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# Guide Form Specification for Medium Voltage Automatic Metal-Enclosed Harmonic Filter System

## - Mining Application -

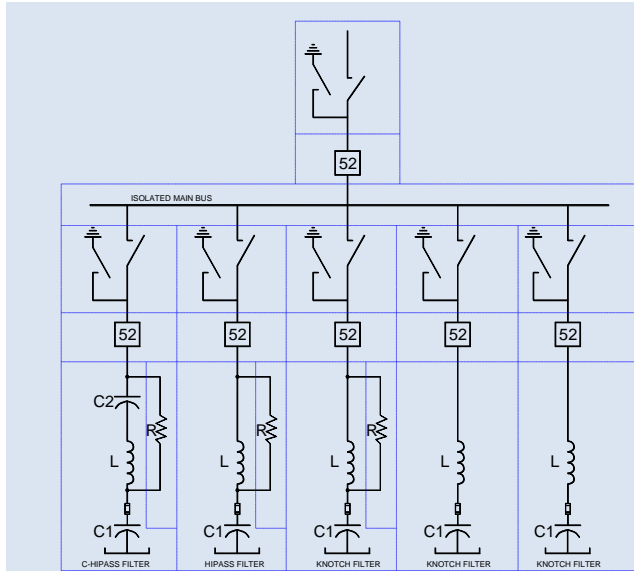
*(With Integrated Main Bus, Disconnect Switches and Breakers)  
(Branch Switching)*

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](http://www.nepsi.com).

## 1 General

- 1.1 This specification is for a medium-voltage three-phase metal-enclosed harmonic filter system intended for large remote mining applications. The primary purpose of this filter system is to correct power factor, reduce harmonic voltage and current distortion in the mine facility that consists of large variable speed drives and cyclo-converters. The filter system consists of C-high-pass, standard high-pass, and notch filter branches. The filter branches are switched and controlled by a remote central protection and control system to be provided by the vendor. The control system must interface and communicate with the Mine DCS system as well as other upstream protective relays and IED's.

Figure 1 below provides a general layout of the filter system. The filter system consists of a main incoming fixed mounted breaker and a key interlocked disconnect switch and ground switch for isolation and safety during maintenance. The main incoming fixed mounted breaker supplies power to an isolated main bus that is connected to key interlocked disconnect switches that supply power to the filter bank tuned branch breakers. These breakers can be switched individually or in blocks to accomplish var and voltage support as well as harmonic distortion mitigation. Individual filter branches can be shut down and safely maintained while other filter branches are in operation.



**Figure – 1** Typical filter bank configuration

Figure 1 to the left shows a multi-stage harmonic filter bank. This equipment comes fully assembled, tested and ready for connection.

The blue lines represent isolated compartments. Resistor compartments are stainless steel and are normally mounted on top of the harmonic filter bank. All other compartments are integrated into an 11 gauge enclosure that is self-supported and can be lifted and placed onto a concrete pad.

HMI control and protection system can be integrated into the main filter bank enclosure or mounted separately in an E-House for remote control by fiber optic cable.

1.2 The Vendor shall have in-house engineers and harmonic analysis software that utilizes complex modeling techniques to predict filter bank performance. This software shall be utilized to confirm basic operating parameters of the filter bank and confirm the power factor and harmonic studies provided by other design engineers or the supplier of the Ball/Sag Mill Motors. Acceptable harmonic analysis software packages include:

- Easy Power
- HarmFlo
- Vharm
- PSS/U

1.3 The ratings of the harmonic filter bank 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 at Capacitor Bank (RMS Symmetrical Amps)..... \_\_\_\_\_  
 Line-Ground Short Circuit Rating at Capacitor Bank (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 of the equipment and will result in equipment that is less likely to flash over or fail.

1.4 Harmonic Filter Bank Elevation ..... \_\_\_\_\_ (meters)

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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 Humidity .....Min. \_\_\_\_/Max\_\_\_\_\_ (%)

1.7 Solar radiation for design purposes shall be as follows:

Average annual solar radiation ..... \_\_\_\_\_ (kW/m<sup>2</sup>)

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<sup>2</sup>)

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 automatic 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

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- IEEE Std. 1036-1992, IEEE Guide for Application of Shunt Power Capacitors
  - Optional – Arc Flash Hazard Mitigation, IEEE C37.20.7-2007, IEEE Guide for Testing Metal-Enclosed Switchgear Rated Up to 38kV for Internal Arcing Faults
  - CP-1 NEMA Standard on Shunt Capacitors
  - UL – 519
  - REA Standards
  - NESC Standards

### 3 Product Listing

- 3.1 The filter bank control panel shall be UL508A Certified for both Canadian and US products.
- 3.2 The harmonic filter bank 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+G11 + G12 (R2004)

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

### 4 Enclosure Construction

- 4.1 The harmonic filter system shall consist of multiple flush door enclosure(s) with NEMA 3R construction that house all components, including breakers, fuses, capacitors, reactors, switches, resistors, disconnect switches, and associated controls. All components shall be accessible and removable from the front, side, or rear of the enclosure. Bolted panel construction, and switchgear cubicle style enclosures will not be allowed and will be rejected.

