Guide Form Specification for Medium Voltage
Thyristor Switched & Conventionally Switched Harmonic Filter Bank

(Hybrid Design - For Voltage Sag, Voltage Flicker, Power Factor, and Attenuation of Harmonic Distortion)

Brown text is related to arc flash hazard mitigation features that strive to either minimize the level and exposure to an arc flash event or reduce the probability that an arc flash event will occur. Consult NEPSI's technical note for more information about arc flash hazard mitigation at www.nepsi.com.

1 General

This specification is for a medium voltage three phase metal-enclosed thyristor switched and conventionally switched harmonic filter bank. This equipment is designed to provide "fast" vars, using thyristor valves to mitigate voltage flicker and voltage sags, and "slow" vars using conventional capacitor switches to economically correct power factor and attenuate harmonic distortion attenuation.

The thyristor switch filter bank(s) shall consists of __________ steps of __________ kvar tuned to the ________ Harmonic. The thyristor switch harmonic filter bank is designed to mitigate voltage sags, associated with large reactive power disturbances. These disturbances may be caused by high-power rapid impact loads, operation, connection, and disconnection of large motors, and remote power system faults.

The conventionally switched harmonic filter bank shall consists (*single tuned, multi-tuned, high-pass tuned*) automatic harmonic filter stages consisting of __________ steps of __________ kvar at _________ kv tuned to the _________ Harmonic(s).

Note: The kvar specified in the preceding paragraphs is the <u>output</u> kvar of the filter step(s) at the specified voltage and not the <u>installed</u> kvar.

The thyristor switched and conventionally switched harmonic filter bank shall be housed in a single compartmentalized enclosure. All controls, disconnecting devices, thyristor valves, capacitor switches, capacitors, iron-core filter reactors, and protection features shall be included. The equipment 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".

1.1 The equipment shall be designed to not amplify existing harmonic levels and shall, limit current and voltage distortion to IEEE 519 limits or another quantified level. Unless otherwise specified, the point of common coupling is considered to be located at the metering point.

1.2 The Vendor shall have in-house engineers and harmonic analysis software that utilizes complex modeling techniques to predict the thyristor switched filter bank performance. The expected equipment performance shall be provided with the approval drawings and should account for varying system impedances, nearby filter banks and capacitor banks, as well as normal and abnormal system conditions. This work shall not be contracted to a third party. Acceptable harmonic analysis software packages include:

- Easy Power
- HarmFlo

- Vharm
- PSS/U
- MicroCAP

A digital copy of the analysis shall be provided upon request.

1.3 The thyristor switched bank shall meet specific voltage sag/flicker levels during operation. Vendor shall analyze the power system and target load to verify that the thyristor switched steps and total thyristor switched filter bank capacity shall meet or better the intended sag /flicker levels. The sag/flicker levels should account for varying system impedances, as well as normal and abnormal system conditions. Vendor should perform this analysis based upon:

- Fault Current [at Point of Common Coupling]
- Power System X/R [at Point of Common Coupling]
- A single-line showing PCC, all transformers, breakers, thyristor switched and conventionally switched filter bank bus, facility capacitor banks, and details of all loads for which the thyristor switched filter bank is to correct.
- A detailed listing of transformer and motor nameplate characteristics.
- IEEE-1453 shall be used as the target sag/flicker levels unless otherwise specified.

The conventionally switched harmonic filter bank shall be designed to reduce system voltage and current distortion levels at the PCC (point-of-common-coupling) to within IEEE 519 limits. The conventially switched stages shall respond to power factor and shall regulator to the power factor to 1.0 *(specify power factor lead/lag if not 1.0)* at the PCC.

A digital copy of the analysis shall be provided upon request.

1.4 The ratings of this equipment and associated switchgear, switching devices, capacitors, reactors, fuses, and all other applicable components shall have ratings designed for application on the following system:

Nominal System Voltage, (Kv)……………….…. _______________
Maximum System Voltage, (Kv)…………….….. _______________
System BIL, (Kv)……...……………………………. _______________
Three Phase Short Circuit Rating
(RMS Symmetrical Amps)…………_______________
Line-Ground Short Circuit Rating
(RMS Symmetrical Amps)…………_______________

(Optional – Arc Flash Hazard Mitigation) For Arc Flash Hazard Mitigation – Consider increasing equipment BIL by one level. A higher BIL will provide more strike distance and creep distance at a fraction of the cost and will result in equipment that is less likely to flash over or fail.

