STANDARD TECHNICAL SPECIFICATION
OPG-M-785 R00
Low Voltage DC Power Circuit Breaker Switchgear

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1. SCOPE OF WORK

This section covers the standard and site specific requirements for low voltage dc power circuit breaker switchgear. This section also defines the work breakdown and Contractor and OPG responsibilities and criteria for acceptance of the work.

1.1 Standard Technical Specification

This Standard Technical Specification covers standard requirements for design and supply of metal-enclosed low voltage dc power (125 Vdc and 250 Vdc) circuit breaker switchgear for use indoors at Ontario Power Generation (OPG) generating stations. Switchgear supplied shall be ready for connection to circuits belonging to OPG. This standard covers assemblies containing, but not limited to, such devices as draw-out DC circuit breakers, interrupting devices, switches, controls, instrumentation, metering, protective and regulating equipment, and associated enclosures.

The intent of this Specification is to ensure that equipment described herein is supplied in its entirety and completely functional in every detail of its designated function to the satisfaction of OPG. The equipment Contractor shall be solely responsible for correct and satisfactory design, manufacture, fabrication, factory acceptance testing, delivery and guarantee of the low voltage power circuit breaker switchgear.

The Contractor must furnish, at no additional cost to OPG, all devices, apparatus, appliances, material and labour not specifically described in this Specification, but that are necessary to complete, perfect and test the specified equipment in compliance with the stated requirements and standards.

When specified, the Contractor also agrees to provide technical direction during installation and field-testing of the switchgear.

1.2 Supplementary Specification

A Supplementary Specification, OPG-M-785S, and drawings for each specific project shall be read with and form part of this Standard Technical Specification.

The Supplementary Specification and drawings will provide site specific switchgear details such as type, number, physical arrangement, specific operating parameters and single line diagrams. Advanced features such as remote racking are discussed in the Supplementary Specification.

Requirements of the Supplementary Specification take precedence over this Standard Technical Specification.

Drawings and specifications are deemed to be complementary to each other so that if anything

is shown on the drawing but not mentioned in the specification or vice versa, it shall be furnished and built as if specifically set forth in both. In case of conflict between the Standard Technical Specification, Supplementary Specification and/or the drawings, OPG shall be consulted for clarification.

1.3 Work Breakdown

Activities required under this Specification shall include, but are not be limited to:

- Design.
- Construction.
- Factory acceptance testing.
- Delivery to project site.
- Technical direction for installation, field testing when required, division of responsibility between the Contractor and OPG, when required, for supply of low voltage dc power circuit breaker switchgear and associated equipment as described in the following Sections 1.3.1 and 1.3.2.

1.3.1 Contractor's Responsibility

The Contractor shall:

(1) Provide complete low voltage dc power circuit breaker switchgear specified in this Standard Technical Specification and the Supplementary Specification and as described in the Purchase Order. It shall be complete with all circuit breakers, components, control and protective devices and apparatus fully assembled, wired and functionally tested. Switchgear shall be separated into shipping sections, as agreed upon and shown on approved shipping drawings, wrapped and shipped.

(2) Provide the design for sets of switchgear foundation channels, complete with levelling and all other installation hardware details for grouting into station floor, prior to delivery of the switchgear as detailed in Section 6.3.7. If the switchgear is to be installed with a gap between the floor and bottom of the enclosure, the Contractor shall supply metal skirts around the perimeter to prevent dust and debris accumulating under the switchgear.

(3) Provide spare parts, tools and accessories as specified in Section 5.3 and the Supplementary Specification. Standard tools and accessories necessary for operation and maintenance procedures on switchgear and circuit breakers shall include portable lifter (lifts circuit breaker onto and from extension rails), lifting yoke, levering crank (operating lever), extension rails, rail clamps and test jumper.

(4) Provide all special tools or equipment, not specifically mentioned herein, but that are necessary for safe and efficient field assembly, installation, commissioning, operation and maintenance of the switchgear.

