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# Guide Form Specification for Medium-Voltage Metal-Enclosed Harmonic Filter Banks for Mining and Mineral Processing Applications

**Design Criteria:** Mining and Mineral Processing Applications. Typical for SAG and ball mills, overland conveyors, cycloconverter and VFD drive systems, electrowinning circuits, desalination systems, high-lift pump stations, and other remote or weak-grid mining power system applications.

## 1 General

### 1.1 Scope of Work

This specification governs the design, manufacture, and testing of a medium-voltage, three-phase, metal-enclosed automatic harmonic filter bank intended for application on mining and mineral processing power systems. Typical applications include SAG and ball mills, overland conveyors, cycloconverter and variable frequency drive systems, electrowinning circuits, desalination systems, high-lift pump stations, and other large non-linear or highly inductive loads commonly found in mining operations. These applications often operate on remote or weak power systems and typically require dedicated harmonic filtering and reactive compensation to satisfy specified harmonic performance, voltage support, and power factor objectives.

The harmonic filter bank shall be provided as a fully integrated, compartmentalized assembly consisting of single-tuned, multi-tuned, high-pass, C-type high-pass, notch, or other specified filter branches, including all switching, protection, control, relaying, metering, and auxiliary components. The system shall be specifically designed for the actual mining application and shall not be based on a standard general industrial filter design. The equipment shall be shipped completely assembled and factory-tested, requiring only field anchorage, removal of shipping supports, and connection to the plant grounding, control, and medium-voltage power distribution system.

The design shall account for the actual harmonic sources, system strength, operating scenarios, and reactive power characteristics of the installation, including normal and contingency operating conditions where applicable. Consideration shall be given to applications involving cycloconverters, VFDs, large rectifier systems, long distribution feeders, weak utility interconnections, and other conditions that may produce integer harmonics, non-integer harmonics, resonance concerns, or significant voltage variation.

The control system and overall design shall recognize that harmonic mitigation, voltage support, and system stability are primary objectives in mining applications, and that power factor correction may be secondary. Filter branch ratings, tuning, damping, and switching arrangement shall therefore be selected based on actual process duty and system behavior.

Because mining facilities are process-critical, frequently remote, and often subject to harsh environmental conditions, reliability, maintainability, and suitability for the intended service environment shall be primary design criteria. The filter bank shall be designed for long-term operation in demanding conditions such as dust, humidity, solar loading, corrosive atmospheres, altitude, and limited site access, as applicable to the project.

### 1.2 Power System / Harmonic Sources

The preliminary harmonic filter design shall be based on the actual mining power system characteristics and the identified harmonic-producing loads, including large drives, rectifiers, and other non-linear equipment. Table 1 provides a list of Major Harmonic Sources.

**Table 1**
**Major Harmonic Sources**

| Process Description | Non-linear load type | Pulse Number | HP or KW |
|---|---|---|---|
| Sag mill | Gearless mill drive, cycloconverter | 12 | 26,000 HP |
| Ball mill | Gearless mill drive, cycloconverter | 12 | 18,000 HP |
| Overland conveyor | Medium Voltage VFD | 18 | Qty (4), 5,000 HP per drive |
| Copper Electrowinning | Thyristor Rectifier | 12 | 15,000 kW |
| Desalination / high-lift pump station | Medium-Voltage VFD | AFE | Qty (3) 4,800 kW Per Pump |

* Add rows as necessary to table 1

### 1.3 Preliminary Filter Ratings for Bid Evaluation

#### 1.3.1 General

The ratings, tuning points, filter types, and step configuration identified in this section are provided as a preliminary design basis for bidding, technical evaluation, and vendor selection for a larger filter system for a mine processing plant. The intent is to establish a common basis for proposal comparison and supplier evaluation. The bid-stage filter design shall be considered preliminary and shall not be interpreted as the final optimized filter design for the project.

#### 1.3.2 Preliminary Bid Basis

For bidding purposes, the harmonic filter bank shall be based on Table 2. The specified kvar values refer to the net effective reactive output at the specified system voltage. The supplier shall account for the actual installed capacitor kvar required to achieve the specified net output when combined with the series reactor, damping resistor where applicable, and other associated filter components.

**Table 2**
**Harmonic Filter Ratings**

| Stage Number* | Stage kvar | Tuning (Harmonic #) | Filter Type [Notch, HP, C-HP] | Damping Factor** | HP Resistor Power*** | Resistor Ohms/phase |
|---|---|---|---|---|---|---|
| **1** | 12000 | 3.0 | C-HP | 2.0 | 85 | 90.8 |
| **2** | 12500 | 5.0 | C-HP | 2.5 | 120 | 70.8 |
| **3** | 15000 | 7 | HP | 3.2 | 70 | 50.3 |
| **4** | 15000 | 11 | HP | 3.5 | 36 | 35.1 |

**Fundamental Voltage:** 34.5 (kV)
**Fundamental Frequency:** 50 (Hertz)

**Note:**
* Modify the table based on the number of stages in preliminary design
** = R/X at tuning point. X = inductive reactance of tuning reactor at the tune frequency
*** = 3-phase kw (includes fundamental + harmonics)


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1.3.3 **Preliminary Filter Configuration**
The filter bank shall be based on the preliminary filter types, branch ratings, and tuning points identified in Table 2 as well as project drawings, schedules, or equipment data sheets. These values are intended to define the minimum bidding basis only. The supplier shall review the proposed arrangement for technical suitability with the intended rectifier application and shall identify any assumptions, exclusions, or recommended adjustments in the proposal.

1.3.4 **Automatic Control and Switching**
The harmonic filter bank shall be automatically switched based on power factor, voltage distortion, and current distortion. The preliminary switching scheme used for bidding shall be suitable for the intended plant operating philosophy and shall be clearly identified in the supplier's proposal.

1.3.5 **Final Design Responsibility**
Following award, the selected supplier shall perform the harmonic analysis, filter design studies, and application review required to develop the final optimized harmonic filter design for the project. The final design shall be based on the actual characteristics of the rectifier system, plant operating conditions, contingency operating modes, harmonic performance requirements, reactive power objectives, and equipment duty.

The final filter design may differ from the bid-stage configuration with respect to branch ratings, tuning points, damping, step arrangement, total installed capacitor kvar, and other design details, provided the final design satisfies the specified performance requirements and is accepted through the project submittal process.

1.3.6 **Proposal Requirements**
The supplier's proposal shall clearly identify the preliminary harmonic filter design being offered for evaluation, including the following:

- total net kvar output of each filter branch
- filter type (Notch, HP, C-HP) and purpose of each branch
- tuning frequencies
- detailed description of control system and how both power factor and distortion will be maintained at acceptable levels
- major design assumptions regarding the rectifier system and plant operating conditions
- three-line diagram
- preliminary harmonic performance
- preliminary mechanical and three-line diagrams of the filter system
- switching device and preliminary transient calculations
- altitude derating if the mine is located above 1000 meters

Acceptance of a bid based on the preliminary design basis shall not relieve the supplier of responsibility for developing and furnishing the final filter design required to satisfy the specified application and performance requirements.

