1000 cycles, CS-17 wheel: 102 mg weight loss.
- Impact resistance (ASTM D2794): Direct 24 in.lb and Reverse 6 in.lb.
- Moisture vapor transmission (ASTM F1249): 4.49 g/m^2.
- Adhesion (ASTM D4541): 900 PSI
- NFPA Class A Qualification

Top Coat Specification:
All surfaces, inside and out, shall be top coated with a High-Solid Epoxy paint with a dry film thickness of 2 to 4 mils. This will provide a total dry film thickness of 4 mils minimum and 8 mils maximum. The minimum acceptable measure total dry film thickness shall not be less than 4 mils.

The paint utilized on the top-coat shall have the following properties:

- Salt Spray (ASTM B 117) 5500 Hours with no face blistering
- Humidity (ASTM D2247) 5500 Hours with no face corrosion or blistering
- Gloss retention (ASTM G53) QUV-B bulb: Greater than 50% gloss retention at 26weeks.
- Elongation (ASTM D5222) 14%
- Abrasion resistance (ASTM D4060) 1 kg *load/1000* cycles, CS-17 wheel: 53 mg weight loss.
- Impact resistance (ASTM 02794): Direct 24 in.lb and Reverse 6 in.lb.
- Adhesion, elcometer (ASTM D4541): 2700 PSI • NFPA Class A Qualification

Paint shall also provide excellent chemical resistance to splash, spillage, fumes and weather for acidic, alkaline, salt solutions (acidic, neutral, and alkaline salt solutions), fresh water, solvents and petroleum product environments.

Upon request, the manufacturer shall provide supporting documents (surface preparation procedures as well as paint manufacturer's paint specifications) showing the above requirements are met. Failure to comply with this request will be cause for cancellation of order.

The following standard features should also be included:

5.13 Doors providing access to disconnect/interrupter switch shall be provided with a wide-view window constructed of an impact/UV-resistant material, to facilitate checking the switch position without opening the door.

5.14 The access cover to the Ground Switch shall be provided with a wide-view window constructed of an impact/UV-resistant material, to facilitate checking the switch position during maintenance or routine inspections.

5.15 Doors on the compartments that contain the power capacitor stages shall be provided with a wide-view window constructed of an impact/UV-resistant material, to allow inspection of the components in each stage without opening the door or de-energizing the unit.

The following optional features may be specified as required:

5.16 The main incoming fuse compartment shall be provided with a wide-view window constructed of an impact/UV-resistant material, to allow inspection of the fuses without opening the door or de-energizing the unit.

6. DISCONNECTING DEVICE

6.1 If required, the capacitor bank shall be supplied with a snap-action, load break interrupting, externally operated, air insulated main disconnect switch operated with a chain or direct drive handle.

6.2 The main disconnect switch shall have a minimum continuous current rating and minimum load break current rating of 135% of the power capacitor bank's nominal current rating and have a 40-kA RMS momentary asymmetrical rating.

6.3 The main disconnect switch shall be capable of being locked in the closed or open positions.

6.4 The main disconnect switch shall be key interlocked when vacuum switches are utilized to prevent opening the switch when the vacuum switches are closed.

6.5 The main disconnect switch must meet ANSI C37.20.4, C37.22 and C37.72 standards.

7. MAIN FUSES

7.1 The bank shall be equipped with main current-limiting fuses rated a minimum of 135% of the nominal current of the capacitor bank.

7.2 The main fuse shall be connected to the load side of the main disconnect switch.

7.3 The main fuse shall be accessible only when the main disconnect switch is open.

8. GROUNDING SWITCH

8.1 The capacitor bank shall be equipped with a main ground switch operated with a chain or direct drive handle. The ground switch must ground the load-side terminals of the air disconnect switch.

8.2 The ground switch shall be pad-lockable in either the open or closed position.

8.3 The ground switch shall be interlocked with the disconnect switch to prevent closing the ground switch when the disconnect switch is in the closed position.

8.4 The ground must be equipped with a limit switch which re-closes the vacuum switches on automatic banks to complete the grounding circuit when the ground switch is closed.

9. LIGHTNING/SURGE ARRESTERS

9.1 The capacitor bank shall be equipped with heavy duty distribution class surge arresters. The

maximum continuous operating voltage capability [MCOV] of the arresters shall be specified by the capacitor bank manufacturer.