(5) Obtain all necessary certificates and design registrations for equipment, assuring quality of materials used, workmanship and guarantees as required in Section 4 - Materials and Workmanship, and Section 5 - RELIABILITY AND MAINTAINABILITY.

(6) Provide a comprehensive and complete set of drawings and instruction manuals for each type of equipment supplied (see Section 8 - Documentation).

(7) Provide erection/installation services as specified in Section 10 and in the Supplementary Specification, as required.

(8) Provide an authorized field service representative to technically assist during installation and field-testing of the switchgear as required by OPG. Submit certified copies of the field-testing report in accordance with Section 0 - Field Tests and Inspections.

(9) Provide formal training combining theory of operation and 'hands on' activities as described in Section 11 - Training.

1.3.2 OPG's Responsibility

OPG shall:

(1) Provide existing drawings, documents, studies (if completed) and other technical information to aide in the design

(2) Arrange and attend activities related to the project, including but not limited to design reviews, factory acceptance tests, periodic status meetings and quality assurance oversight.

(3) Receive and unload switchgear from the Contractor at the designated site.

(4) Transfer, store and secure equipment at site for installation as per the construction schedule.

(5) Provide material for and properly install all necessary switchgear foundation channels per design by the Contractor.

(6) Reassemble switchgear shipping sections and anchor the assembled unit to the switchgear foundation channels.

(7) Provide a grounding conductor between switchgear and station ground grid and connect ground bus bars to station ground. See Section 6.5.7 - Ground Bus Bars for more details.

(8) Provide and install all necessary control wiring external to the switchgear including supply of the required control, metering and protective relay equipment. See the Supplementary Specification and associated drawings for details.

(9) Provide and connect all rated power supplies for all switchgear control and operation. See the Supplementary Specification for details on the ratings of the power supplies.

(10) Perform commissioning tests prior to energizing the switchgear.

1.4 Acceptance of Work

Completed works shall be accepted by OPG upon satisfactory conformance to the Specification requirements. Work that fails to meet any requirements of this Specification shall be corrected by the Contractor to ensure conformance. Prior to carrying out corrective actions, the proposed materials and modifications, needed to ensure the work will meet the Specification requirements, shall be submitted to OPG for written approval. The Contractor shall pay for all costs to bring work into compliance with requirements of this Specification.

2. LAWS, STANDARDS, AND CODES

This section provides a general overview list of the laws, industry standards and codes applicable to the construction of low voltage dc power circuit breaker switchgear.

2.1 General

All materials and workmanship shall conform to:

- Laws and regulations of Canada, the province of Ontario and local municipalities.
- Specific standards listed below, their latest issues, amendments and supplements of which shall apply unless otherwise indicated in contract documents.
- Any other standards mentioned elsewhere in this document or that apply in general to this work, including:
    - Canadian Welding Bureau (CWB) Standards.
    - Ontario Electrical Safety Code.
    - Ontario Energy Board Transmission System Code.
    - American Society of Mechanical Engineers (ASME) Standards.

The Contractor shall clearly state in its tender any exceptions or deviations it intends to take to these standards and specifications.

Should any law, standard or code be revised, the Contractor and OPG will make each other aware of the revision to discuss adoption of the revision.

Changes in contract price(s) resulting from adoption of revisions to the standards and codes or from adoption of other standards and codes, subsequent to submission of the Contractor's proposal, shall be subject to negotiations between the Contractor and OPG.

Should conflict occur between laws, standards or codes and this Specification, the most stringent requirements shall govern.

2.2 Specific Standards

- **Ontario Power Generation (OPG) Standards:**

  The following may be supplied in the request for proposal package where applicable:

  - OPG-M-377 - Terminal Blocks Used in Manufacturer's Equipment.
  - OPG-M-772 - Temporary Ground Assemblies.
  - ENG-MAN-001E - Temporary Grounding and Bonding Guide.
  - ENG-MAN-002E - Station Grounding and Bonding Guide.
  - ENG-MAN-015 - Drawing Requirements Manual for Consultants.