Enclosures that are longer than standard flatbed truck lengths shall be supplied with appropriate parts and components to allow filter enclosure sections to be slid up against each other and interconnect to form a single filter enclosure system. All hardware and interconnection wiring, busing, and cabling shall be prefabricated and shipped with the filter system.

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



The above picture shows two harmonic filter systems installed at a mine. The filter system consist of three 40' sections that are interconnected with pass-throughs. Each filter section contains multiple tuned filter stages (branches) and associated disconnect switches, ground switches, reactors, capacitors, etc.

- 4.2 The manufacturer of the enclosure shall also be the assembler of the 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.
- 4.3 The enclosure shall be fabricated from a minimum of 12-gauge stainless steel or (11 gauge 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. Drip shields shall be provided above all doors.
- 4.4 The filter enclosure shall be compartmentalized, with a minimum amount of openings between compartments where bus or controls wire may pass through. Energized bus must pass through walls with through-wall bushings. The following compartments shall exist for each filter system:
  - Incoming compartment – This compartment shall contain the ground switch and disconnect switch – but no other components.
  - Incoming fixed mounted breaker – This compartment shall contain the fixed mounted breaker and shall have dead front access to the front side of the breaker.
  - Isolated main bus compartment – This compartment is fed from the incoming fixed mounted breaker compartment. It shall be completely isolated from all other compartments.
  - Stage (or tuned branch) disconnect and ground switch compartment – This compartment shall contain the ground switch and disconnect switch for the associated tuned filter branch – but no other components. This disconnect switch shall receive power from the main isolated bus.
  - Stage (or tuned branch) fixed mounted breaker compartment. This compartment receives power from the associated disconnect and ground

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switch compartment. The breaker shall have dead front access to the front side of the breaker.

- Reactor/Capacitor Compartment – This compartment may contain the stage capacitors, reactors, and fuses, and other protection devices such as the current transformers and potential transformers.
- Control compartment – This compartment contains the interface for all customer control wires and shall be completely isolated from all other compartments.
- Resistor Compartment – This compartment shall be stainless steel (due to heat from resistors), unpainted, well ventilated, and mounted on top of the above compartments.

- 4.5 The enclosure shall be prepared and painted with a high-solid epoxy coating as specified below. The inside and outside shall be ANSI gray 61 – Munsell No. 8.3G 6.10/0.54.

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.

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 5 mils. This will provide a total dry film thickness of 3.5 to 8 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.

- 4.6 The enclosure shall have a continuous 1/4" x 2" Tin-Plated Copper Ground Bus that spans the full width of the enclosure.
- 4.7 The doors shall be of a flush design (no over hanging door sills) equipped with heavy-duty stainless steel hinges and 3-point stainless steel pad-lockable latching handles. The Doors shall

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be removable in the open position.

- 4.8 All doors providing access to high voltage compartments shall be equipped with door stays to hold doors in the open position.
- 4.9 All single door access points and double door access points shall be equipped with Fluke CLKT C-Range infrared Window (part #: 3460439 FLK-100-CLKT). Crystal insert diameter shall be no less than 100 mm (3.94in). Mesh grids designs will not be accepted.
- 4.10 (Optional – Arc Flash Hazard Mitigation) The doors shall be capable of withstanding the effects of an internal arcing fault.
- 4.11 In addition to the enclosure door, the compartment containing the 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.
- 4.12 The base of the enclosure shall be constructed from hot-dipped galvanized C-Channel. A minimum of C4x5.4 structural steel channel shall be utilized. Removable steel lifting plates consisting of 1/2" steel shall be located at each corner. Formed channel bases will not be accepted.
- 4.13 All ventilation louvers shall be located on the front, side, or rear of the enclosure. Washable, 1 inch high-air-volume aluminum filters shall be provided. They shall be UL Rated 900 Class 2 and shall be removable from the outside of the filter bank while it is energized. Protective steel barrier shall exist to prevent accidental contact with live parts.
- 4.14 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.
- 4.15 Thermostatically controlled Krenz-Vent F16 fan(s) shall be provided to cool the harmonic filter bank.
- 4.16 Thermostatically Controlled Strip Heaters shall be supplied in all non-ventilated compartments.
- 4.17 The capacitor bank shall be name plated with a riveted stainless steel nameplate containing the following information:
- Nominal System Voltage
  - Maximum System Voltage
  - Number of Steps, Stages, and Switching Sequence
  - kvar per step, kvar of each stage, and tuning point of each stage
  - BIL
  - Name of manufacturer, date of manufacture, and phone number of service center