1.5 Ambient Air Temperature for design shall be as follows:

Average annual temperature……………..…….Min______/Max______ (degrees C)
Average Daily variation ………………………….… _______________ (degrees C)
Design temperature ………………………Min. _____/Max_______ (degrees C)

1.6 Relative Humidity for design shall be as follows:

Monthly Average Relative Humidity ……………….…….Min.______/Max______ (%)
DesignRelative Humidy …………………..………………Min. _____/Max_______ (%)

1.7 Solar radiation for design purposes shall be as follows:

Average annual solar radiation ……………………………….……… ______ (kW/m^2)

1.8 Precipitation for design shall be as follows:

Average annual precipitation …………………………………………….______ (mm)

1.9 Snow Load for design shall be as follows:

Maximum design snow load ………………………………………..…….______ (kG/m^2)

1.10 Wind for design shall be as follows:

Basic wind speed (V) ………………………………………….……………______ (km/h)
…………………………………………………corresponding to a 3 second gust speed
…………………………………………….……….. Standard height of 10m above ground

Prevailing winds ……………………………………… ____________ (N, S, E, W, etc)

1.11 Seismology for design shall be as follows:

All building, structures, and components shall be designed for earthquake forces according to the ____________________. Note the following data as it pertains to this location:

2 Compliance with Standard & Codes

The metal enclosed thyristor switched harmonic filter bank shall conform to or exceed the applicable requirements of the following standards and codes:

- UL-347, High Voltage Industrial Control Equipment
- UL-508, Industrial Control Panels, Issue Number: 2, October 1993
- UL-50, Standard for enclosures for Electrical Equipment
- ANSI Z535.4 Product Safety Label Standard July 1, 2002.
- Applicable portions of Article 710 in the National Electrical Code
- Article 460 of the National Electrical Code
- ANSI C37.20.2 – Guide for Enclosure Categories and Related Requirements
- IEEE C37.20.7-2007 Guide for Testing Metal-Enclosed Switchgear Rated Up to 38kV for Internal Arcs
- IEEE Std. 1036-1992, IEEE Guide for Application of Shunt Power Capacitors
- IEC61954, Static var compensators (SVC) – Testing of thyristor valves
- CP-1 NEMA Standard on Shunt Capacitors
- UL – 519
- REA Standards
- NESC Standards
- IEEE Std. 519-1992 IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems

- IEEE Std. 1453-2004 IEEE Recommended Practice for Measurement and Limits of Voltage Fluctuations and Associated Light Flicker on AC Power Systems

Specify if any of the following performance standards are being utilized for voltage sags or voltage flicker:

- SEMI (Semiconductor Equipment and Materials International), F47-0706, F49-0200, and F50-0200s
- CBEMA (Computer and Business Electronic Manufacturers Association), curve referenced in ANSI/IEEE Std. 446-1987
- ITIC (Information Technology Industries Council) tolerance curve
- IEEE Standard 1346-1998, Recommended Practice for Evaluating Electric Power Systems Compatibility with Electronic Process Equipment
- IEEE 1250-1995, Guide for Service to Equipment Sensitive to Momentary Voltage Disturbances.
- IEC 61000-4-11 and 61000-4-34, (International Electrotechnical Commission)
- IEEE Std. 1453-2004, Table A.1

3 Product Listing

3.1 The control panel shall be UL508A Certified for both Canadian and US products.

3.2 The equipment shall be "listed" per OSHA (in the USA) and the Standards Council of Canada (in Canada) to the following standards.

- For products shipping to the United States, IEEE C37.20.3-2001
- For products shipping to Canada, C22.2 No. 190-M1985+GI1 + GI2 (R2004)

A copy of the NRTL Certificate showing compliance with the above shall be included with the bid.

4 Enclosure Construction

4.1 The manufacturer of the enclosure shall also be the assembler of the thyristor & conventionally switched harmonic filter bank. This is to ensure the highest degree of control with respect to critical enclosure manufacturing processes such as cleaning and surface preparation, welding, priming, and painting. Verification of enclosure manufacturing by supplier (on-site visit, photos, raw material invoices) may be required. No exceptions allowed

4.2 The enclosure shall flush door design with NEMA 3R construction that will house all components, including fuses, capacitors, valves, reactors, switches and associated controls. All components shall be accessible and removable from the front or side of the enclosure. Bolted panel construction, transclosure style, and switchgear cubicle style enclosures will not be allowed and will be rejected. For Arc Flash Hazard Mitigation it is recommended that the equipment be placed outside in switchgear yard. Arc blast dissipates at a rate which approximates the inverse-square rule for distance. Keeping workers away from the equipment is an easy way to ensure worker safety. Save on E-house/switchgear room space, put this equipment outdoors.

4.3 The enclosure shall be fabricated from 11-gauge cold rolled A60 galvaneal steel. All seams shall be welded and ground smooth to present an attractive appearance. The roof shall be cross-kinked, half gabled, or full-gabled to allow for watershed.

4.4 The enclosure shall be prepared and painted with a high-solid epoxy coating as specified below. The inside shall be white while the outside shall be (ANSI gray 61 – Munsell No. 8.3G 6.10/0.54, ANSI Gray 70 – Munsell No. 5BG 7.0/0.4 or Green - Munsell No. 7Gy 3.29/1.5).