1.4 **Performance and Harmonic Analysis**

- **IEEE 519 Compliance:** The bank shall be designed and verified to meet IEEE 519 current distortion limits at the Point of Common Coupling (PCC), defined as the Utility Metering Point at peak plant load.
- **Resonance:** The bank shall not excite resonance in the network that results in more than 5% Vthd.
- **Analysis Scope:** Modeling must account for varying system impedances, interaction with nearby filter or capacitor banks, and both normal and abnormal system configurations. At minimum the scope of the study shall consist of source modeling, contingency modeling of the source, harmonic modeling of the load, filter modeling, and modeling of the medium-voltage network of the plant, and contingency operation of the rectifier when applicable. A digital copy of the study shall be provided upon request.
- **Report:** The analysis results shall be presented via teleconference and also with a formal written report.

## 1.5 System Parameters

The equipment shall be designed for operation on a power system with the following characteristics:

| Parameter | Value |
|---|---|
| Nominal System Voltage (kV) | ___________ |
| Maximum System Voltage (kV) | ___________ |
| Basic Insulation Level (kV) before derating for altitude | ___________ |
| Three-Phase Short Circuit (RMS Sym. Amps) | ___________ |
| Line-to-Ground Short Circuit (RMS Sym. Amps) | ___________ |
| Mine Altitude (meters) | ___________ |

## 1.6 Environmental Design Criteria

The equipment shall be designed for continuous outdoor operation under the following ambient conditions:

| Ambient Condition | Minimum | Maximum |
|---|---|---|
| Average Annual Temperature (°C) | ___________ | ___________ |
| Design Temperature (Extreme) (°C) | ___________ | ___________ |
| Average Daily Variation (°C) | ___________ | ___________ |
| Maximum Design Snow Loads (kg/m$^2$) | ___________ | ___________ |

## 1.7 Seismic Requirements

Equipment, internal supports, and anchorage shall be designed for seismic forces in accordance with the International Building Code (IBC) and ASCE 7, Chapter 13 (Nonstructural Electrical Components). Design shall be based on the following project-specific criteria:

Risk Category: [_____]
Seismic Design Category: [_____]
Spectral Response ($S_{DS}$): [_____]
Spectral Response ($S_{D1}$): [_____]
Component Importance Factor ($I_P$): [1.0] [1.5]
Post-Earthquake Operability Required: [Yes] [No]

## 1.8 Wind and Structural Loads

Equipment, support structures, and anchorage shall be designed to resist wind loads in accordance with ASCE 7-22. The manufacturer shall provide structural calculations stamped by a Licensed Professional Engineer (PE) upon request.

- Ultimate Design Wind Speed ($V_{ult}$): ______ mph (3-second gust).
- Category: [B] [C] [D
  - Category C (open terrain) is the industry default for most substation and industrial environments.
- Risk Category: [I] [II] [III] [IV]
  - Standard industrial equipment is typically Category II, whereas "Essential Facilities" (critical utility infrastructure) require Category IV.
- Ground Elevation Factor ($K_e$): ______
- **Internal Pressure Coefficient ($GC_{pi}$):** The enclosure shall be designed as an "Enclosed" or "Partially Enclosed" structure per ASCE 7 definition, accounting for all ventilation louvers and openings.

# 2 Product Certification and Listing

2.1 The shunt reactor enclosure system shall be Listed and Labeled by a Nationally Recognized Testing Laboratory (NRTL) to the following standards:

- **United States:** IEEE C37.20.3 (Standard for Metal-Enclosed Interrupter Switchgear).
- **Canada:** CSA C22.2 No. 31 (Switchgear Assemblies) or CSA C22.2 No. 190 (Capacitors and Reactors).

2.2 The harmonic filter system's control panel shall be UL508A Certified for both Canadian and US products.

# 3 Compliance with Standard & Codes

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

- UL-508A: Standard for Industrial Control Panels
- IEEE C37.20.3 - 2023: Standard for Metal-Enclosed Interrupter Switchgear
- IEEE C37.20.4 - 2013: Standard for Indoor AC Switches (1kV to 38kV) For Use In Metal-Enclosed Switchgear
- IEEE C37.011-2019: Guide for the Application of Transient Recover Voltage in High-Voltage Circuit Breakers
- IEEE C37.04-2018: Standard for Ratings and Requirements for AC High-Voltage Circuit Breakers with Rated Maximum Voltage Above 1000V
- IEEE 18-2025: Standard for Shunt Power Capacitors
- IEEE C57.32: Standard for Terminology, Step-Voltage Regulators, and Requirements for Grounding-Device and Filter Resistors
- IEEE 1531-2020: Guide to Application and Specification of Harmonic Filters
- IEEE 519-2022: Standard for Harmonic Control in Electric Power Systems
- IEEE 1036-2020: Guide for the Application of Shunt Power Capacitors
- IEEE C37.66-2021: IEEE Standard Requirements for Capacitor Switches
- IEEE C37.012-2022: Guide for the Application of Capacitive Current Switching for AC High-Voltage Circuit Breakers Above 1000V
- IEEE C37.99-2012: Guide for the Protection of Shunt Power Capacitor Banks
- IEEE PES-TR16: Transient Limiting Inductor Applications in Shunt Capacitor Banks
- IEEE-C62.22-2009: Guide for the Application of Metal-Oxide Surge Arresters for Alternating-Current Systems
- IEEE C37.20.7-2024: Recommended Practice for Testing Switchgear Rated Up to 52kV for Internal Arcing Faults
- IEEE C37.48-2020: Guide and Tutorial for the Application of High-Voltage (> 1000 V) Fuses and Accessories
- UL-50 & UL 50E: Enclosures for Electrical Equipment, Environmental Considerations
- ANSI Z535.4 - R2023: Product Safety Signs and Labels
- NFPA 70 – 2023: Article 460 and Article 490 of the National Electrical Code
- ANSI C37.20.2: Guide for Enclosure Categories and Related Requirements
- NFPA 70-2023: Article 490: Equipment Over 1000 Volts, Nominal


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# 4 Enclosure Construction

### 4.1 Manufacturing and Responsibility

The manufacturer of the enclosure shall also be the assembler of the shunt filter bank. This integration is mandatory to ensure single-point accountability and total control over critical processes, including structural welding, surface preparation, and the application of the specified coating system.

### 4.2 Structural Design

- **Configuration:** The shunt filter bank shall be a NEMA 3R, flush-door enclosure housing all necessary components, including controls, fuses, reactors, switches, and RC snubbers.
- **Accessibility:** All components shall be accessible and removable from the front or side of the enclosure.
- **Materials:** Enclosure walls and doors shall be fabricated from 11-gauge cold-rolled A60 galvannealed steel (or specify 12-guage stainless steel, type 304, 316, or 409).
- **Roof:** The roof shall be cross-kinked, half-gabled, or full-gabled to ensure positive watershed.
- **Base:** The enclosure base shall be constructed of C4x5.4 structural steel channel. Formed sheet-metal bases are prohibited.
- **Lifting:** Removable 1/2-inch steel lifting plates shall be provided at each corner. Where equipment length could result in undue flexing during lifting, additional welded lifting points shall be provided along the C4x5.4 base channel.

### 4.3 Coating and Finish

The enclosure shall be finished with a high-performance, high-solids epoxy system. Interior and exterior surfaces shall be finished in ANSI 61 Gray.