34.5 KV CAPACITOR BANK							
VOLTAGE: 34.5 kV		FREQUENCY: 60 HZ		DATE: 11-17-08			
CONNECTION: UNGROUNDED WYE				BIL: 150 KV			
SERIAL #: #####							
TOTAL KVAR: 20,000				MAX. SYSTEM VOLTAGE: 38 KV			
KVAR/STEP: 10,000		SWITCHED STAGES: 2		SEQUENCE: 1:1			
CUSTOMER NAME: #####							
STAGE	FIXED	- 1 -	- 2 -	- 3 -	- 4 -	- 5 -	
KVAR	N/A	10,000	10,000	-	-	-	
AMPS	N/A	167.5	167.5	-	-	-	
JOB NAME: #####							
CAP RATING: QTY ##, ### KVAR, ###,## KV CAPS/STEP - 2 BUSHING							
Northeast Power Systems, Inc				<b>NEPSI</b>			
66 Carey Road							
Queensbury, NY 12804							
Phone: 518-792-4776							
Webpage: WWW.NEPSI.COM							
<b>POWER FACTOR CORRECTION AND HARMONIC FILTERS</b>							

- 4.18 Each pad lockable 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.

Warning Label Requirements per above section	
<i>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)</i>	<i>HAZARDOUS VOLTAGE. Contact may cause electric shock or burn. Turn off and lock out system power before servicing.</i>

- 4.19 In addition to the above tags, every door, in an alternation fashion shall be labeled with one of the following 10" x 14" danger signs.





4.20 All pad lockable doors shall be clearly labeled as to what is behind the door with UV resistant labels. In addition, where applicable, the following Caution and Danger Tags shall be utilized. Tags shall be UV rated and shall be blind riveted on the enclosure and shall have a minimum size of: 2.75" x 2.25".

Danger and Caution Tag Schedule



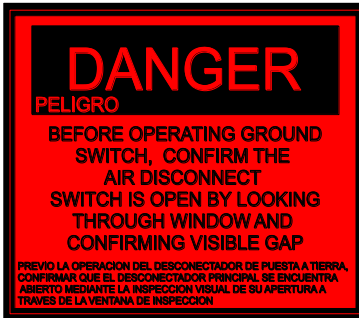
Above tag to be placed on all bolted access doors that are not equipped with key interlocks.



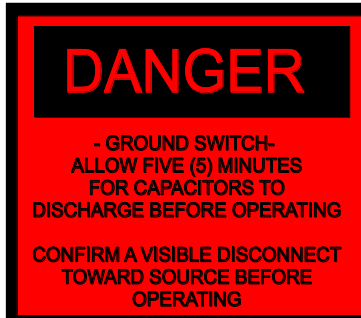
Above tag to be placed on all capacitor bank access doors.



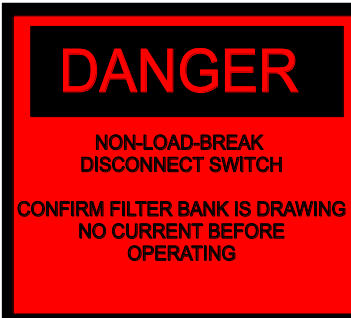
Above tag to be placed on air-disconnect internal barrier door.



Above tag to be placed above all ground switches



Above tag to be placed above ground switch



Above tag to be placed above non-load break disconnect switch

- 4.21 Doors providing access to interrupter switches shall be provided with a wide-view gasketed window constructed of an impact-UV-resistant material, to facilitate checking of switch position without opening the door.
- 4.22 The main incoming fuse compartment shall be equipped with a wide-view gasketed window constructed of an impact-UV-resistant material, to facilitate checking of the main fuses without opening the door or de-energizing the bank.
- 4.23 The capacitor 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.
- 4.24 (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.