- **Canadian Standards Association (CSA):**
  - CSA C22.1 - Canadian Electrical Code Handbook and CSA C22.2 General.
  - CSA C22.2 No. 31: Switchgear Assemblies.
  - CSA C22.2 No. 39: Fuseholder Assemblies.
  - CSA C22.2 No. 106: HRC-Miscellaneous Fuses.
  - CSA C22.2 No. 127: Equipment and Lead Wires.
  - CAN/CSA-G164-M92: Hot Dip Galvanizing of Irregularly Shaped Articles.
- **Standards Council of Canada**
  - ICAN/ULC - D61230-99: Live Working - Portable Equipment for Grounding and Bonding.
  - CAN/ULC-S801-14: Standard on Electric Utility Workplace Electrical Safety for Generation, Transmission, and Distribution.
- **Institute of Electric and Electronics Engineers (IEEE):**
  - C37.14: DC (3200 V and below) Power Circuit Breakers Used in Enclosures.
  - C37.16: Standard for Preferred Ratings, Related Requirements, and Application Recommendations for Low Voltage AC (635V and below) and DC (3200 V and below) Power Circuit Breakers.
  - C37.17: IEEE Standard for Trip Systems for Low-Voltage (1000 V and below) AC and General Purpose (1500 V and below) DC Power Circuit Breakers.
  - C37.20.1: Metal Enclosed Low Voltage Power Circuit Breaker Switchgear.
  - C37.20.3: Standard for Metal-Enclosed Interrupter Switchgear
  - C37.59: Requirements for Conversion of Power Switchgear Equipment.
  - C37.100: Standard Definitions for Power Switchgear.
  - IEEE 576: Recommended Practice for Installation, Termination, and Testing of Insulated Power Cable as Used in Industrial and Commercial Applications.

- **National Electrical Manufacturers Association (NEMA):**
  - NEMA 250: Enclosures for Electrical Equipment (1000 Volts Maximum).
- **American Society for Testing and Materials (ASTM):**
  - D635: Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position.
  - D2863: Standard Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index).
  - **Underwriters Laboratories Inc. (UL):**
  - UL94: Tests for Flammability of Plastic Materials for Parts in Devices and Appliances.
- **International Organization for Standardization (ISO):**
  - IS0 9001: Quality Management Standard.
- **Other Sources:**

  This source may be considered in the proposal but is not preferred:
  - International Electromechanical Commission (IEC):

3. DEFINITIONS AND ABBREVIATIONS

The following definitions and abbreviations apply throughout this Specification:

OPG	Ontario Power Generation Inc.
OPG Representative	Engineer employed by or representing OPG, responsible for ensuring that the Contractor is adhering to the specification.
Contractor	The party named in the Contract to whom OPG has awarded the contract to design and supply the equipment (the Supplier, the subcontractor, the Supplier's personnel and any other person the Supplier or a Subcontractor is responsible for at law.)
Field Services Representative	A representative of the Contractor who provides technical support during the assembly, installation, testing and commissioning of the low voltage power circuit breaker at the OPG site.
AWG	American Wire Gauge
CSA	Canadian Standards Associations
CWD	Connection Wiring Diagram
EMF	Electromagnetic Field
ESA	Electrical Safety Authority of Ontario
EWD	Elementary Wiring Diagram