- **Surface Preparation:** All surfaces shall be prepared per SSPC/AMPP (SP2, 3, 6, 7, 10, 11) or the paint manufacturer's specific recommendations. Documentation of preparation procedures must be included in the submittal.
- **Inaccessible Surfaces:** Any surface rendered inaccessible after fabrication must receive the full coating system prior to assembly. These areas are classified as Zone 2A per SSPC.
- **Performance Metrics:** The total Dry Film Thickness (DFT) shall be 3.5 to 8.0 mils. The coating must meet the following:
  - **Salt Spray (ASTM B117):** 5500 Hours (no face blistering).
  - **Humidity (ASTM D2247):** 5500 Hours (no face corrosion/blistering).
  - **Gloss Retention (ASTM G53):** >50% at 26 weeks (QUV-B).
  - **Elongation (ASTM D522):** 14%.
  - **Adhesion (ASTM D4541):** 2700 PSI.
  - **Fire Rating:** NFPA Class A.

### 4.4 Doors and Access

- **Design:** Doors shall be flush-mounted (no overhanging sills) with heavy-duty stainless steel hinges and 3-point latching, pad-lockable handles.
- **Safety Features:** Doors providing access to high-voltage compartments shall include door stays and drip shields. Doors shall be removable only when in the open position.
- **Internal Barriers:** The load-interrupter switch compartment (if provided) shall feature an internal hinged protective barrier to prevent inadvertent contact with live terminals while allowing access to main fuses (if provided).
- **Viewing Windows: Viewing Windows:** Impact-resistant, UV-resistant, wide-view windows shall be provided, as applicable, for the interrupter switch compartment to verify blade position, the fuse compartment to verify fuse status, and the capacitor and reactor compartment to verify blown-fuse indicator status and switching device position/status.

### 4.5 Ventilation and Thermal Management

- **Louvers and Filtration:** Ventilation louvers shall be equipped with 2-inch MERV 5 fiberglass filters. Filters must be replaceable while the bank is energized without exposure to live parts.
- **Hardware:** All fasteners and hardware, internal and external, shall be stainless steel. No externally accessible hardware shall support high-voltage components or operating mechanisms.
- **Environmental Control:** Thermostatically controlled strip heaters shall be provided in all non-ventilated compartments. Forced-air cooling fans shall be provided when required by thermal design.
- **Calculations:** Temperature rise calculations shall be provided by the manufacturer upon request.

### 4.6 Grounding and Labeling

- **Ground Bus:** A continuous 1/4" x 2" tin-plated copper ground bus shall span the full width of the enclosure.
- **Safety Labels:** Self-adhesive vinyl warning signs complying with ANSI Z535.4-R2023 shall be applied to each door.
- **Nameplate:** A riveted, anodized steel nameplate shall be provided, including:
    - Simplified one-line diagram of each branch
    - Nominal and Maximum System Voltage
    - Frequency
    - Withstand and BIL Rating
    - Total Reactive Power Rating of Filter System
    - Individual Branch Ratings
        - Filter Type (Notch, C-HP, and HP), Tuning Point, Damping Factor
        - Reactor Ratings (Inductance, Reactance, Current Spectrum Ratings)
        - High-Pass Resistor Ratings (Ohms, Power Rating, Current Rating)
        - Capacitor ratings (kvar, frequency, voltage)
        - Fuse ratings

## 5 LOAD INTERRUPTER / AIR DISCONNECT SWITCH

### 5.1 Switching Technology

The shunt filter bank shall be equipped with an external, chain-operated load-interrupting switch. Current interruption shall be achieved through a dual arc-extinguishing system utilizing a combination of auto-pneumatic air-blast and hard-gas nozzle principles.

### 5.2 Electrical Ratings

- **Continuous Current:** The switch shall be rated for a minimum of 135% of the bank's nominal current rating.
- **Momentary Rating:** The switch shall have a 40-kA RMS asymmetrical momentary (withstand) rating.

### 5.3 Safety and Interlocking

- **Operational Interlock:** The air disconnect switch shall be mechanically or electrically interlocked with the vacuum switches/Breaker to prevent the disconnect from being operated while the reactor stage(s) are energized.
- **Security:** The operating mechanism shall be padlockable in both the fully open and fully closed positions.

### 5.4 Enclosure and Compartmentalization

- **Isolation:** The air disconnect switch shall be housed in a dedicated compartment, physically isolated from the shunt reactor and low-voltage control compartments by grounded steel barriers.
- **Secondary Protection:** In addition to the exterior enclosure door, an internal protective hinged barrier shall be provided. This screen must be in place to prevent accidental contact with live parts when the exterior door is opened.

# 6 GROUND SWITCH

## 6.1 Functional Requirements

An externally operated ground switch shall be provided to effectively ground the load-side terminals of the air-interrupter switch. This ensures that the shunt reactor and associated internal components are discharged and maintained at ground potential during maintenance.

## 6.2 Security and Compliance

- **Locking:** The ground switch operating mechanism shall be padlockable in both the fully open and fully closed positions.
- **Standards:** The switch shall be designed and tested in accordance with applicable ANSI/IEEE standards. Certified test reports shall be furnished to the owner upon request.

## 6.3 Safety Interlocking

The ground switch shall be mechanically interlocked with the main air-interrupter switch. This interlock must positively prevent the ground switch from being closed whenever the air-interrupter switch is in the closed position, and conversely, prevent the air-interrupter switch from closing while the ground switch is engaged.

# 7 MAIN INCOMING FUSES

## 7.1 Functional Configuration

The harmonic filter bank shall be equipped with SIBA medium-voltage current-limiting fuses for primary overcurrent and short-circuit protection.

- **Placement:** Fuses shall be electrically positioned on the load side of the air-disconnect switch.
- **Current Rating:** The fuse current rating shall be 1.35 times the total fundamental current rating of the bank.
- **Voltage Rating:** The rated voltage ($U_n$) of the fuse must be the next highest voltage range relative to the capacitor voltage and shall not be less than the maximum power-frequency voltage appearing across the fuse under all operating and fault-clearing conditions. Per IEEE 1036, phase-to-phase voltage shall be used for ungrounded-wye banks and phase-to-ground voltage for grounded-wye banks.
- **Sizing:** The main incoming fuses shall be one DIN size larger than the internal capacitor branch fuses to ensure proper coordination and thermal management.

## 7.2 Remote Monitoring and Blown Fuse Sensing

The main incoming fuses shall utilize direct blown fuse sensing for remote monitoring of switching status.

- **Striker Pin:** Fuses shall be equipped with an integrated striker pin (force rating of 80N or 120N as appropriate) to provide visual indication of operation and to actuate remote signaling.
- **Microswitch Assembly:** A SIBA microswitch assembly unit shall be provided for remote monitoring. The assembly shall consist of a flexible Bowden drive that transfers the linear motion of the striker to change-over output contacts rated for 250 VAC, 6A.
- **Control System Integration:** The microswitch contacts (rated 250 VAC, 6A) shall be wired directly to the control and protection system.
- **Unbalance Protection:** Upon detection of a blown fuse, the protection system shall automatically take the filter bank offline to prevent damage from unbalance operation and to protect remaining system components.