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- 4.25 (Optional – Arc Flash Hazard Mitigation) The enclosure shall be of an arc resistant design and shall include integral (specify back or top – 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 harmonic filter system 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 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 The capacitors shall be connected in ungrounded wye and shall be protected from sustained over voltages due to capacitor unit failure and/or system ground faults 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.
- 5.4 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 shall be provided with Bid):
- All Harmonic current producing loads are at 100% and their associated peaks are 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.
- 5.5 Capacitors shall be mounted on C4x5.4 structural steel channel. The capacitors shall be removable from the front or rear of the enclosure without the use of a ladder or lifting means.
- 5.6 In case of a dielectric fluid leak, the capacitors and oil filled CPT's shall be mounted above

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removable drip pans that have the capacity to contain the dielectric fluid.

(Optional – Arc Flash Hazard Mitigation) Consider using capacitors that have an extra 10% voltage margin on them from your harmonic design 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 or rear 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. The filter system shall communicate the blown fuse condition to the Mine's DCS system.
- 6.3 An option for 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.

## 7 Iron-Core Filter Reactors

- 7.1 The harmonic filter bank shall be equipped with single-phase iron-core dry-type reactors. They shall have Copper 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 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.

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- $I_1 = 1.21 \times$  Fundamental Current Rating of the Stage (for multi-stage banks) or Bank at the Nominal System Voltage.
  - $I_{\text{Tuned Frequency}} = 1.0 \times$  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 Reactor Protection

- 8.1 A three-phase digital overload relay shall be provided to protect the 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 Mine's DCS system. On overload, the stage with the overload shall be shut down.

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## 9 High-Pass Filter Resistor Modules

- 9.1 Stainless steel grid resistor modules shall be utilized for the harmonic filter stages that are specified as C-High-Pass or Standard High-Pass filter branches.
- 9.2 The resistor modules shall come fully assembled and ready for installation on the roof of the harmonic filter bank. All interconnection cables, through-roof bushings, and lugs shall be provided with the equipment. The resistor modules shall be easy to install and to interconnect with the main filter branches.
- 9.3 The resistors modules shall consist of a stainless steel, self-ventilated, unpainted enclosure.
- 9.4 Resistors shall be protected from overload with an overload protection relay. 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)
  - 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.
- 9.5 The overload relay shall communicate with the HMI as well as with the Mine's DCS system. On overload, the stage with the overload shall be shut down.



The picture to the left shows a stainless steel grid resistor enclosure that uses natural ventilation to keep the high-pass filter resistors cool. The resistor enclosure is roof-mounted. Cable pass-throughs as well as all cable and terminals are supplied by NEPSI.

(Optional – Arc Flash Hazard Mitigation) – Over-rating resistor watt ratings beyond calculated watt losses is a good way to improve reliability of the harmonic filter bank and reduce the probability of failure and possible arc flash event. NEPSI usually recommends a least a factor of 2.0.

## 10 Load Interrupter - Air Disconnect Switches

- 10.1 The harmonic filter system shall be supplied with external chain operated load interrupting switches for each of the stages (or tuned branches) as well as for the main incoming power. The purpose of these switches are to allow for visible disconnection of stages or the main filter system.
- 10.2 The disconnect switches shall accomplish 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 nominal current rating and shall have a 40-kA RMS

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momentary asymmetrical rating. This switch shall be interlocked with the filter branch 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.

- 10.3 The Air Disconnect Switches shall be located in a separate isolated compartment that are isolated from all other compartments. In addition to the exterior enclosure door, a protective barrier (behind the door) door with a viewing window shall be provided before access to the switch is allowed. Above the switch operating handle, there shall be a red UV resistant Lamacord Tag stating the following:

**DANGER**

THIS COMPARTMENT MAY  
CONTAIN LIVE TERMINATIONS

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BEFORE ENTERING, CONFIRM  
UPSTREAM DISCONNECT IS OPEN  
AND LOCKED OUT

- 10.4 (Optional – Arc Flash Hazard Mitigation) The load interrupter switch shall be equipped with a motor operator for remote electrical opening and closing.
- 10.5 (Optional – Arc Flash Hazard Mitigation) The load interrupter switch terminals or shall be equipped with medium voltage indicators that flash when voltage is present.