Surface Preparation:
All steel surfaces shall be prepared per SSPC-SP2, 3, 6, 7, 10, 11 or the paint manufacturer's recommendations. Exceptions to the manufacturer's requirements shall be approved by the paint manufacturer and provided with the submittal documents.

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.

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 3 mils.

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

- Salt Spray (ASTM B117) 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 26 weeks.
- Elongation (ASTM D5222) 14%
- Abrasion resistance (ASTM D4060) 1kg load/1000 cycles, CS-17 wheel: 53 mg weight loss.
- Impact resistance (ASTM D2794): 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.

4.5 The enclosure shall have a continuous 1/4" x 2" Tin-Plated Ground Bus that spans the full width of the enclosure.

4.6 The doors shall be of a flush design (no over hanging door sills) equipped with heavy-duty stainless steel hinges and 3-point latching handles. The handles shall be pad lockable. The Doors shall be removable in the open position.

4.7 All doors providing access to high voltage compartments shall be equipped with door stays to hold doors in the open position. All doors shall be equipped with a drip shield.

4.8 In addition to the enclosure door, the compartment containing the incoming load-interrupter switch shall be equipped with an internal hinged protective screen/barrier that is either bolted shut or pad-lockable 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.

4.9 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 at each corner. Formed channel bases will not be accepted.

4.10 All ventilation louvers shall be located on the front, (you may also specify back or sides) of the enclosure and shall be equipped with 2" (5.08 cm) 20x20x2 MERV 5 Fiberglass filters. Filters shall be removable while bank is energized. Live parts shall not be accessible while filters are removed.

4.11 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 filter bank.

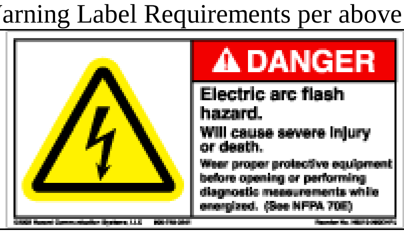
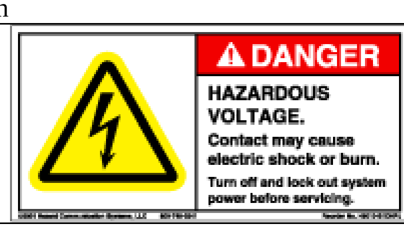
4.12 Thermostatically controlled fan(s) shall be provided to cool the thyristor switched harmonic filter bank. (*As an option, the specifying engineer can request the fan be removable without having to enter the medium voltage compartment*).

4.13 Thermostatically Controlled Strip Heaters shall be supplied in all non-ventilated compartments and the control compartment.

4.14 The equipment shall be name plated with a riveted anodized steel nameplate containing the following information:

- Equipment Type: Thyristor & Conventionally Switched Harmonic Filter Bank
- Nominal System Voltage
- Maximum System Voltage
- Number of Steps, Stages, and Switching Sequence for Thyristor Switched Harmonic Filter Bank
- Number of Steps, Stages, and Switching Sequence for Conventionally Switched Harmonic Filter Bank
- BIL
- Hazardous Flash Boundary, PPE requirements, and incident energy at 18" in cal/cm^2

4.15 Each door of the enclosure shall be equipped with self-adhesive vinyl warning signs that comply with ANSI Z535.4 Product Safety label Standard dated July 1, 2002.

<table>
<tr><th colspan="2">Warning Label Requirements per above section</th></tr>
<tr><td>
</td><td>
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Electric arc flash hazard. Will cause severe injury or death. Wear proper protective equipment before opening or performing diagnostic measurements while energized. (See NFPA 70E)	*HAZARDOUS VOLTAGE. Contact may cause electric shock or burn. Turn off and lock out system power before servicing.*

4.16 The compartment containing the incoming air disconnect switch and ground switch (if supplied) shall be equipped with an internal hinged protective barrier door to guard against inadvertent entry to the terminals of the load-interrupter switch. Access to any portion of the air disconnect switch shall be blocked by the protective door while allowing access to the air disconnect switch and main fuses (if supplied) and capacitor compartments.

4.17 (Optional – Arc Flash Hazard Mitigation) The internal hinged protective barrier door shall be key interlocked with the upstream feeder breaker.

4.18 The main incoming fuse compartment *(if provided)* shall be equipped with a wide-view window constructed of an impact-UV-resistant material, to facilitate checking of the main fuses without opening the door or de-energizing the bank.

4.19 The capacitor/reactor/valve/switch compartment shall be equipped with a wide-view gasketed window constructed of an impact-UV-resistant material, to facilitate checking of capacitors and capacitor fuses without opening the door or de-energizing the bank.