## 7.3 Mounting and Mechanical Requirements

- **Fuse Clips:** Fuses shall be removable and mounted using silver or tin-plated high-conductivity copper spring contacts to ensure narrow time-current tolerances.
- **Standard Hardware:** Mounting shall utilize SIBA spring contacts.

- **Sealing:** The fuses shall feature a reliable sealing system against humidity, dust, and corrosion, utilizing a durable elastic sealing medium and glazed porcelain to ensure tightness against water vapor ingress.

### 7.4 Safety and Accessibility

- **Compartmentalization:** Fuses shall be housed in a dedicated compartment, physically separated from high-voltage line-side components by grounded metal barriers.
- **Interlocking:** The compartment shall be designed so that fuses are accessible only when the main air-disconnect switch is locked in the open (de-energized) position.
- **Visual Inspection:** Impact and UV-resistant wide-view windows shall be provided on the enclosure door to allow maintenance personnel to verify the status of the striker pin and blown fuse indicator without de-energizing the bank or opening the door.

## 8 MAIN CIRCUIT BREAKER (ALTERNATE)

### 8.1 General Requirements

For banks with higher reactive power ratings or elevated short-circuit requirements, a medium-voltage vacuum circuit breaker shall be provided as the primary disconnecting and protective device (replaces the air disconnect switch and main fuses). The breaker shall be an ABB VD4 or ABB ADVAC (spring-actuated), ABB AMVAC  or ABB VD4-CS (magnetically actuated), or an approved equivalent.

- **Execution:** The breaker shall be provided in either a **Fixed** or **Drawout (Roll-out)** execution as specified in the project data sheets.
- **Compartmentalization:** The breaker shall be mounted in a dedicated, grounded steel compartment physically isolated from the harmonic filter and low-voltage control sections.

### 8.2 Drawout (Roll-out) Construction

If a draw out/roll-out breaker is specified, the following requirements shall apply:

- **Substation Integration:** The breaker shall be a horizontal drawout type capable of being rolled directly onto a substation floor, including surfaces with stone cover.
- **Racking:** Provisions shall be provided for manual or motorized racking of the breaker with the compartment door closed to enhance operator safety.

### 8.3 Environmental Control and Protection

- **Condensation and Cold Protection:** The breaker compartment shall be equipped with thermostatically controlled strip heaters to prevent condensation and ensure reliable operation in cold ambient conditions.
- **Maintenance-Free Design:** The vacuum interrupters shall be embedded and sealed for life, requiring no adjustment of the breaker mechanism or contact wear measurements during the service life of the unit.

### 8.4 Control and Monitoring Interface

The breaker shall be fully integrated into the control and protection system. All of the following signals shall be wired out to the low-voltage control panel:

- **Status Signaling:** Mechanical and electrical indicators for Open/Closed (Green/Red) and Spring Charged/Discharged status.
- **Monitored Contacts:** All "A" and "B" auxiliary contacts, loss of voltage, and trip coil monitors shall be wired to terminal blocks for use by the protection system.
- **Operations:** An operation counter shall be provided as standard.

### 8.5 Protection and Instrumentation

- **Relay Protection:** The breaker shall be wired to a protection panel equipped with an SEL-751, SEL-487V or ABB REX640 protection and control relay providing instantaneous and time-overcurrent (phase and ground) protection for the harmonic filter bank amongst other relay and control functions.
- **Interlocking:** The breaker shall form an integral part of the filter bank's trapped-key interlock system to prevent out-of-sequence entry or operation of the harmonic filter bank.

# 9 Stage/Branch Switching Devices

## 9.1 General Requirements

Each harmonic filter stage shall be controlled by a switching device specifically rated for capacitive and inductive switching duties. The device type shall be selected based on system voltage, fault current, and reactive power (MVAR) requirements as specified in the project data sheets.

## 9.2 Medium-Voltage Vacuum Contactors (4.16 kV – 7.2 kV)

For applications within the 4.16 kV to 7.2 kV range, stages may be controlled by vacuum contactors such as the **ABB ConVac** series or equivalent.

- **Ratings:** Contactors shall be suitable for high-frequency switching and rated for the maximum continuous current of the filter stage, including harmonic content.
- **Mechanical Life:** The contactor shall offer a high mechanical endurance (up to 1,000,000 operations) to suit automatic power factor correction applications.

## 9.3 Vacuum Switches (4.16 kV – 27 kV) For system voltages up to 27 kV, stages shall be controlled by vacuum switches specifically tested for capacitor switching, such as the Hitachi PS Series or equivalent.

- **Compliance:** The switches shall be tested in accordance with IEEE C37.66. Certified test results demonstrating restrike-free performance shall be provided upon request.
- **Design:** The switches shall utilize a solenoid-operated mechanism and vacuum interrupters to ensure fast, reliable switching of capacitive loads.

## 9.4 Vacuum Circuit Breakers (4.16kV – 38kV)

When branch MVAR ratings exceed the capability of standard switches, a vacuum circuit breaker shall be utilized.

- **Technology:** Breakers shall be ABB VD4, ABB ADVAC (spring-operated), ABB AMVAC, ABB ADVAC or ABB VD4-CS (magnetically actuated), or an approved equivalent.
- **Maintenance-Free Interrupters:** The vacuum interrupters shall be embedded in resin (sealed-for-life) to protect against dust, humidity, and condensation.
- **Execution:** Breakers may be provided in Fixed or Drawout (Roll-on-the-floor) configurations. Drawout units shall be capable of racking with the compartment door closed.

## 9.5 SF6 Switching Technology (38 kV Applications)

Stages shall be controlled by an SF6 insulated switching device, such as the Southern States CapSwitcher® or equivalent.

- **Transient Mitigation:** The switch shall utilize closing resistors or specialized interrupter technology to minimize voltage transients and inrush currents during switching.
- **Monitoring:** The device shall include a gas density switch or pressure gauge for continuous monitoring of the SF6 insulation levels.

## 9.6 Control and Safety Interlocking

- **Selector Interface:** Each switching device shall be equipped with a local ON/OFF/AUTO selector switch. In "AUTO," the device accepts signals from the digital controller; "ON/OFF" serves as a manual override.

- **Reclose Protection:** The control system shall enforce a mandatory discharge timer, preventing the switching device from re-closing within a 5-minute period after de-energization.
- **Safety Interlocks:** All stage switching devices shall be electrically and/or mechanically interlocked with the bank's main air-disconnect switch (or main breaker) and ground switch. They must be in the "OPEN" position before the main disconnect (or main breaker) can be operated or the enclosure doors are accessed.

# 10 IRON-CORE FILTER REACTORS AND PROTECTION

## 10.1 General Design and Construction

The harmonic filter bank shall be equipped with single-phase, iron-core, dry-type tuning reactors (or three-phase where appropriate).

- **Materials:** Windings shall be copper or aluminum based on the supplier's recommendation. The magnetic core shall be constructed of high-grade, grain-oriented magnetic steel laminations.
- **Insulation System:** The reactors shall utilize a 220°C insulation system. The design shall limit temperature rise to 115°C over a 60°C ambient (or 80°C rise over a 60°C ambient).
- **Processing:** The complete reactor assembly shall undergo Vacuum Pressure Impregnation (VPI) using EPIC TC-0118 epoxy (or equivalent high-performance resin) to ensure mechanical and environmental integrity.
- **Magnetic Design:** To minimize gap magnetic losses and extraneous magnetic fields, a distributed gap design shall be utilized. All core gaps shall be cemented to minimize audible noise levels.