## 11 Ground Switches

- 11.1 An externally operated ground switch shall be provided to ground the load-side terminals of the main incoming disconnect switch as well as each of the stage (or tuned branch) disconnect switches. The ground switches shall be pad-lockable in either the open or closed position. The ground switches must be tested in accordance with ANSI/IEEE standards. Test reports shall be furnished upon request.
- 11.2 The ground switches shall be interlocked with associated Air Disconnect Switch to prevent closing of the ground switch when the air disconnect switch is in the closed position. Above the ground switch handle shall be a red Lamacord warning tag stating the following:

**DANGER**

- GROUND SWITCH -  
ALLOW FIVE (5) MINUTES  
FOR CAPACITORS TO DISCHARGE BEFORE  
OPERATING

CONFIRM A VISIBLE DISCONNECT  
TOWARD SOURCE BEFORE OPERATING

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## 12 Incoming Circuit Breaker

- 12.1 The harmonic filter system shall be equipped with a main incoming appropriately rated fixed mounted breaker for the purpose of disconnecting the filter system from the mine's power system. The breaker shall also provide short circuit and over-voltage protection for the entire filter system.
- 12.2 The breakers shall be equipped with an appropriate 3-phase over-current relay, lockout relay, and breaker controls to open and close the breaker. The breaker shall form an integral part of the filter system key interlock system, protection system, and control system.
- 12.3 Aux contacts for indication of breaker open and close status shall be wired out the filter control system. In addition to the above, and open and close indicator shall be visible from outside of the filter enclosure through a viewing window.
- 12.4 The breaker shall be dead-front accessible and shall be connected to the load side terminals of the incoming air disconnect switch to allow for maintenance of the breaker.

## 13 Filter Bank Stage (or Tuned Branch) Breakers

- 13.1 The harmonic filter stages shall be equipped with a appropriately rated fixed mounted breaker for the purpose of switching filter stages on and off. These breakers shall also provide short circuit and over-voltage protection for the filter stage.
- 13.2 The breakers shall be equipped with an appropriate 3-phase over-current relay, lockout relay, and breaker controls to open and close the breaker. The breaker shall form an integral part of the filter system key interlock system, protection system, and control system.
- 13.3 Aux contacts for indication of breaker open and close status shall be wired out the filter control system. In addition to the above, and open and close indicator shall be visible from outside of the filter enclosure through a viewing window.
- 13.4 The breaker shall be dead-front accessible and shall be mounted on the load side of the stage disconnect switches to allow for maintenance of the breaker.
- 13.5 The control system shall prevent the stage breakers from operating more than once in a 5-minute period.
- 13.6 The stage breakers shall be interlocked with the stage air-disconnect switch and ground switch.
- 13.7 To prevent internal filter resonance, the switched stages shall be energized in sequence. For example, higher-tuned filters shall not be allowed to come on before lower tuned filters come on.

## 14 Lightning/Surge Arresters

- 14.1 The harmonic filter system shall be equipped with station-class lightning arresters. The rating of the lightning arrester shall be recommended by the harmonic filter bank supplier.



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## 15 Phase and Ground Bus

- 15.1 All phase and ground bus shall be Tin-plated for maximum conductivity and corrosion resistance. The bus shall be Square edge. Bolted bus-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<sup>2</sup>. Where expansion capability is required, the bus shall be rated for the maximum capacity of the bank.
- 15.2 The bus supports, bus, and interconnections shall withstand the stress associated with the available short-circuit current at the filter bank.
- 15.3 (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.

## 16 Interlocks

- 16.1 The harmonic filter system shall be equipped with a keyed interlock system to prevent unauthorized and out of sequence entry into the filter bank.
- 16.2 The key interlock system shall provide controlled and safe entry into each of the isolated enclosure compartments. Separate key interlock schemes shall allow for entry into the main incoming compartment, the stage disconnect switch compartments, or to the stage filter compartments while allow for other parts of the equipment to remain operational.
- 16.3 A typical arrangement and description is as follows:

Entry into Main Incoming Compartment (Door 2)			
Step	Procedure/Description	Key Interchange(s)	Remark
1	Turn off all filter bank stages/branches by turning D1/A, C1/A, B1/A and A1/1 to the off position. These key is located at the HMI.	D1/A, C1/A, B1/A, A1/A	It is highly recommended to start with the D1/A and work sequentially toward A1/A.
2	Open and Rack out H11-HF1. Lock H11-HF1 in the racked out position.	H11-HF1	Mount Milligan standard procedures for lock-out and tag out should also be followed. Wear proper PPE for the operation.
3	With the H11-HF1 key in hand, proceed to Door 2 for access.	H11-HF1	Before entry, allow 5 minutes for capacitors to discharge. Follow standard lock-out and tag-out procedures.
4	Reverse the above procedure to energize.		