9.2 The arresters shall be connected to the load side of the main disconnect switch.

9.3 The arresters shall only be accessible when the main disconnect switch is open and the ground switch has been properly closed and locked.

10. HARMONIC FILTER REACTORS

10.1 The filter bank shall be equipped with three phase iron core or single phase air-core series tuning reactors. They will be tuned as required for the application. In most application the reactors tune the capacitor bank below the 5th harmonic. The iron core reactors shall be completely impregnated with an epoxy resin that will reduce noise, promote heat dissipation, and provide protection in harsh environments.

10.2 The reactor core shall be rated so it will not saturate for currents less than 250% of the fundamental rating of the reactor. When expansion capability is necessary, the rating shall be sufficient for the maximum capacity of the stage.

10.3 The iron core reactors have he following features:

- Windings — 100% Copper Magnet Wire, rectangular to reduce eddy currents
- Insulation System — R220ºC
- Impregnation Process — Vacuum Pressure Impregnation
- Laminations — High-Grade Magnetic Steel
- BIL & Voltage — Per Applications requirements
- Current Rating — Per Design Requirements
- Taps — ± 2.5 % taps as required
- Gap Design — Distributed and cemented to reduce noise

11. STAGE VACUUM OR OIL SWITCHES

11.1 The capacitor bank stages shall be controlled by either [3] single phase motor/solenoid operated vacuum switches or [1] one three phase vacuum contactor that have been tested for capacitor switching. Capacitor switches (when utilized) shall be tested in accordance with ANSI Standard C37.66.

11.2 The vacuum switches/contactors shall be controlled by an **"ON /OFF/AUTO"** switch. In the **AUTO** position, the switches shall accept control from the selected controller. In the **"ON/OFF"** position, the vacuum switches will be forced **ON** or **OFF**, regardless of the controller output signal.

11.3 The capacitor stage control systems shall have an integral 5 minute time delay relay to prevent the switching of any stage more than one in 5 minutes. This control should be in addition to the time delay setting on the capacitor bank controller.

11.4 The bank switches shall incorporate an electrical operated key interlock system that coordinates the bank access doors, main disconnect switch and ground switch. The interlock system must include a limit switches that re-closes the vacuum switches once the ground switch is closed.

12. POWER CAPACITORS

12.1 The capacitor bank shall be equipped with all-film, low loss, double-bushing or single bushing

capacitors. The capacitors shall be designed, manufactured, and tested to meet and/or exceed all applicable NEMA and ANSI/IEEE standards. Capacitors must be manufactured by Cooper Power Systems, General Electric, or ABB.

12.2 Each capacitor shall contain an internal discharge resistor to reduce the stored voltage to 50 volts or less within 5 minutes from disconnection.

12.3 The capacitors shall be connected in ungrounded wye or a double ungrounded wye configuration. When the bank has more than one [1] capacitor unit connected in parallel per phase in a single ungrounded wye configuration the capacitor units shall be protected from sustained over-voltages due to capacitor unit failure and/or system ground faults by a neutral unbalanced voltage detection system.

12.4 The capacitors shall be located in a compartment that is separate from the main incoming fuses and the air disconnect switch.

12.5 Capacitors shall be mounted horizontally or vertically depending on the application and shall be mounted on structural steel channel. The capacitors shall be removable from the front of the enclosure.

13. CAPACITOR CURRENT LIMITING FUSES

13.1 Each capacitor shall be protected by a full range current limiting fuse with a pop-up type blown fuse indicator. Fuses shall be a direct connect bolt-tab or tab-tab design and shall be visible and accessible from the front of the Enclosure.

13.2 A neutral unbalance voltage detection system shall be provided to indicate a blown fuse and to protect the capacitors from sustained over-voltages due to capacitor unit failure and/or system ground faults. The neutral sensor shall be a precision resistive voltage divider, calibrated to better than 1 % accuracy. It shall be molded from POLYSIL, a high dielectric strength anti-tracking material. The relay shall have two (2) set points. The first set point shall alarm for a blown capacitor fuse that will not cause damage to the remaining capacitors. The second set point shall trip the bank off-line for voltages that will cause capacitor damage. The relay shall be equipped with a digital display that indicates the neutral voltage at all times. This relay shall be pre-set at the factory. Factory setting shall be included in the O & M Manuals.