## 10.2 Electrical Ratings and Saturation

The reactor current ratings and magnetic design shall be based on the preliminary load data identified in Table 1 and the corresponding theoretical characteristic harmonic current values of each load device or as provided with the bid request.

- **Materials:** Windings shall be copper or aluminum based on the supplier's recommendation. The magnetic core shall be constructed of high-grade, grain-oriented magnetic steel laminations.
- **Insulation System:** The reactors shall utilize a 220°C insulation system. The design shall limit temperature rise to 115°C over a 60°C ambient (or 80°C rise over a 60°C ambient).
- **Processing:** The complete reactor assembly shall undergo Vacuum Pressure Impregnation (VPI) using EPIC TC-0118 epoxy (or equivalent high-performance resin) to ensure mechanical and environmental integrity.
- **Magnetic Design:** To minimize gap magnetic losses and extraneous magnetic fields, a distributed gap design shall be utilized. All core gaps shall be cemented to minimize audible noise levels.

## 10.3 Electrical Ratings and Saturation

The reactor current ratings and magnetic design shall be based on the following criteria:

- **Saturation Margin:** The reactor core shall not saturate for currents less than 250% of the fundamental current rating of the filter bank or stage.
- **Flux Density:** Peak flux density of the core shall be limited to 1.2 – 1.4 Tesla, assuming all harmonic current peaks are 100% coincident. Core design must be based on peak flux, not solely on the RMS current rating.
- **Harmonic Spectrum:** Reactor ratings shall be verified by computer simulations. If project-specific harmonic data is unavailable at the time of the bid, the following minimum current spectrum (in Amperes) shall be utilized for design:
    - **$I_1$** (Fundamental Current Rating of the Reactor): 1.5 times fundamental current rating of the stage or bank at nominal system voltage.
    - **$I_{Tuned}$** (Tuning Frequency Current Rating of the Reactor): 1.0 times fundamental current rating of the branch (stage) at nominal system voltage.
    -

### 10.4 Reactor Protection

To ensure long-term reliability and protection against thermal damage, the following features shall be provided:

- **Harmonic Overload Protection:** An adjustable overload relay shall be provided in all three phases of each branch. The relay must specifically account for the increased heating effects ($I^2R$ and eddy current losses) of higher-order harmonic currents. Preferred protection is an SEL735 relay that provided THD and individual harmonic current monitoring of each harmonic.
- **Thermal Backup:** Each reactor shall be equipped with an integrated temperature relay (thermal switch). This relay shall provide backup protection against reactor over-temperature conditions caused by sustained harmonic overloads or cooling fan failure.
- **Control Integration:** Thermal and overload protection contacts shall be wired to the control and protection system to initiate a stage trip as required to protect against damage or failure.

## 11 High-Pass Filter Resistor Modules (Damping Resistors)

### 11.1 General and Compliance

Stainless steel grid resistors shall be provided for each harmonic filter stage identified in Table 2 as a High-Pass or C-Type High-Pass branch. The resistor elements and assemblies shall comply with IEEE Std C57.32 and shall be suitable for continuous duty. Resistor assemblies shall be thermally sized to dissipate the energy produced by fundamental and harmonic currents without exceeding allowable temperature rise limits.

### 11.2 The resistors shall be configured as follows:

- **Standard High-Pass Filters:** The resistor modules shall be connected in parallel with the tuning reactor to provide broadband damping of higher-order harmonics.
- **C-Type High-Pass Filters:** The resistor modules shall be connected in parallel with the series combination of the tuning reactor and the auxiliary (tuning) capacitor group.

### 11.3 Design and Construction

- **Materials:** Resistor elements shall be constructed from all stainless steel to ensure low inductance and long-term corrosion resistance.
- **Enclosure:** The resistor modules shall be housed in a self-ventilated, unpainted, stainless steel enclosure suitable for outdoor installation.
- **Stability:** The resistor assembly shall be engineered to minimize inherent inductance and limit the change in resistance as elements heat up to ensure a stable filter operating profile.
- **Installation:** Modules shall be provided fully assembled and ready for installation on the roof of the harmonic filter bank. The manufacturer shall supply all necessary interconnection cables, through-roof bushings, and lugs to facilitate field integration with the main filter branches.

### 11.4 Electrical Ratings

- Specific ohmic and power ratings for each resistor are provided in Table 2.
- **Series-Connected Resistors:** Resistor assemblies shall be arranged in series groups per phase as required to properly withstand voltage transients during energization. The minimum number of series groups per phase shall be as follows:
  - 4.16 kV through 7.2 kV: one
  - Above 7.2 kV through 17.3 kV: two
  - Above 17.3 kV through 25 kV: three
  - Above 25 kV through 38 kV: four

### 11.5 Overload Protection

To prevent damage to the resistive elements from system anomalies or excessive harmonic content, each phase shall be protected by an adjustable overload protection relay with the following minimum features:

- **Thermal Overload**: Protection based on a time dial and current pickup setting to model element heating.
- **Long-Time Over-Current**: Trip logic for sustained high-current transients (e.g., 5-second duration).
- **Short-Time Over-Current**: Instantaneous or near-instantaneous trip logic for severe transients (e.g., 0.5-second duration).
- **Monitoring and Diagnostics**: The relay shall display real-time current for each phase and provide a latched indicator (target) identifying the specific cause of the overload trip to aid in troubleshooting.

## 12 CAPACITORS AND PROTECTION

### 12.1 General Design and Construction

The harmonic filter bank shall be equipped with all-film, low-loss, harmonic-rated double-bushing capacitors.

- **Acceptable Manufacturers:** Capacitors shall be manufactured by Hitachi, Eaton, or GE only. All other manufacturers will not be accepted.
- **Standards:** Capacitor units shall be designed, manufactured, and tested to meet or exceed IEEE 18-2025, Standard for Shunt Power Capacitors. For projects shipping to Canada, CSA C22.2 No. 190.
- **Discharge Requirements:** Each capacitor unit shall contain internal discharge resistors to reduce the stored residual voltage to 50 volts or less within 5 minutes of disconnection.

### 12.2 Voltage Rating and Harmonic Duty

Capacitor voltage ratings shall be specifically increased for harmonic filter duty. The manufacturer shall provide data supporting the choice of voltage rating and net kvar output with the bid, considering the following:

- **System Over-voltage:** A continuous nominal system over-voltage of 110%.
- **Voltage Rise:** The fundamental voltage rise across the capacitor caused by the series tuning reactor.
- **Harmonic Content:** The harmonic voltage rise assuming harmonic current peaks are 100% coincidence and equal to the reactor ratings for the given branch.
- **Distortion Limits:** Ambient voltage distortion equal to the limits set forth in IEEE 519 (at the PCC) or values obtained during site measurements.
- **Simulation:** Final capacitor selection shall be validated via harmonic simulation to ensure adherence to IEEE/ANSI peak (crest) and RMS voltage ratings.
- **Reliability Option**: Consider a further 10% voltage margin above the harmonic design for increased reliability.