Entry into Filter Branch Breaker/Disconnect Compartments (Door 3, Door 7, Door 12, Door 16)			
Step	Procedure/Description	Key Interchange(s)	Remark
1	Turn off all filter bank stages/branches by turning D1/A, C1/A, B1/A and A1/1 to the off position. These keys are located at the HMI.	D1/A, C1/A, B1/A, A1/A	It is highly recommended to start with the D1/A and work sequentially toward A1/A.
2	Remove the M1/A key from the HMI and proceed to the filter bank main incoming air disconnect switch.	M1/A	
3	Use the M1/A key to unlock the main incoming air disconnect switch. Open the air disconnect switch.	M1/A	Follow proper PPE for this operation. This disconnect switch isolates the main filter bank bus bars (all branches).
4	Remove the M2/A key from the disconnect switch and proceed to the ground switch.	M2/A	
5	Unlock the ground switch with the M2/A key and close the ground switch.	M2/A	This ground switch grounds the main filter bank bus bars (all branches).
6	Remove the M3/A key and proceed to the filter bank main compartment doors. Doors 3, Door 7, Door 12, Door 16.	M3/A	
7	Reverse the above procedure to energize.		

Entry into 3 <sup>rd</sup> C-HP Compartment (Door 4, Door 5, Door 6)			
Step	Procedure/Description	Key Interchange(s)	Remark
1	Turn the A1/A key at the HMI to open the 3 <sup>rd</sup> C-HP filter breaker. Remove the A1/A key and proceed to the 3 <sup>rd</sup> C-HP air disconnect switch handle operator.	A1/A	This will open the 3 <sup>rd</sup> C-HP breaker. Also, since this stage is the lowest tuned stage, the higher tuned stages will trip off-line. Follow standard lock-out and tag-out procedures.
2	Open the air disconnect switch and remove the A2/A key and proceed to the filter branch ground switch.	A1/A	Removing the A2/A key will lock the disconnect in the open position.
3	Wait 5-minutes and then unlock and close the ground switch and remove the A3/A key and proceed to the filter bank branch compartment doors.	A2/A	Removing the A3/A key will lock the ground switch in the closed position.
4	Open the filter branch compartment doors.	A3/A	
5	Reverse the above procedure to energize the filter branch.		

16.4 The keyed 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.

## 17 Protection & Control System

17.1 The filter bank protection and control system shall be capable of interfacing directly with the mine DCS control system. The details of the control scheme shall be worked out collectively with the mine engineers. In general terms, the filter bank shall be capable of accepting control signals from the mine DCS system that will force stages on and off based on plant operations.

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This control can be via fiber or by direct sensing of contact closure. Under conditions when key mine machinery is not operating, the filter system shall function on its own in power factor correction mode.

- 17.2 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.
- 17.3 All Control wires that connect to components inside high voltage compartment shall be enclosed in metal conduit or wire troughs that are formed as part of the filter bank enclosure.
- 17.4 The digital power factor control relay (if provided) shall be equipped with a digital display of power factor and capacitor stages. There shall be visual indication by means of an LED for energized filter stages, capacitive/inductive load, and target power factor obtained. The controller shall have a built in 5 minute time delay. (Note, the filter system can be controlled in many ways – one such way is to receive power flow information from upstream IED's or from the DCS system. Another way is with local measurement through bus mounted CT's and PT's.)
- 17.5 The complete control circuit shall be protected by a main circuit breaker. Each major component within the control circuit shall be equipped with its own control power circuit breaker.
- 17.6 As part of the HMI, 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 filter 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.

For Arc Flash Hazard Mitigation, there shall be a 10 second delay before switching when switching from the off to the on position or the on to the off position to allow workers to move outside the arc flash danger zone.

- 17.7 The Capacitor/Reactor Compartment, Control Compartment, Air-Disconnect Switch Compartment, and Breaker Compartments shall be equipped with lights that are controlled by an ON/OFF switch located in the control compartment.
- 17.8 (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.
- 17.9 (Optional – Arc Flash Hazard Mitigation) The harmonic filter 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.

