A. General

The automatic power factor correction capacitor bank shall be a self-contained, automatically and manually-controlled self-protecting capacitor bank. The capacitor equipment shall allow automatic or manual switching in KVAR increments required to meet the application.

B. Ratings

1. System Voltage: 3PH, 60Hz, 208V, 240V, 480V, or 600V
2. KVAR: As specified

C. Automatic Switched Capacitor Bank

The switched capacitor bank shall be three-phase, individual step fuse-protected, and contactor-controlled. Each capacitor shall include capacitor discharge resistors.

1. Incoming Power Connections

   a. The incoming power connection options shall include main lug only or, when specified, a circuit breaker sized no less than 135% of assembly KVAR rating at rated voltage.

   b. The circuit breaker interrupt rating shall be no less than the available fault current available at point of connection.

   c. The circuit breaker shall be provided with mechanical lugs or lug pads to accommodate customer incoming cable connections.

2. Fuses

   a. The capacitor bank shall be individually fused on the line side of the contactor with Class J or Class T fuses having an interrupting capacity of 200,000 symmetrical amperes. Fuses shall be rated to protect the contactor, capacitor, and interconnecting wiring.

   b. When specified, each capacitor bank fuse shall be provided with a blown fuse indicator consisting of an indicating lamp which shall be illuminated when a capacitor bank fuse has blown. The indicating lamp shall be visible from the front of the enclosure when the door is closed.

   c. A nameplate identifying the associated capacitor bank fuse shall also be included with each lamp.

3. Contactors

   a. Contactors shall be three-pole, 600-volt type provided with silver-coated contacts and rated for capacitor duty to withstand the in-rush currents imposed by dynamic capacitor switching.

4. Reactors

   a. Reactors shall be designed to create a tuning point at the 3.78^{th} when placed in series with each capacitor stage.

   b. Reactors shall be iron core construction in either single-phase or three-phase configurations as best suited for the application. Reactor construction shall be in accordance with UL-508, IEC 76 and IEC 289.

c. Reactors may be constructed with either aluminum or copper windings and shall have solid copper terminals.

d. Reactors shall utilize a 180 degree C (Class H) insulation system and operate at a maximum temperature rise of 115 degrees C, in a 50 degree C ambient.

e. Fringing flux losses and extraneous magnetic fields shall be minimized by utilizing PolyGap™ construction to maximize the number of air gaps and minimize the length of any individual air gap.

f. Reactors shall be vacuum and pressure impregnated using either epoxy or varnish.

g. Reactors shall be electrically and thermally tested in accordance with the magnitudes of fundamental and harmonic frequency currents for which they were designed.

h. The supplier shall furnish a test report of the actual reactor performance under specified harmonic currents when requested. The test report shall illustrate the temperature rise, watts loss and inductance when specified fundamental and harmonic currents are simultaneously applied to the reactor.

i. Inductance tolerance of each reactor phase (coil) shall be -2% to +3% of the nominal inductance rating.

j. Reactors shall be Hi-Pot tested between each coil to ground and coil to coil at 3kV for one minute.

5. Capacitors

a. Capacitors shall be dry-type of the self-healing type utilizing a UL-recognized pressure sensitive interrupter that disconnects all three phases in each capacitor cell. The pressure interrupter must break all three phase when it engages.

b. Capacitors shall be constructed with self-healing metalized polypropylene film and shall be designed with segmented film for maximum safety and protection against over voltage transients.

c. Losses shall be a no more than 0.5 watts per KVAR including losses associated with the discharge resistor.

d. Capacitors shall be able to carry continuous current of at least 1.5 times the nominal current corresponding to its KVAR rating, at full ambient temperature and altitude without the need to de-rate the capacitor cells voltage rating.

e. Capacitance tolerance shall be +/-5%.

f. Capacitors shall have a rated life expectancy of 20 years continuous operation at its full rated specification.

g. Capacitor cells shall be delta connected.

h. Capacitors shall include an integral discharge resistor to reduce the residual voltage to 50V or less within sixty seconds after the capacitor is disconnected from the power source.

i. Capacitors shall not have any PCB's.

j. Capacitors shall be suitable for continuous operation in ambient temperature from -40^{o}C (-40^{o}F) to +60^{o}C (140^{o}F) without de-rating.

k. Capacitors shall be suitable for use at altitudes up to 4000 meters (13,124 ft) without de-rating.

l. Capacitors shall be suitable for use in non-condensing 95% relative humidity.

m. The dielectric strength of the capacitor cells shall be tested at the factory as follows:

1) Terminal-Terminal: 2.15 x V_{rated} for 2 seconds followed by 1.85 x V_{rated} for 18 seconds.