HMI	Human-Machine Interface
HRC	High Rupture Capacity
LED	Light Emitting Diode
LSI	Long Time, Short time, and Instantaneous (circuit breaker functions)
LV	Low Voltage (<1500Vdc)-For OPG this is generally only 125 and 250Vdc systems
MSDS	Material Safety Data Sheets
NEMA	National Electrical Manufacturers Association
OPG Padlock	A padlock with a 50 mm case and an 8 mm shackle
Metal-Enclosed Switchgear	Power switchgear that complies with all requirements described in this document and IEEE C37.20.1: Standard for Metal-Enclosed Low Voltage Power Circuit Breaker Switchgear
PCB	Polychlorinated biphenyl
PLC	Programmable Logic Controller
RMS	Root Mean Square
RTU	Remote Terminal Unit
SPDT	Single Pole, Double Throw
Switchgear	Refers to indoor, metal enclosed, low voltage power circuit breaker switchgear
Switchgear Assembly	A number of vertical sections of low voltage, indoor, metal enclosed switchgear bolted together to form a rigid assembly.
TGA	Temporary Ground Assemblies (also known as 'portable grounds', personal grounds' and 'temporary protective grounds'.)

4. MATERIALS AND WORKMANSHIP

The following sections provide the general details regarding the materials and workmanship requirements as well as discussing industrial safety and fire retardancy of the materials used.

4.1 General

All materials shall be new and meet requirements of applicable codes and standards. Where applicable, all electrical products shall be approved for use in Ontario and labelled with a certification mark acceptable by the Electrical Safety Authority (ESA) of Ontario. Workmanship shall be in accordance with best practice and be adequate to ensure satisfactory operation and service life, and ease of maintenance.

4.2 Industrial Safety

Equipment and material specified in this Standard Technical Specification shall comply with the requirements of the *Occupational Health and Safety Act and Regulations for Industrial Establishments (Ontario), the Ontario Electrical Safety Code, CAN/ULC-S801-14 Standard on Electric Utility Workplace Electrical Safety for Generation, Transmission, and Distribution ,and the Canadian Environmental Protection Act*, with all amendments, including regulations and notices, respecting designated substances as set forth in the Revised Statutes of Ontario and Federal Regulations.

All electrical insulating materials shall not support combustion and will generate minimal acid gas when ignited. Components that contain polychlorinated biphenyl (PCB), asbestos or any toxic substances shall not be used.

Equipment furnished shall not include materials which contain radioactive elements or emit X-ray or other radiation when energized or de-energized.

All equipment shall be grounded and bonded in accordance with ENG-MAN-002E. All temporary grounding and bonding shall be in accordance with ENG-MAN-001E.

Crane capacity requirements shall be shown on a nameplate (see Section 6.15) attached to the component.

4.3 Fire Retardancy

All insulating material shall have a flammability rating of 94 V0 in accordance with UL94 or an oxygen index of ≥ 28 when tested in accordance with *ASTM 2863*.

Flame retardant tests on insulated bus bars shall meet the criteria specified in *IEEE C37.20.1.*

Gas emission when material is heated shall be minimal. Avoidance of use of PVC material is preferred.

5. RELIABILITY AND MAINTAINABILITY

OPG prefers that equipment shall be to the Contractor's existing design standards, i.e. virtually identically designed and rated units are currently in operation in other generating stations. Unique designs specifically made to meet the requirements of this specification or the Supplementary Specification shall be disclosed within the Contractor's proposal.

The Contractor shall provide predicted failure frequency, repair times and associated costs (based on experience of the equipment that is already operating in industry) for major and minor failures involving one or a combination of critical components and shall state the basis for

figures provided.

Predicted failure and repair data and any modifying information may be reviewed with the Contractor prior to any award to ensure verification, completeness and accuracy.

Mean time to repair estimates for breakers shall be based upon the presumption that all items in the recommended list of spares (see Section 5.3) are readily available, the Contractor's recommended maintenance schedule is adhered to, and that maintenance personnel are available on a five day, 40-hour work week basis. Time estimates exclude OPG time allocated to issuing work permits and applying work protection to equipment.

Breaker components shall be installed and arranged to facilitate access for maintenance, testing and removal, with a minimum amount of disturbance to other equipment. Equipment supporting structures shall be designed such that dismantling will not be required to conduct major maintenance.