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- 17.10 (Optional – Arc Flash Hazard Mitigation) The control system shall be equipped with a “maintenance switch” that enables instantaneous settings on the harmonic filter 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.
- 17.11 (Optional – Arc Flash Hazard Mitigation) The filter bank shall be equipped with an arc flash detection relay that provides high speed tripping of the filter 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.
- 17.12 A 20-amp GFI Convenience outlet shall be provided in the control compartment as well as in the HMI.
- 17.13 The Medium Voltage Capacitor Bank Control System shall be listed under UL 508A for Industrial Control Panels.
- 17.14 UL Rated Control Power Circuit breakers shall be utilized in the control circuit for protection and switching of key control components.
- 17.15 A high-end multifunction three-phase power meter shall be provided on each filter tuned branch as well as on main filter feeder cable. This meter shall receive its voltage and current signals from current transformers mounted within the filter bank and two potential transformers located inside the incoming compartment. The meter shall be pre-programmed at the factory and shall have the following minimum features:
- Web Server and Email Sending
  - Power Quality Analysis
  - Switch Status Monitoring
  - Individual Harmonic measurement from 2<sup>nd</sup> to 63<sup>rd</sup> Harmonic
  - Data Logging
  - 10M/100M Ethernet, Profibus-DP/VO, Profibus slave mode, Modbus – RTU
  - Qty 2 digital output relays set to trip on over-voltage, harmonic over-current, harmonic over-voltage and RMS over-current.

## **18 Clean Agent Fire Suppression System (optional)**

- 18.1 The harmonic filter bank shall be equipped with an automatic “Total Flood” Clean Agent Fire Suppression System designed in accordance with NFPA No. 2001 – Clean Agent Fire Extinguishing Systems.
- 18.2 The fire suppression system shall come installed and be complete in all ways with a minimum amount of field work to put the system into operation. It shall at minimum, include all mechanical and electrical installation, all detection and control equipment, agent storage containers, FM-200 agent, discharge nozzles, pipe and fittings, manual release and abort stations, audible and visual alarm devices, auxiliary devices and controls, shutdowns, alarm interface, caution/advisory signs.

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- 18.3 The fire suppression system should form an integral part of the filter bank enclosure system. The FM-200 storage containers and fire suppression automatic control and detection system shall be located in an isolated compartment that is separate from the filter bank control and protection system. The storage containers shall be of high-strength low alloy steel construction and conform to NFPA 2001. Containers shall be actuated by a resettable electric actuator with mechanical override located at each agent container or connected bank of containers. Each container shall have a pressure gauge and low pressure switch to provide visual and electrical supervision of the container pressure. The low-pressure switch shall be wired to the control panel to provide an audible and visual trouble alarms in the event the container pressure drops outside of allowable pressure range. Containers shall be equipped with pressure relief provisions.
- 18.4 Engineered discharge nozzles shall be provided in each filter compartment to distribute the FM-200 agent throughout the protected spaces of the harmonic filter bank. The nozzles shall be designed to provide proper agent quantity and distribution.
- 18.5 Distribution piping and fittings shall be installed in accordance with the manufacturer's requirements, NFPA 2001 and approved piping standards and guidelines.
- 18.6 At least two detectors shall be spaced and installed in each protected compartment in accordance with the manufacturer's specification and the guidelines of NFPA 72.
- 18.7 The fire suppression and detection system shall either utilize DC station power (customer supplied 125VDC) or be equipped with a battery stand-by power supply taking into consideration the power requirements of all alarms, initiating devices and auxiliary components under full load conditions.
- 18.8 The fire detection system shall utilize cross-zoned detection requiring two detectors to be in alarm before agent release. Automatic operation in the protected areas shall be as follows:
- Actuation of one (1) detector, within the system, shall illuminate the "ALARM" lamp on the control panel face, energize an alarm bell and/or a visual indicator, and open/close a dry contact for customer remote indication.
  - Actuation of a 2<sup>nd</sup> detector, within the system shall illuminate the "PRE-DISCHARGE" lamp on the control panel face, energize a pre-discharge horn or horn/strobe device, shut down the ventilation system and close all ventilation openings, start a time-delay sequence (not to exceed 60 seconds) allowing for a system abort sequence.
  - After completion of the time-delay sequence, the FM-200 Clean Agent system shall discharge and illuminate a "SYSTEM FIRED" lamp on the control panel face, shutdown of all filter branch stages, trip the filter banks main breaker if present, and close an aux contact for tripping an upstream breaker if necessary for isolation.
  - The system shall be capable of being actuated by manual discharge devices located at the filter bank control compartment and the fire protection control/agent compartment. Operation of a manual device shall duplicate the sequence description above except that the time delay and abort functions shall be bypassed. The manual discharge station shall be of the dual action electrical actuation type and shall be supervised at the main control panel.
- 18.9 The kirk key interlock system shall prevent re-energization and access to the protected spaces

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for a “hold” period of 10-minutes to protect against agent loss and/or leakage.