4.20 (Optional – Arc Flash Hazard Mitigation) Infrared Sightglasses shall be provided for viewing internal components of all medium voltage compartments of the metal-enclosed power capacitor bank. At least one sightglass shall be provided for every 3 linear feet (1 meter) of enclosure length. Sightglasses shall be arc-flash tested to a maximum of 40kA in accordance with IEEE and IEC standards, and shall be NEMA Type 3/12 (IP65) rated.

4.21 (Optional – Arc Flash Hazard Mitigation) Ultrasound Inspection Ports shall be provided on each door for consistent and quality acoustic data identifying potentially hazardous faults such as arcing, tracking, and corona before the occur.

4.22 (Optional – Arc Flash Hazard Mitigation) The enclosure shall be of an arc resistant design and shall include integral (specify <u>back</u> or <u>top</u> – NEPSI recommends back for outdoor gear with a fenced off protective zone and top for indoor gear) pressure release flaps to facilitate a controlled release of arc created overpressures, smoke, and gasses. (For indoor applications, an enclosed arc-chamber with arc duct exit shall be provided. Field assembly of the arc chamber and arc-duct shall be by the installation contractor. Where venting is intended to penetrate an external wall, the vent shall be covered such that it meets all specified environmental requirements (e.g., rain-tight, dust-tight, vermin-proof)). Arc exhaust location shall be shown on equipment drawings.

Arc Resistant Construction Types (specify one):

- Type 1 – gives the equipment arc resistant protection on the front only.
- Type 2 – gives the equipment arc resistant protection on the front, rear, and sides of the gear.

- Type 1D-SR-SL – gives the equipment arc resistance protection on the front, right side, and left side.

5 Capacitors

5.1 The thyristor & conventionally switched harmonic filter bank shall be equipped with all-film, low loss, harmonic rated double-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 in North America and shall be manufactured by Cooper, GE, or ABB.

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

5.3 For the thyristor controlled filter bank stages, the capacitors shall be connected in *(specify delta for system voltages from 2.4kV through 6.9kV, specify delta or wye-grounded for system voltages greater than 6.9kV to 13.8 kV, specify wye-grounded for systems greater than 13.8kV to 23 kV) a* Delta configuration in series with the iron-core filter reactor, valve, and capacitor fuse. The capacitors shall be protected from sustained over voltages due to capacitor unit failure by a blown fuse detection system.

5.4 For the conventionally switched filter bank stages, the capacitors shall be connected in ungrounded wye configuration and shall be protected from sustained over voltages due to capacitor unit failure by a blown fuse detection system. In cases where the bank can be de-tuned, or in multi-tuned filter banks, the stage and all other appropriate stages should be taken off line.

5.5 The capacitor's voltage ratings shall be increased for harmonic filter duty with the following considerations (data to support choice of capacitor voltage rating and kvar output of each step <u>shall be provided with Bid</u>):

- Harmonic current peaks having 100% coincidence
- Nominal system over-voltage of 5%
- Ambient voltage distortion equal to the limits set forth by IEEE 519 (at the PCC) or values obtained during measurement
- Adherence to IEEE/ANSI peak (crest) and RMS voltage ratings.

5.6 The capacitors shall be located in a compartment that is separate from the main incoming fuses (if provided) and incoming air-disconnect switch compartments (if provided).

5.7 Capacitors shall be mounted on C4x5.4 structural steel channel. The capacitors shall be removable from the front of the enclosure.

5.8 (Optional – Arc Flash Hazard Mitigation) Consider using capacitors that have an extra 10% voltage margin on them for increased reliability. Don't forget, kvar output varies by the voltage squared and that more kvar will be required.

6 Capacitor Protection

6.1 Each capacitor shall be protected by a current limiting fuse that is equipped with a blown fuse indicator. Fuses shall be clip mounted to allow for easy change-out and shall be visible and accessible from the front of the enclosure.

6.2 Each capacitor stage shall be equipped with a blown fuse protection system. The protection system shall utilize direct fuse sensing, and in addition to detecting a blown fuse, shall also protect the fuse from over-load using a built-in thermal element. Both a blown fuse condition, and an overloaded fuse condition, should result in the control system taking the stage off-line.

6.3 External Indication of a blown fuse shall be provided by an externally mounted Roof Top NEMA 4X Strobe Light. The Strobe light shall flash at a rate of 80 per minute and shall have a peak candlepower of 175,000 *(optional – this option is not always wanted, depending on application and location).*

7 Iron-Core Filter Reactors

7.1 The thyristor & conventionally switched harmonic filter bank shall be equipped with single-phase iron-core dry-type reactors. They shall have *Copper/Aluminum (NEPSI recommends vendor have the choice)* windings and a 220°C insulation system with a 115°C temperature rise over a 40°C ambient.