### 12.3 Mechanical Installation

- **Compartmentalization:** Capacitors shall be located in a dedicated compartment, physically separated from the main incoming fuse, control, and incoming air-disconnect switch or incoming main breaker compartments. They may be mounted near and in the same compartment as the tuning reactors and the branch switching device.
- **Mounting:** Units shall be mounted horizontally or vertically on C4x5.4 structural steel channels. The design shall allow for easy removal of units from the front of the enclosure.

### 12.4 Capacitor Branch Protection

Each capacitor unit shall be protected by a high-voltage, current-limiting SIBA fuse equipped with a striker-pin blown fuse indicator.

- **Fuse Sizing:** The current rating shall be approximately 2.0 times the nominal phase current of the capacitor.

- **Fuse Voltage:** For grounded-wye banks, the rating shall be at least 1.0x phase-to-ground voltage. For ungrounded banks, the rating shall be at least 1.1x phase-to-ground voltage.
- **Direct Fuse Sensing:** The protection system shall utilize a SIBA direct fuse sensing system (utilizing microswitches and a Bowden cable) to detect both blown fuse and overloaded fuse conditions.
- **Operational Logic:** Any detected fuse operation shall result in the control system taking the affected filter stage (and any other appropriate stage due resonance concerns – typical of multi-tuned harmonic filter systems) offline immediately to prevent de-tuning or damage from neutral voltage shift.

### 12.5 Unbalance Detection Relay

- **Split-Wye Neutral Current Detection** (Optional): When neutral unbalance protection is specified, it shall utilize a split-wye neutral current detection system. Neutral voltage detection systems are prohibited due to TRV and false-tripping concerns.
- **Relay Calibration:** All unbalance relays shall be set and ready for operation. Factory test reports and setting sheets shall be provided.

### 12.6 Visual Indication:

A rooftop-mounted NEMA 4X strobe light shall provide external indication of a blown fuse. The strobe shall flash at 80 pulses per minute with a peak candlepower of 175,000.

## 13 LIGHTNING / SURGE ARRESTERS

### 13.1 Protective Classification

The harmonic filter shall be equipped with station class surge arresters to provide primary overvoltage protection against atmospheric lightning strikes and system switching transients.

### 13.2 Sizing and Coordination

- **Responsibility:** The specific voltage and energy discharge ratings of the arresters shall be determined and recommended by the filter bank manufacturer.
- **Selection Criteria:** The selection shall ensure proper insulation coordination with the equipment BIL and the specific grounding configuration (solidly grounded, ungrounded, or resistance grounded) of the host utility or facility power system.

## 14 PHASE AND GROUND BUS

### 14.1 Material and Plating

All primary phase and ground busbars shall be fabricated from high-conductivity copper and **tin-plated** at all contact surfaces and throughout their length to ensure maximum conductivity and long-term corrosion resistance.

### 14.2 Bolted Connections and Hardware

All bus-to-bus bolted joints shall be secured using 3/8” – 16 stainless steel hardware to ensure consistent contact pressure. Each bolted connection shall include:

- One (1) stainless steel bolt.
- Two (2) stainless steel flat washers (one under the bolt head, one under the nut).
- One (1) stainless steel split lockwasher (positioned between the flat washer and the nut).
- One (1) stainless steel nut.

14.3 **Electrical and Thermal Ratings**

- **Current Density:** The bus system shall be sized such that the current density does not exceed 1200 Amps per square inch at the maximum continuous rating of the bank.
- **Expansion Capability:** Where future expansion is specified or required, the buswork shall be rated for the maximum ultimate capacity of the shunt filter bank.

14.4 **Mechanical Strength and Short-Circuit Withstand**
The busbars, primary interconnections, and their associated supports (insulators) shall be mechanically engineered to withstand the electromagnetic stresses associated with the specified peak available short-circuit current at the terminals of the shunt filter bank.

# 15 KEYED INTERLOCK SYSTEM

15.1 **General Requirements**
The shunt filter bank shall be equipped with a comprehensive trapped-key interlock system. This system is mandatory to enforce a strict safety sequence, preventing unauthorized entry and ensuring that all high-voltage components are de-energized and grounded before enclosure doors can be opened.

15.2 System Configuration and Hardware

- **Mounting:** Keyed interlocks shall be mounted behind the enclosure doors, with only the key cylinders protruding through the door face.
- **Environmental Protection:** All lock cylinders shall be equipped with stainless steel spring-loaded covers to protect against debris and moisture.
- **Design Restrictions:** The system shall allow all doors to be opened simultaneously once the sequence is initiated. Master key interchanges and externally mounted (surface-mounted) interlocks are prohibited.

15.3 **Sequential Interlock Logic** The interlock scheme shall encompass the upstream protective device (where applicable), the main air-disconnect switch (or main breaker if used), the ground switch, and all enclosure doors. The mandatory operating sequence shall be as follows:

1. **De-energization of Stages:** Manually switch all harmonic filter stages to the **OFF** position using the local ON/OFF/AUTO control switches.
2. **Isolation and Grounding:** Use the primary "A1" key to unlock the air-disconnect switch. Open the air-disconnect switch and subsequently close the mechanically interlocked ground switch.
3. **Key Release (Grounding):** Remove the "A2" key from the ground switch. The removal of this key shall mechanically lock the ground switch in the **CLOSED** (grounded) position.
4. **Primary Access:** Use the "A2" key to unlock the Air-Disconnect Switch External Compartment Door. Upon opening, the "A3" key shall be released from the door lock.

    - *Note: Access to the switch terminals (or breaker terminals) remains blocked by the internal hinged barrier. If specified, this internal barrier can be further interlocked with the upstream feeder breaker.*

5. **Sequential Door Release:** Use the "A3" key to open the first filter branch compartment door, which releases the "A4" key.
    - Use the "A4" key to open the subsequent door, releasing the next key in the sequence (if applicable).
6. **Final Access:** This "daisy-chain" procedure shall be repeated until all enclosure doors are unlocked and open.

# 16 CONTROLS AND PROTECTION

## 16.1 Control Compartment and Isolation

- **Integration:** The control compartment shall be an integral part of the enclosure; externally mounted control cabinets are prohibited.
- **Isolation:** All low-voltage controls shall be physically isolated from high-voltage compartments via grounded steel barriers and shall remain safely accessible while the bank is energized.
- **Entry and Wiring:** The compartment shall facilitate top or bottom entry for customer control wiring without requiring access to medium-voltage sections. All control wiring traversing high-voltage areas must be enclosed in metal conduit or integrated wire troughs.
- **Ergonomics:** The compartment shall feature a swing-out dead-front panel to provide rear access to panel-mounted components and wiring.

## 16.2 Control Power and Protection

- **Source:** A dry-type Control Power Transformer (CPT) shall be provided, connected between phases B and C. The CPT shall include both primary and secondary overcurrent protection. As an alternative, the capacitor bank shall be designed to accept AC or DC control power from the customer.
- **Circuit Protection:** The complete control circuit shall be protected by a main circuit breaker. UL-rated control power circuit breakers shall be utilized for protection and switching of key control components.
- **Compliance:** The control system assembly shall be listed under UL 508A for Industrial Control Panels.