13.3 External indication that a power capacitor unit fuse has operated shall be provided by an externally mounted **"RED"** strobe light.

14. POWER AND GROUND BUS

14.1 All phase and ground bus shall be Silver plated Copper for maximum conductivity and corrosion resistance. The copper shall be CA110 Square edge, hard temper per ASTM B187.

14.2 Bolted copper-to-copper connections shall be made with stainless-steel hardware with two stainless steel flat washers, one under the bolt head and one under the nut and with a stainless steel split lock washer between the flat washer and the nut. The bus shall not have a current density greater than 1200 amps/in^2. Where expansion capability is required, the bus shall be rated for the maximum capacity of the bank.

14.3 The bus shall be braced to withstand the forces that can be developed by the available short-circuit current at the point where the power capacitor bank is connected to the electrical system.

15. KEY INTERLOCK SYSTEM

15.1 The capacitor bank shall be equipped with a safety keyed interlock system to prevent

unauthorized and out of sequence entry into the capacitor bank.

15.2 The interlock scheme shall include the upstream protective device (where applicable), the capacitor banks disconnect switch, ground switch, and the enclosure access doors.

The interlock scheme shall function as follows:

1) Turn all capacitor stages **"OFF"** manually with the **"ON /OFF/AUTO"** switches.
2) Upon a waiting period of **5 minutes** (beyond the time that all stages have been turned off), key "A1" shall be released. An indicating light on the electrical interlock will illuminate indicating that key "A1" is available.
3) Use the "A1" key to unlock the disconnect switch. Open the Disconnect Switch and engage key "A2" locking the switch in the open position.
4) Remove the "A2" key from the Disconnect Switch Handle and proceed to the Ground Switch External Operating Handle. Insert key "A2" in the vacant lock and unlock the Ground Switch.
5) Close the ground switch. (Note: On automatic banks the vacuum switches will re-close completing the ground circuit when the ground switch is closed).
6) Remove the "A3" key from the Ground Switch Operating Handle.
7) Use the "A3" key to open access doors to the capacitor compartments and other medium voltage sections.

16. CONTROLS

16.1 All low voltage controls, where practical shall be isolated from the medium voltage compartments. All controls shall be accessible while the bank is energized. The control compartment shall form an integral part of the enclosure (no externally mounted control compartments shall be allowed). The control compartment shall allow for bottom or top entry of customer control wires without having to enter the medium voltage compartment. The controls compartment shall be equipped with a swing out panel to allow access to panel mounted controls.

16.2 All Control wires that connect to components inside the high voltage compartments shall be separated, isolated and supported within the capacitor bank enclosure.

16.3 The automatic capacitor bank shall be equipped with a power factor controller that will automatically switch **equal** or **unequal** capacitor bank stages in or out to regulate a facilities power factor to a preset value. The controller shall monitor individual stages for loss in kvar, and shall continue to regulate to a preset value in the event there is a defective stage. In addition,

The controller shall consist of the following features:

- Digital setting of individual parameters including target power factor, switching time, step limit, etc.
- Digital indication of preset power-factor, preset parameters, and specified installation data.
- Automatic Self-Adjustment to any capacitor step value.
- Plug-in Terminal Connection.
- Automatic elimination of defective capacitor steps and their indication (e.g. blown capacitor fuses, welded contacts, etc.).
- Visual Display of Harmonic Voltage & Current Alarms

The controller shall also have the following alarm features available for the customer:

- Low Power Factor
- Hunting
- Abnormal Cos Phi
- Low Voltage
- Overcapacitive
- Wrong Frequency

- Over Voltage & Current
- Over Temperature

16.4 The bank shall be provided with a maintenance interval timer that can be set to alert plant personnel of a maintenance requirement.

16.5 A counter that counts the number of times each stage has been energized shall be provided. The counters shall be equipped with set points that allow an indicator to be lit when the set point value is reached.