7.2 The reactors shall be Vacuum Pressure Impregnated (VPI) with EPIC TC-0118 Epoxy. The iron laminations shall be a hi-grade magnetic steel. To reduce gap magnetic losses and extraneous magnetic fields, a distributed gap design shall be utilized.

7.3 All gaps shall be cemented to reduce noise levels.

7.4 The iron-core reactor current ratings and design shall be based on the following considerations:

- The reactor core will not saturate for currents less than 250% of the fundamental current rating of the filter bank or filter bank stage.
- Peak flux density of the core shall be less than 1.2 – 1.4 Tesla assuming all harmonic current peaks are 100% coincident (Core design shall not be based on RMS current rating of reactor).
- Reactor currents are based on computer simulations. Results of such simulations shall be provided with the approval drawings. Where the necessary data for doing the simulations are not been provided, the following minimum current spectrum in amps should be utilized.
    - I_1 = 1.21 x Fundamental Current Rating of the thyristor switched stage at nominal system voltage.
    - $I_{Tuned\ Frequency}$ = 0.5 x Fundamental Current Rating of the stage (for multi-stage banks) or Bank at the Nominal System Voltage.

If proper data has not been provided to do the simulations, the vendor shall submit their bid utilizing the above minimal current ratings. The vendor will be required to submit a data request upon issue of an order so that computer simulations can be conducted to check for proper reactor ratings. Results of harmonic simulations shall be provided with the approval drawings.

(Optional – Arc Flash Hazard Mitigation) – Over-rating iron-core reactors beyond calculated current ratings is a good way to improve reliability of the harmonic filter bank and reduce the probability of failure and possible arc flash event.

8 Iron-Core Filter Reactor Protection

8.1 A three-phase digital overload relay shall be provided to protect the iron-core filter reactors from harmonic current overload. The overload protection shall account for the increased heating effects of higher order harmonic currents. The relays shall be field adjustable. The relays shall have the following minimum protection features:

- Thermal Overload (over current greater than time dial and current pickup setting)
- Under Current (filter drew less than undercurrent setting for 3 seconds)
- Phase Failure (one or more phases lost for 3 seconds)
- Phase Unbalance (one or more phases unbalanced by 50% for 5 seconds)
- Long-Time Over-Current (the filter drew short-time high current for 5 seconds)
- Short-Time Over-Current (the filter drew short-time high current for 0.5 seconds)
- The relay shall display actual current for each phase during operation and shall provide a latch indicator as to the cause of the overload trip.

8.2 An overload temperature relay shall be provided as backup protection for the Iron-Core Reactors and also to protect against fan failure.

8.3 The overload temperature relay and overload relay shall communicate with the HMI as well as with the facilities DCS system. On overload, the stage with the overload shall be shut down.

9 Thyristor Valves

9.1 Each stage of the thyristor controlled filter bank shall be equipped with single phase thyristor valves that are (specify continuously or transiently) rated for the application. For transient operation, the valve shall be able to operate for ______ minutes every ______ minutes with no more than _______ operations per hour in 60 °C ambient.

9.2 The thyristor valves shall have minimum N+1 device redundancy; redundant firing circuits and both hardware and software misfire prevention protection.

9.3 The thyristor valve shall utilize Non-PCB Mineral oil or natural ester fluid for insulation and cooling. A pressure relief valve shall be included as a means to relieve pressure in excess of pressure resulting from normal operation.

9.4 The valve tank shall consist of 16 gauge stainless steel. The tank cover shall consist of 0.25" stainless steel with threaded bolt holes. The tank shall have an internal mark, which indicates the proper oil level.

9.5 Cooling fins and transformer cooling fans shall be provided as necessary for valve cooling.

9.6 The valves shall utilize two high-voltage porcelain bushings with proper chosen BIL and creepage distance for the system voltage and elevation. The valve shall have provisions for ground lug or ground connection.

9.7 The thyristor valves shall be controlled by a controller as described later in this specification. Control wiring to the valve shall be made by means of an oil tight threaded military connector..

10 Vacuum Switches

10.1 Each stage of the conventionally switched filter bank shall be equipped with single phase vacuum switches or contactors that have been tested for capacitor switching. When capacitor switches are utilized, the test results showing compliance to ANSI Standard C37.66 shall be made available.

10.2 The vacuum switches shall be controlled by an on/off/auto type controls. When in the auto position, the switches shall accept control from the controller. When in the on/off position, the vacuum switches will be forced on or off, regardless of the controller request.