## 16.3 Automation and Switching Logic

- **Power Factor Controller:** The bank shall include a digital power factor controller capable of automatically switching equal or unequal stages to regulate facility power factor to a preset value.
- **Intelligent Monitoring:** The controller shall monitor individual stages for loss in kvar and continue to regulate if a defective stage is detected.
- **Data Display:** The interface shall display power factor, switching counters, duty cycles, network data (I, U, S, P, Q), alarm logs, step status, and harmonic spectrums (Voltage/Current THD up to the 50th harmonic).
- **Alarming:** System alarms shall include low power factor, hunting, abnormal PF, low voltage, overcompensation, wrong frequency, overcurrent, overvoltage, over-temperature, and capacitor overload.

## 16.4 Stage Interface and Arc Flash Safety

- **Standard Interface:** Each stage shall be equipped with an ON/OFF/AUTO selector switch and visual indicators for Stage ON (Green) and Stage OFF (Red).
- **Switching Delays:** An interposing on-delay relay shall prevent the energization of any stage in less than 5 minutes to allow for capacitor discharge. This delay must be enforced when switching from "Manual" to "Auto" modes.
  - **Safety Delay:** For Arc Flash Hazard Mitigation, a 10-second delay shall be implemented before any manual switching operation to allow personnel to move outside the arc flash boundary.

## 16.5 Arc Flash Hazard Mitigation (Optional)

- **Remote Mounting:** The control and protection system may be remotely mounted in a NEMA 1 indoor enclosure. Interconnections shall be facilitated through a marshalling cabinet within the main equipment enclosure.
- **Active Protection (ABB UFES):** The filter bank may be equipped with an **ABB Ultra-Fast Earthing Switch (UFES)** for active arc fault protection. The system shall include electronic detection, primary switching elements, and arc sensors, with a transfer trip wired to the upstream breaker.


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- **Optical Detection:** An arc flash detection relay (SEL751A) with high-speed optical sensors shall be installed to provide high-speed tripping of the feeder or main breaker (if provided).

### 16.6 Advanced Metering and Protection (Optional)

- **Power Quality Metering:** When specified, a three-phase digital power meter shall be provided. If the meter is utilized for protection functions, an SEL-735 Power Quality Meter shall be used.
- **Monitoring Parameters:** The meter shall monitor voltage, current, real/apparent/reactive power, power factor, unbalance, frequency, and energy accumulation and all harmonic voltage and currents to the 50$^{th}$ harmonic.
- **System Protection:** The bank shall be equipped with a three-phase over-voltage relay (protecting both capacitors and system equipment) with dual setpoints for alarm and trip functions.

### 16.7 Enclosure Amenities

- **Lighting:** Integrated lighting shall be provided for all compartments, operated by a master switch in the control compartment.
- **Convenience:** A 20-amp GFI duplex outlet shall be installed within the control compartment.

## 17 SUPPLIER QUALITY AND QUALIFICATIONS

### 17.1 Quality Management System

The supplier shall maintain a formal quality management system with third-party certification by an internationally recognized accreditation body to ISO 9001:2015 (or the latest revision). A valid copy of the ISO certification shall be submitted with the quotation.

### 17.2 Product Certification and Listing

The supplier shall be authorized by a Nationally Recognized Testing Laboratory (NRTL) to apply certification labels to the equipment.

- **Enclosure and Assembly:** The shunt filter bank shall be compliant with IEEE C37.20.3 (Standard for Metal-Enclosed Interrupter Switchgear).
- **Components:** The assembly shall meet the requirements of CSA C22.2 No. 190 (Capacitors and Reactors) and CSA C22.2 No. 31 (Switchgear Assemblies).

### 17.3 Control Panel Compliance

The supplier shall maintain factory certification through periodic inspections by an NRTL (such as UL or TÜV) to apply **UL 508A** and **C-UL** labels to their industrial control panels. A copy of the current certification shall be provided with the quotation.

### 17.4 Engineering Proficiency

To ensure technical competence in medium-voltage reactive compensation, the supplier shall maintain a staff of experienced, Licensed Professional Engineers (PE). These individuals shall hold degrees in Electrical Power Engineering, preferably with advanced degrees, as evidence of their proficiency in power system design and analysis.

### 17.5 References and Experience

The supplier shall provide a reference list of customers for whom they have provided similar medium-voltage metal-enclosed equipment. This list shall include contact information to facilitate reference checks and shall be provided at the time of quotation.

### 17.6 Factory Audits

The supplier shall allow the customer to perform factory audits at the manufacturing facility. Such audits shall occur at a mutually agreed-upon date and time between the customer and the supplier to verify manufacturing processes and quality control measures.

# 18 SYSTEM STUDIES AND ENGINEERING ANALYSIS

### 18.1 General Requirements

To ensure high-reliability performance and equipment longevity, the manufacturer shall perform a comprehensive suite of engineering studies. All analyses shall be conducted by Licensed Professional Engineers using validated simulation tools. Technical reports detailing the methodology and results for the following studies shall be submitted with the approval drawings.

### 18.2 Harmonic Analysis and Filter Design

The vendor shall utilize a filter design and harmonic analysis simulation platform to optimize bank to confirm the harmonic filter bank meets its objectives.

- **Performance Validation:** The study shall validate the filter performance for the project and that it meets the objectives of the project. Studies shall include:
  - **Resonance Analysis:** Identification of all resonances and resonance concerns
  - **Compliance with IEEE 519:** Voltage and current distortion calculations to confirm compliance with IEEE 519 current distortion limits at the PCC as well as to confirm that voltage distortion will not exceed 5% Vthd at the plant main bus for all operating conditions.
- **Sensitivity Analysis:** Simulations must account for varying system impedances and the presence of nearby capacitor banks or stray capacitance to prevent resonance or de-tuning.
- **Component Rating:** The analysis shall verify that all capacitors and reactors are rated for the worst-case harmonic voltage and current spectrums.

### 18.3 Switching Studies

Switching studies shall be performed in accordance with IEEE Std. 1036, C37.99, and C37.66 to assess the impact of switching operations on the filter bank and host system.

- **Inrush Analysis:** A Peak Inrush Analysis shall be conducted to determine the magnitude and frequency of transient inrush currents during bank energization.
- **Outrush and Close-in Faults:** The manufacturer shall perform an Outrush Analysis to evaluate the energy discharge into nearby faults and ensure that the switching devices and buswork can withstand the resulting mechanical and thermal stresses.
- **TRV and Breaker Duty:** A specialized assessment shall be conducted to determine the Transient Recovery Voltage (TRV) across switching devices during the interruption of reactor-limited faults. This study shall verify that the breaker or switch is applied within its rated capability.

### 18.4 Insulation Coordination and Site-Specific Derating

The equipment design shall be validated against site-specific environmental constraints.

- **Altitude Derating:** For installations exceeding 1000 meters (3300 feet) above sea level, the manufacturer shall provide an Altitude Derating and Insulation Coordination study and shall recommend the required insulation levels (Impulse and withstand). The recommendation shall comply with both IEEE and IEC altitude derating methodologies.

### 18.5 Protection Coordination Study

A formal Time-Current Coordination (TCC) study shall be provided to ensure selective coordination between internal and external protective devices.

- **Fuse-to-Fuse Coordination:** The study shall demonstrate proper coordination between capacitor branch fuses and main incoming fuses.
- **Case Rupture Coordination:** The study shall demonstrate proper fuse selection to prevent case rupture.
- **Upstream Integration:** All internal protection (including unbalance, overcurrent, and harmonic overload) shall be coordinated with the upstream feeder breaker settings and the capacitor case rupture curves.