18.10 Signs shall be provided to comply with NFPA 2001 and the recommendations of the FM-200 equipment supplier. At minimum, a manual discharge sign shall be supplied at manual discharge stations, and an entrance sign on compartment door.

## 19 Supplier Quality System

19.1 The supplier shall have third party certification by an internationally recognized accreditation body to the most recent version of the ISO 9001 standard for quality management systems. The certification certificate shall be provided with the quote.

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”. The certification certificate shall be provided with the quote.

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

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. The customer lists shall be provided with the quote.

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 provide an Inspection Test Plan (ITP) detailing all tests, tests reports, and certifications and their schedule for submission from date-of-award.

21.2 Supplier must provide a Supplier Document List (SDL) detailing all submittal and close-out

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documentation that will be provided, along with a submittal schedule (in weeks after award).

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

21.4 The bid shall include:

- 3-Line Diagram of proposed filter system showing all switching devices, CT's, PT's, fuses, resistors, reactors, protection relays, and metering
- External elevation drawings
- Pad layout drawing of entire filter system including recommend pad

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

21.6 Supplier must provide product, quality, and UL certifications and customer list with Bid.

21.7 Quotes are to be FOB factory, freight allowed.

## 22 Testing and Test Reports

22.1 All components shall be tested in accordance with the relevant standards. Tests to be conducted shall be included in an Inspection Test Plan (ITP), and provided with the bid. At a minimum, the tests included in this section shall be included in the ITP.

22.2 A Power-Frequency Withstand Test and a Lightning-Impulse Withstand Test shall be conducted by the assembler in accordance with IEEE C37.57-2003 (2010), IEEE C37.20.3, and IEEE Std. 4 - 2013. The Test Voltages shall be in accordance with C37.20.3-2013 Table 1. Multiple test shall be conducted to demonstrate insulation levels under various operating modes, i.e. main switch open, main switch closed, capacitor stage switch open, capacitor switch stage close.

22.3 All relays and control devices shall be programmed, tested, and calibrated prior to shipment. The results of the calibration shall be issued with the test report. Relay and control settings shall be documented and included with the equipment installation, commissioning, and maintenance instructions.

22.4 Air Disconnect Switch shall include the following test: Contact Resistance Test, HiPot Test (1 min) at standard voltage per applicable standard, and operation test.

22.5 Lightning Arresters shall include the following test: Reference Voltage, Residual / Discharge Voltage, Partial Discharge Test, Power Frequency Test.

22.6 Instrument Transformers shall include the following: Turns Ratio Test, Polarity Check, Insulation Test, and Excitation Test per IEEE Std. C57.13.

22.7 Capacitors shall include the following test: Leak test, low voltage capacitance test, ground test over-voltage, capacitance and loss measurement, discharge resistor measurement, and visual inspection for damage.



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- 22.8 Southern States CapSwitcher shall include the following test: Hi-Pot Testing, Timing Test, Resistance Check, Heater Wattage Check, SF6 Leak Check, Slow Close Operation Test, Wiring Check, Gas Density Switch Check (when applicable).
  - 22.9 SF6 Circuit Breaker shall include the following test: Mechanical Operation Tests, Power Frequency Voltage Withstand Test, Contact Resistance Test, Operating Time Test.
  - 22.10 The equipment shall be fully assembled and tested prior to shipment. Certified test reports in accordance with the vendors inspection test plan (ITP) shall be issued and approved prior to shipping.
  - 22.11 The client reserves the right to witness any and all tests performed at no additional cost. Sufficient notification shall be given to allow client's representative(s) to be present for the tests. A minimum of 15 working days shall be allowed.

## 23 Acceptable Product & Suppliers

- 23.1 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.
- 23.2 Supplier must be able to meet testing requirements.
- 23.3 The supplier must have a current ISO 9001 certification and be certified by an independent ISO accredited firm. The ISO 9001 certificate shall be provided with the bid.
- 23.4 Supplier must have a licensed professional engineer on staff that has a post graduate degree in electric power engineering. Credentials shall be supplied upon request.
- 23.5 Supplier must show that they are a regular supplier of 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.
- 23.6 Suppliers must be able to provide performance guarantee in regards to harmonics and power factor.
- 23.7 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](http://www.nepsi.com)  
Quote request: [sales@nepsi.com](mailto:sales@nepsi.com)



Typical Harmonic Filter System installed at a remote mine at 10,000' in South America. This system consisted of three large multi-tuned harmonic filter banks. Enclosures were built with low profile design to allow for shipment in high-cube containers.