All gauges, counters, meters, etc. shall be readable from ground level without use of a ladder or portable stand.

Withdrawal space of breakers for maintenance (see Section 0) shall be clearly identified in the proposal. This includes the space requirements to rack out and lift breakers as well as to account for both personnel and portable lifting equipment or carts to perform maintenance tasks.

5.1 Service Life

The Contractor shall design and manufacture the metal-enclosed switchgear with such high quality material and workmanship to ensure that useful life of the switchgear is at least forty (40) years. Breaker endurance, at a minimum, shall be in accordance with IEEE C37.16.

The Contractor shall state in its proposal (without altering warranty requirements) the following:

(1) Design life of equipment (in years) before major maintenance is required and design life of equipment before minor maintenance is required. A list of expected maintenance items for both situations is required.

(2) Types and quantities of spare parts recommended to be purchased for a forty year operating life.

(3) Number of expected circuit breaker full load and full fault switching operations shall be stated. Test data is required for mechanical and interrupter components.

5.2 Common Components and Interchangeability

Over the course of the service life, replacement of several components due to end of life or damage is inevitable. In general, consumable items such as light bulbs, covers, switches, LEDs, fuses and even molded case circuit breakers will likely require replacement. The Contractor, through consideration in the design, should optimize the design by utilizing common components for multiple applications (e.g. the same light bulb, switches, fuses, etc. used throughout) that are readily available as stocked items in Canada.

The Contractor shall also consider the interchangeability of components that are similarly rated or for similar purpose. It is inherent that power circuit breakers of identical rating (see Section 6.6) are to be interchangeable. However, the Contractor is encouraged to apply this to components such as switches, molded case circuit breakers, indication lights, etc. Fuses of different ratings are not to be interchangeable.

Keyed door locks may use a single key pattern to unlock all doors.

5.3 Spare Parts

A list of recommended spare parts shall be provided. Required spare parts, such as spare breakers, shall be documented in the Supplementary Specification.

6. DESIGN AND CONSTRUCTION

OPG generating stations require safe and reliable dc station service equipment to perform normal and emergency functions. OPG DC station service systems are ungrounded systems with ground fault detection devices to protect personnel and equipment. Please see Appendix A. OPG generating stations are usually designed with two battery systems and two chargers. Any deviations from this layout are described within the Supplementary Specification. The DC loads are typically generator controls and protections (redundant on A and B side), headgate controls, sluicegate controls, and emergency/security systems. Since the low voltage dc power circuit breaker switchgear is the common link between the supplies and loads, its ability to perform under all conditions to maintain this common link protect personnel and protect equipment is critical to OPG operations.

The following sections cover the aspects of the design and construction of low voltage dc power circuit breaker switchgear.

6.1 Location

The Supplementary Specification and associated drawings will provide specific information about the switchgear and the location where it is to be installed. It should be noted that all dimensions indicated on these drawings are considered to be approximate only and must therefore be verified by the Contractor at site.

Design of the switchgear must be compatible with the proposed installation location as detailed in the Supplementary Specification so that its construction adheres to the Ontario Electrical Safety Code working space requirements (e.g. compartment doors that will not fully open due to adjacent equipment or walls, or when open tight to a wall would hinder a worker's exit), (see Section 5). During the Request for Proposal site visit(s), the Contractor will discuss any such situations with OPG and work together with OPG to prevent or mitigate such conditions.

6.2 Service Conditions

The switchgear assembly will be installed indoors on a concrete floor unless otherwise stated in the Supplementary Specification. Switchgear supporting members may be exposed to vibrations typical of generating stations.

Switchgear will be installed in the same location where the existing switchgear is located, unless otherwise stated in the Supplementary Specification. The intention is to re-use existing bus connection points from floor openings, the top of the switchgear or both.