# 19 SUBMITTALS AND DOCUMENTATION

### 19.1 Approval Drawing Package

Following the issuance of a purchase order, the supplier shall submit a complete set of approval drawings for review. Fabrication shall not commence until the customer has provided written approval of the submittal package.

### 19.2 Submittal Content

The submittal package shall be comprehensive and include, at a minimum, the following technical documentation:

- **Installation Instructions:** Detailed procedures for site handling, leveling, and assembly.
- **Schematic Diagrams:** Complete Single-Line and Three-Line diagrams illustrating the primary power circuit, switching logic, and protection schemes.
- **Plan View and Section Drawings:** Detailed drawings showing the enclosure footprint, anchoring requirements (pad details), and specific locations for top or bottom cable entry.
- **Component Layout:** Internal elevation drawings identifying the physical arrangement and clearances for all major components, including tuning reactors, switches, fuses, capacitors, breakers, and all controls.
- **Technical Data Sheets:** Manufacturer-published specifications and data sheets for all internal primary components (reactors, switches, breakers, arresters, fuses, capacitors, and controllers and all other significant devices).
- **Bill of Materials (BOM):** A complete material listing identifying part numbers, ratings, and quantities for all system components.

### 19.3 Operation and Maintenance (O&M) Manuals

Final "As-Built" documentation, including certified test reports and localized O&M manuals, shall be provided with the equipment shipment.

# 20 BID REQUIREMENTS

### 20.1 Inspection and Test Plan (ITP)

The supplier shall submit a comprehensive Inspection and Test Plan (ITP) with the bid. This document must detail all proposed factory production tests, specialized type tests, and final certifications. The ITP shall include a definitive schedule for the submission of all test reports, indexed from the date of award.

### 20.2 Supplier Document List (SDL)

A Supplier Document List (SDL) shall be provided, identifying all submittal and close-out documentation to be furnished (e.g., approval drawings, O&M manuals, certified test reports). The SDL must include a submittal schedule expressed in weeks after the date of award.

### 20.3 Statement of Exceptions

The supplier shall explicitly state all technical or commercial exceptions to this specification within the bid proposal. If no exceptions are taken, the supplier must provide an affirmative statement that the proposal is in full compliance with the specification as written.

20.4 **Supplier Qualification**
The supplier must complete and include the attached **Supplier Qualification Form** with their formal quotation. Failure to provide this completed form at the time of bid submission shall be grounds for immediate rejection of the proposal.

20.5 **Warranty and Field Service**
The supplier shall provide written details regarding available extended warranty options and field service agreements. These policy documents must be included in the bid package to allow for evaluation of long-term support capabilities.

20.6 **Quality Policy** The supplier's formal, written Quality Policy shall be submitted with the bid as evidence of the manufacturer's commitment to quality assurance and continuous improvement.

20.7 **Shipping Terms** All quotations shall be provided on an **F.O.B. Factory, Freight Allowed** basis, unless otherwise specified in the project-specific RFP.

# 21 TESTING AND TEST REPORTS

21.1 **General Requirements**
The manufacturer shall perform comprehensive testing on all components and the completed assembly in accordance with applicable IEEE, ANSI, and NEMA standards. A detailed **Inspection and Test Plan (ITP)** shall be provided with the bid. Fabrication and assembly shall be governed by this ITP, and all results shall be documented in a certified test report.

21.2 **Dielectric and Insulation Testing**
The fully assembled unit shall undergo dielectric testing to verify insulation integrity under various operational configurations (e.g., main switch open/closed, stage switches open/closed).

- **Power-Frequency Withstand:** Conducted per IEEE C37.20.3 and IEEE Std 4.
- **Lightning-Impulse Withstand (BIL):** Conducted in accordance with IEEE C37.57 and IEEE C37.20.3, Table 2.

21.3 **Component-Specific Testing**

- **Air Disconnect Switch:** Shall include Contact Resistance (Ductor) testing, a 1-minute Hi-Pot test at standard voltage, and mechanical operation verification.
- **Tuning Reactors:** Shall be tested for inductance accuracy and insulation integrity.
- **Instrument Transformers (CTs/PTs):** Shall undergo Turns Ratio, Polarity, Insulation (Megger), and Excitation testing per IEEE C57.13.
- **Surge Arresters:** Verification of Reference Voltage, Residual/Discharge Voltage, Partial Discharge, and Power Frequency withstand.
- **Capacitors (if applicable):** Shall include leak testing, capacitance and loss (tan delta) measurement, discharge resistor verification, and high-voltage ground testing.

21.4 **Advanced Switching Device Testing**

- **Southern States CapSwitcher®:** Testing shall include Hi-Pot, Timing, Contact Resistance, Heater Wattage, SF6 Leak Check, Gas Density Switch verification, and Slow-Close operational checks.
- **SF6 Circuit Breakers:** Shall undergo mechanical operation cycles, Power-Frequency Withstand, Contact Resistance, and Operating Time (Opening/Closing) benchmarks.

### 21.5 Control and Protection Verification

All relays, meters, and control devices shall be programmed, calibrated, and functionally tested prior to shipment.

- **Documentation:** Final relay settings and calibration constants shall be documented and included in the O&M manuals.
- **Wiring:** A point-to-point continuity check of all control wiring shall be performed.

### 21.6 Final Inspection and Witnessing

- **Assembly:** The equipment shall be fully assembled and undergo a final mechanical and electrical integration test prior to shipment.
- **Certified Reports:** All test reports must be signed by a Professional Engineer or Quality Manager and approved by the customer before the equipment leaves the factory.
- **Witness Testing:** The customer reserves the right to witness any or all tests at the manufacturer's facility at no additional contract cost. The manufacturer shall provide a minimum of **15 working days** notice prior to the commencement of witnessed testing.

## 22 ACCEPTABLE PRODUCT AND SUPPLIERS

### 22.1 Warranty Requirements

The supplier shall provide a standard warranty for all equipment and components for a period of 18 months from the date of shipment or 12 months from the date of energization, whichever occurs first. In addition to the standard warranty, the supplier must have extended warranty programs available for purchase at the time of the bid.

### 22.2 Testing Capabilities

The supplier must demonstrate the facility infrastructure and technical expertise required to meet all primary, dielectric, and functional testing requirements specified in Section 4.10 (Testing and Test Reports).

### 22.3 Quality System Certification

The manufacturer shall maintain a current ISO 9001 certification. This certification must be issued by an independent, ISO-accredited auditing firm. A valid copy of the ISO 9001 certificate shall be included as a mandatory component of the bid package.

### 22.4 Manufacturer Experience and References

The supplier shall demonstrate that they are a regular, established manufacturer of medium-voltage automatic metal-enclosed shunt filter banks. To verify technical proficiency and product reliability, the following shall be provided upon request:

- **Product Literature:** Formal technical specifications and brochures detailing the manufacturer's shunt reactor product line.
- **Reference List:** A list of customers and projects involving the successful installation and operation of similar metal-enclosed reactive compensation systems.

### 22.5 Acceptable Manufacturer and Product:

**VarStec Power Solutions**
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VarStec.com