16.6 The complete control circuit shall be protected by main fuses or a circuit breaker.

16.7 Each stage shall be equipped with on/off/auto switches, stage on indicator (**GREEN**) and stage off indicator (**RED**). An interposing on-delay relay shall be provided to prevent the energization of a capacitor bank in less than 5 minutes. The manufacturer of the bank shall confirm that when going from the "Manual" position to the "Auto" position on any stage, that the corresponding stage will not be energized in less than 5-minutes.

16.8 The bank shall be equipped with a control power transformer that has both primary and secondary over-current protection. The control power transformer shall be connected between phases B and C.

16.9 A 15-amp GFI Convenience outlet shall be provided in the control compartment [as required].

16.10 The Medium Voltage Capacitor Bank Control System shall be listed under UL 508A for Industrial Control Panels.

16.11 UL class CC 600 volt current limiting fuses shall be provided to protect the control circuit.

17. ADDITIONAL OPTIONAL CONTROL EQUIPMENT

17.1 **Single Phase Over-Voltage Relay:** This relay shall protect the electrical system from over-voltages that may occur during light or low load conditions. The relay shall be equipped with two (2) set points to alarm and trip the capacitor bank.

17.2 **Three-Phase Multifunction Panel Meter:** This meter shall receive its voltage and current signals from three current transformers and two potential transformers located inside the capacitor bank. The meter shall be pre-programmed at the factory and shall have the following features:

- Voltage, per phase & average
- Current, per phase & average
- Real Power, per phase & total
- Apparent Power, per phase & total
- Power Factor, per phase and total
- Voltage & Current Unbalance
- Frequency
- Imported, exported, absolute and net kWH & KVARH
- Accumulated KVAH
- Sliding Window, Predicted, & Thermal Demand on KW, KVAR, KVA, & I average
- Minimums and Maximums are stored for Voltage, Current, kW, KVAR, KVA, Power Factor, Frequency, & Sliding Window Demand for kW and KVA
- Individual and Total Harmonic Distortion on Voltage & Current Inputs up to 15th harmonic
- The meter shall have 4 digital outputs that can be wired for relay control based on any of the measured values above.

18. QUALITY CONTROL SYSTEMS

18.1 Supplier must have a documented quality system established with a focus on prevention versus detection.

18.2 Quality system shall be designed and administered according to a recognized quality system standard, such as the ISO 9000 series or equivalent.

18.3 Supplier must provide a written quality policy with the Bid if required.

18.4 Quality records shall be available upon request of the customer and shall provide evidence that the quality system is in control.

18.5 The supplier quality system must meet all applicable industry standards, such as UL, NEMA, NEC, ANSI/IEEE, etc.

18.6 Supplier shall have on staff, experienced, licensed professional engineers (PE's) with degrees in Power Engineering (preferably with advanced degrees) as evidence of technical proficiency.

18.7 Supplier must provide a medium voltage metal enclosed customer list with contact information for the purpose of reference checks as required.

18.8 Supplier must allow factory audits to occur at mutually agreed upon dates between the customer an manufacturer.

19. SUBMITTALS

19.1 The manufacturer of the capacitor bank shall provide the following:

- Bill of Material Listing
- Component Data Sheets & Bulletins
- Power Circuit Schematics & Diagrams
- Control Circuit Schematics & Diagrams
- Interior and Exterior Layout Drawings
- MSDS for all appropriate components
- Outline Drawings
- Short Circuit Bracing as required
- Protective Relay Setting as required

20. BID REQUIREMENTS

20.1 The supplier of the capacitor bank shall state all exceptions taken to the specification. If now exceptions are taken the Bid must state that no exceptions are taken

20.2 The supplier should have an optional extended warranty and field services available. Rates and policies shall be provided with the bid.

20.3 Quotes are F.O.B. Factory with freight prepaid and charged.

21. MANUFACTURERS REQUIREMENTS

21.1 The supplier must offer a minimum warrant of twelve [12] months from the equipment startup date

or eighteen [18] months from the date of shipment.

21.2 The supplier should have an optional extended warranty and field services available. Rates and field service policies shall be provided with the bid.

21.3 Supplier must show that they are a regular supplier of medium voltage automatic metal enclosed capacitor banks. Product literature and a list of customers that have purchased similar products shall be supplied upon request.

21.4 The manufacturer shall provide a performance guarantee with respect to harmonic resonance and power factor. **Note: Customer to provide electrical consumption data and harmonic data.**