2) Terminal-Case: 3.9kV for 2 seconds

n. Capacitor cells shall be UL recognized per UL 810 and CSA approved per CSA C22.2, No 190-1985 and C22.2 No 14-10.

o. Capacitors cells shall be UL listed

6. Power Factor Controller

The power factor controller shall by a full featured controller utilizing a color touch screen to program, display, and monitor critical capacitor bank parameters and system data.

The power factor controller shall have the following characteristics:

a. Automatic or manual commissioning

The controller shall be capable of providing a fully automatic commissioning setup to minimize errors and to provide efficient startup assistance.

b. Power and Harmonic Measurements

1) Power

a) KW, KVAR, KVA, Voltage, Current, Power Factor and Night Power Factor

b) All measurements shall be averaged over a one second period

2) Harmonics

a) Total harmonic distortion on voltage and current

b) Individual voltage and current harmonics from the 2^{nd} through the 49^{th} harmonic

c) Individual voltage and current harmonics shall be able to be displayed in a table format or a bar graph

c. Protection

The power factor controller shall be fully programmable to set the following protections:

1) Minimum voltage level, maximum voltage level, maximum current level, maximum voltage distortion level.

2) Temperature protection when optional temperature probes are used

3) One external input is allowed to disconnect the capacitor bank based on a desired external protection scheme.

4) Warning signal for minimum voltage level, maximum voltage level, maximum current level, maximum voltage distortion level.

d. Diagnosis

The following bank monitoring features shall be available from the power factor controller:

1) Diagnosis

a) Lists the total number of operations of each capacitor output relay since the power factor controller has been manufactured

2) Test Function

a) Allows testing of the alarm relay, fan relay and each capacitor output relay

3) Alarm Logging

a) Lists the last five alarm messages with a real time stamp

4) Real Time Clock

a) A real time clock shall be included in the power factor controller including the date and time

b) The real time clock shall be backed up by a battery in case of power loss

e. Event Logging

The power factor controller shall be able to log the amount of time a measured value has exceeded a minimum and maximum threshold.

The following parameters may be set with a minimum and maximum threshold for the event log feature:

a) Voltage, Current, and Frequency

b) KW, KVAR, KVA

c) Missing Reactive Power

d) Voltage and Current Total Harmonic Distortion

e) Temperature

f. Communications

The power factor controller shall be able to communicate via MODBUS RS485 with an optional communication adapter.

g. Technical Data

1) The controller shall be capable of operating in a temperature range from -10^{o}C to 70^{o}C

2) All programmable parameters shall be saved in non-volatile memory

3) The controller shall be insensitive to harmonics during its operation

4) The controller shall be capable of accepting either a 1A or 5A input from the current transformer

5) The power factor controller output relays shall be rated 5A maximum

7. Incoming Power Connections

The incoming power connection options shall include main lug only or optionally a circuit breaker protection sized no less than 135% of assembly KVAR rating at rated voltage.

D. Busing

Provide sufficient cross sectional area to continuously carry full load current without abnormal temperature rise. Bus shall be rated a minimum of 1000A per square inch unless specific UL tests have been performed to ensure the heat rise at connections points are acceptable.

E. Enclosures

Enclosures shall be fabricated and listed to UL50 for UL types 1, 12, 3R, 4, or 4X.

1. The enclosing covers and door(s) shall be fabricated from not less than 14 gauge steel.

2. The enclosure shall be wall mounted and/or free-standing depending on KVAR rating.

3. Fans, ventilation, and/or thermostats shall be provided as required.

4. Enclosure shall be equipped with grounding lugs and removable lifting eyes (when necessary) to facilitate handling.

F. Test Requirements

The power factor assembly shall be assembled, wired and functionally tested at the factory in accordance with applicable standards.

Factory production tests and/or verification shall include the following:

1. Visual inspection
2. Torque mark verification
3. Controller operation
4. Capacitance check
5. Hi-pot test

G. Manufacturer

Equipment shall be NUCO Controls, LLC or approved equal