10.3 The control system shall prevent the vacuum switches from operating more than once in a 5-minute period.

10.4 The vacuum switches shall be interlocked with the bank's air-disconnect switch and ground switch.

11 Load Interrupter - Air Disconnect Switch (optional)

The equipment shall be supplied with an external chain operated load interrupting switch that accomplishes capacitive current interruption utilizing the dual arc extinguishing system based on the auto-pneumatic air-blast and hard gas nozzle principle. The switch shall be rated at 135% of the banks nominal current rating and shall have a 40-kA RMS momentary asymmetrical rating. This switch shall be interlocked with the vacuum switches to prevent it from being opened while the filter stage(s) are energized. The switch shall be pad-lockable in either the open or closed position.

As an option, an air disconnect switch can be provided to isolate the thyristor switched portion of the equipment as well as one for the conventionally switched portion of the equipment. Specifying the equipment in this way would require only a partial shut-down of the equipment during maintenance and repair. Another option would be to include an air disconnect switch for each stage of the conventionally switched and thyristor switched filter stages.

11.1 The Air Disconnect Switch shall be located in a separate compartment that is isolated from the capacitor/reactor/valve compartment and the low voltage control compartment by a steel barrier. In addition to the exterior enclosure door, a protective door (behind the exterior door) shall be provided before access to the switch is allowed.

11.2 (Optional – Arc Flash Hazard Mitigation) The air disconnect switch shall be equipped with a motor operator for remote electrical opening and closing.

11.3 (Optional – Arc Flash Hazard Mitigation) The air disconnect switch terminals shall be equipped with medium voltage indicators that flash when voltage is present.

12 Ground Switch (optional)

12.1 An externally operated ground switch shall be provided to ground the load-side terminals of the air disconnect switch. The ground switch shall be pad-lockable in either the open or closed position. The ground switch must be tested in accordance with ANSI/IEEE standards. Test reports shall be furnished upon request.

12.2 The ground switch shall be interlocked with the incoming air disconnect switch to prevent closing of the ground switch when the incoming air disconnect switch is in the closed position.

13 Main Incoming Fuses (optional)

13.1 The equipment bank shall be equipped with main incoming current limiting fuses. The fuses shall be located on the load side of the main incoming air-disconnect switch and ground switch. The fuses shall be accessible only when the equipment is de-energized by the main incoming air disconnect switch and shall be completely isolated from any live parts.

14 Main Incoming Fixed-Mounted Circuit Breaker *(Alternate to Main*

Incoming Fuses)

14.1 The equipment shall be equipped with an incoming ____kV fixed mounted circuit breaker for the purpose of short circuit protection of the entire thyristor & conventionally switched harmonic filter system.

14.2 The incoming breaker shall be equipped with an appropriate 3-phase over-current relay, lockout relay, and breaker control switch. The breaker shall be form an integral part of the filter system key interlock system, protection system, and control system.

14.3 The breaker compartment shall also consist of 2 line-to-line connected CPT's for the purpose of voltage sensing and local control power. CPT's shall be 3kVA rated and shall be equipped with primary weak-line fuses and a secondary breaker.

15 Lightning/Surge Arresters

15.1 The equipment shall be equipped with heavy duty distribution class lightning arresters. The rating of the lightning arrester shall be recommended by the equipment manufacturer.

16 Phase and Ground Bus

16.1 All phase and ground bus shall be tin-plated for maximum conductivity and corrosion resistance. Bolted but-to-bus connections shall be made with 3/8" – 13 stainless-steel bolts with two stainless steel flat washers, one under the bolt head and one under the nut and with a stainless steel split lockwasher 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.

16.2 The bus supports, bus, and interconnections shall withstand the stress associated with the available short-circuit current at the filter bank.

16.3 (Optional – Arc Flash Hazard Mitigation) All main phase bus shall be insulated with heavy wall anti-track heat shrinkable tubing designed for insulating medium voltage bus bar. Insulation must be tested to ANSI C37.20.2 standards.

17 Key/Electrical Interlocks

17.1 The equipment shall be equipped with a keyed interlock system to prevent unauthorized and out of sequence entry into the filter bank.

17.2 The interlock scheme shall include the upstream protective device (where necessary), the air disconnect switch, ground switch, conventional switches, thyristor valves, and the doors of the enclosure. The interlock scheme shall function as follows:

1) Turn the control off by turning the A1 key to the "release" position.
2) Use the "A1" key to unlock the air disconnect switch. Open the Air-Disconnect Switch and close the mechanically interlocked Ground Switch.
3) Upon a waiting period of 5 minutes remove the "A2" key from the Ground Switch

(Removing of the “A2” key shall lock ground switch in closed position” and proceed to the Air-Disconnect Switch External Compartment Door. Unlock the Air-Disconnect Switch Compartment Door and remove the “A3” key from the lock. (Note: Access to Air-Disconnect Switch terminals is prevented by the interior compartment door. This door can be interlocked with upstream breaker or load interrupter if desired. This would prevent access to terminals of switch unless upstream device was locked out.)

4) Use the “A3” key to open the first door that has access to the capacitor/reactor/valve compartment. (Upon turning of the “A3” key, the vacuum switches shall close to ground all components on the load-side of the vacuum switches.) Remove the “A4” key from the first capacitor/reactor/valve compartment door and proceed to the second capacitor /reactor/valve compartment door.
5) Open the second capacitor/reactor/valve comp compartment door, and proceed with the released key (if one is present) to the next door.
6) The above procedure is repeated until all doors are open.

17.3 The key interlocks on the door shall be mounted behind the enclosure doors with the key-holes protruding through the doors. The locks shall be equipped with stainless steel spring covers. The keyed interlock system shall allow all doors to be opened at one time. Master Key interchanges or externally mounted key interlocks shall not be provided.

18 Controls

18.1 The primary purpose of the thyristor & conventionally switched harmonic filter bank controller is to control power factor and system voltage by commanding the conventional capacitor switches and gating the thyristor switched stage valves in response to measured power system parameters. The structure and function of the active controller is as follows:

- Voltage, current, shall be measured and reactive power measurements calculated at least 20 times per cycle per phase (3600 times/second for 60 Hz systems; 2500 times/second for 50 Hz systems).
- The controller shall generate appropriate firing pulses to the thyristor valves. This shall be determined by reactive power measurements and shall occur three times per cycle (180 times/second for 60 Hz systems; 150 times/second for 50 Hz systems).
- The controller shall measure current in each phase.
- The controller shall measure system voltage at all times. If voltage exceeds a predetermined value, the controller shall reduce compensation levels within a cycle to maintain voltage below predetermined value.
- The controller shall constantly monitor each phase voltage and shall cease applying VARs if loss of a phase, loss of phase rotation, or failure to maintain a minimum phase voltage is detected.
- The controller shall operate by applying the same VAR level on each phase, unless the transient voltage imbalance caused by the load exceeds a pre-set parameter, whereupon the controller shall momentarily operate by applying the differing VARs level on each phase until the imbalance is reduced below pre-set levels, whereupon the controller shall return to normal operation.
- The controller shall be capable of partly-disabled operation such that it can operate with one or more of its branches out-of-service (“run-flat” mode).
- Operate the conventionally switched stages to correct power factor and reduce current and voltage distortion. The conventionally switched stages shall operate without interfering with the dynamic operation of the thyristor controlled stages.

18.2 Supplementary controller settings shall be provided as follows:

- Adjustment of voltage and current sensor readings

- Adjustment of controllers response gain
- Adjustment of controllers to discount steady-state conditions
- Adjustment of over voltage level
- Adjustment of under voltage level
- Ability to shift the controller into a partly-disabled (run-flat) mode.
- Where vacuum-switched banks are present, switching operations, switching feedback, over current protection, and capacitor fuse status shall be controllable by the controller.

18.3 Monitoring and protection of the control system

- The controller shall have an orderly star-up and shutdown sequence, including auto-restart after a power outage.
- Automatic voltage control, operative during start-up to prevent unnecessary switching of the reactive elements.
- Monitoring of the status and condition of each valve including temperature (OK/hot), state (open/closed), and health (OK/failed).
- Monitoring of conventionally switched banks, including switching operations, switching feedback, over current protection, and capacitor fuse status.

18.4 The controller shall have the following protection:

- Power supply failure
- Over-temperature protection for all components
- Capacitor loss/ current imbalance within an acceptable level
- Loss of control power
- Loss of synchronism including change in phase sequence or phase angle
- Loss of system voltage (any phase)
- System voltage above or below software pre-set levels.
- Control system self-monitoring alarms.
- For conventionally switched stages, switching operations, switching feedback, over current protection, and capacitor fuse status shall be monitored by the controller and failures shall be responded to appropriately.

18.5 The control system shall have the following customer interface and logging capabilities:

- It shall include a Graphic User Interface (GUI)
- It shall be accessible both locally and through an Ethernet (TCP/IP) connection.
- All alarms and control settings shall be accessible through the GUI.
- A Data Logger that performs the following:
  - Collects system operation, system performance, and alarm data whenever:
    - The system is operating in response to customer load changes
    - Whenever changes on the power system cause protection alarms
    - Whenever internal controller operations cause alarms
- All data alarms shall be logged on a cycle-by-cycle basis.
- All data and alarms shall be remotely retrievable.

18.6 Remote Access

- The controller shall be capable of secure (VPN) access by the manufacturer.
- Using remote access, manufacturer's support staff shall be able to:
  - Upload and inspect all data logs
  - View controller operation and alarms in real time
  - Diagnose controller error/fault conditions.
  - Assess controller performance
  - Adjust controller performance

18.7 All low voltage controls (where practical) shall be completely isolated from the high 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.

18.8 The complete control circuit shall be protected by a main circuit breaker.

18.9 The capacitor/reactor/valve/switch compartments, control compartment, and incoming air-disconnect switch compartment shall be equipped with lights that are controlled by an on/off switch located in the control compartment.

18.10 A 20-amp GFI Convenience outlet shall be provided in the control compartment.

18.11 (Optional – Arc Flash Hazard Mitigation) The control and protection system shall be remotely mounted from the main equipment enclosure. The remote enclosure shall be NEMA 1 rated for indoor application. All interconnection wiring shall be supplied by the installing contractor. Terminal blocks in the main equipment enclosure shall be located in a marshalling cabinet. Remote I/O blocks may be used when required in the marshalling cabinet.

18.12 (Optional – Arc Flash Hazard Mitigation) The capacitor bank shall be equipped with an ABB UFES (Ultra Fast Earthing Switch) that will provide active arc fault protection for the entire capacitor bank. The UFES system shall be supplied complete with electronic detection and tripping unit, primary switching element, arc sensors and trip cables. The system shall be installed and ready for operation. A transfer trip must be wired out to terminal blocks for tripping upstream feeder breaker in event of fault.

18.13 (Optional – Arc Flash Hazard Mitigation) The control system shall be equipped with a “maintenance switch” that enables instantaneous settings on the capacitor bank feeder breakers (and stage breakers when present) to reduce trip times when workers are near the equipment. The switch shall also inhibit all stage switching to reduce the probability of arc flash event from switch failure or switch restrike while workers are nearby.

18.14 (Optional – Arc Flash Hazard Mitigation) The capacitor bank shall be equipped with an arc flash detection relay that provides high speed tripping of the capacitor bank feeder breaker in the event of an arc flash fault. The relay and optics shall be installed and tested at the factor before shipment. The fast trip relay output shall be wired to terminal blocks for connection to capacitor bank feeder breaker.

18.15 The control system shall be listed under UL 508A for industrial control panels.

18.16 UL Rated Control Power Circuit breakers shall be utilized in the control circuit for protection and switching of key control components.

The following optional requirement can be specified:

18.17 A three-phase panel meter shall be provided. 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.

19 Supplier Quality System

19.1 Supplier shall have third party certification by an internationally recognized accreditation body to ISO 9001:2008. <u>The certification certificate shall be provided with the quote.</u>

19.2 Supplier shall be authorized to label equipment as compliant with IEEE C37.20.3-2001 "*Standard for Metal-Enclosed Switchgear*" and C22.2 No. 190-M1985 *"Capacitors for Power Factor Correction"*. <u>The certification certificate shall be provided with the quote.</u>

19.3 Supplier shall be factory certified through periodic inspection by UL to apply UL and C-UL labels on their control panels. <u>The certification certificate shall be provided with the quote.</u>

19.4 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.

19.5 Supplier must provide a medium voltage metal enclosed customer list with contact information for the purpose of reference checks. <u>The customer lists shall be provided with the quote.</u>

19.6 Supplier must allow factory audits to occur at mutually agreed upon dates between the customer and supplier.

20 Submittals

20.1 Upon issue of a purchase order, the supplier shall provide 3 copies of approval drawings. The submittals shall include:

- Installation Instructions

- Single Line and three line diagrams
- Pad and cable entry drawings
- Drawings showing component layout
- Data sheets for all internal components
- Material listing
- Time coordination plots between capacitor fuses, main disconnect fuses, case rupture curves, and upstream overcurrent protective devices. Damage curve for the capacitor supply cables shall be coordinated with upstream overcurrent protective device.
- Upon approval of above, a digital copy on CD ROM shall be provided.

21 Bid Requirements

21.1 Supplier must state all exceptions in the Bid. If no exceptions are taken, the supplier must state that there are no exceptions.

21.2 Supplier must complete attached supplier qualification form and attach to quote. Failure to provide qualification form with quote will be cause for rejection.

21.3 Supplier must have optional extended warranty and field service agreements available. These policies shall be provided with the bid.

21.4 Supplier must provide their written quality policy with the Bid.

21.5 Quotes are to be FOB factory, freight allowed.

22 Acceptable Product & Suppliers

22.1 Suppliers must offer a 12/18 month (18 months from date of shipment or 12 from date of energization – whichever comes first) warranty and have available extended warranty programs.

22.2 The supplier must have a Quality Assurance Program.

22.3 Supplier must show that they are a regular supplier of medium voltage metal-enclosed thyristor controlled medium voltage automatic metal-enclosed harmonic filter banks for supply into the mining industry. Product literature and a list of customers that have purchased similar products shall be supplied upon request.

22.4 Acceptable Manufacturer and Product:

Northeast Power Systems, Inc.
66 Carey Road
Queensbury, NY 12804

Phone: 518-792-4776

Fax: 518-792-5767

Webpage: www.nepsi.com
Quote request: sales@nepsi.com