In addition to conditions specified in *IEEE C37.20.1*, service conditions inside the station are:

- Ambient Temperature: 40 °C maximum.
- Relative Humidity: 5 % to 90 % non-condensing.

Unusual service conditions (e.g. across the line motor starting, exposure to extreme heat, EMF, dust, steam, etc.) will be listed in the Supplementary Specification, if applicable.

6.3 Switchgear Enclosure

Metal-enclosed switchgear shall consist of a modular assembly of vertical sections or cells as specified in the Supplementary Specification and associated drawings.

The enclosure shall be rated, at a minimum as a NEMA 2 enclosure.

Enclosures shall protect operating personnel from adverse effects caused by internal short-circuits (see Section 6.3.1 for more details). Each vertical section shall consist of a steel frame and sheet steel for front and rear doors, and sides, top and bottom covers. A fabricated compartment shall form a rigid self-supporting structure free from twist, warp, weave and

magnetically induced vibrations. Self-tapping screws and speed nuts are not acceptable. Lifting lugs or eyebolts to facilitate lifting of the assembly shall be supplied. The assembly shall be capable of being jacked and rolled on the floor or fork lifted without distortion or damage.

Ventilation (see Section 6.3.6) shall be provided to prevent condensation and to prevent operating temperatures from exceeding permissible hot spot limits. All metal surfaces shall be chemically cleaned and primed. The finishing coat of paint shall be as specified in Section 6.3.7, Protective Finish - Metal Treatment and Paint Finish. Limiting physical dimensions and weights of switchgear enclosures shall be as described in the Supplementary Specification.

6.3.1 Compartments and Doors

The following are requirements for compartments and doors of the metal-enclosed switchgear assembly:

(1) Each vertical section or cell shall have, or accommodate, the following separate compartments:

- Circuit Breaker.
- Main Bus Bars.
- Secondary Control (See Section 6.3.2 - Control Cabinets).
- Shunts
- Auxiliary (metering, instrumentation).
- Protections
- Power cable termination.

(2) All doors shall fit tightly against their closing surfaces from top to bottom with gaskets to prevent ingress of dust.

(3) When a breaker is removed from a cell, an escutcheon plate must be in place.

(4) Each door shall be labelled in accordance with Section 6.15.

(5) Each door shall be lockable with an OPG padlock.

(6) Each door shall be bonded to ground.

(7) Each door shall be equipped with door stops. The door stops shall limit the door opening between 90 to 135° to the enclosure. The stops shall be accessible to allow personnel to disengage the stops to close the doors. The stops shall not impede racking of the breakers.

(8) Doors shall be sized to allow easy access to equipment and cable terminations.

(9) Front and rear doors shall have hinges. Front doors are preferred to be secured using a single-throw, single handle multi point latching system, however multi-handle latching systems may be proposed. Rear doors shall, at a minimum, be bolted closed.

(10) Gasketed, high impact, thermographic compatible, viewing windows shall be provided in each applicable rear door to permit full view of all pole connections directly behind

each breaker.

(11) The front of each circuit breaker shall have an 'OPEN-CLOSED' indicator to verify status of the circuit breaker operating mechanism. This shall be readable without opening the door.

(12) The colour coding for 'OPEN' is red and green for 'CLOSED' for breaker and switch positions indication. Breaker trip/fault is amber.

(13) It shall be possible to close and latch the breaker doors with the breaker in the disconnected position (see Section 6.5 - Breaker Cells).

6.3.2 Control Cabinets

The control cabinets are the most accessed area of the switchgear assembly. A well organized control cabinet layout is necessary in order to reduce troubleshooting time. The overall layout shall be designed by the Contractor and reviewed by OPG. However, the following are requirements to be applied to the control cabinet design:

(1) Interior painting as stated in Section 6.3.7.

(2) Control wiring and terminal blocks as stated in Section 6.9.

(3) Equipment Nomenclature as stated in Section 6.15.

(4) Grounding bus as stated in Section 6.5.7.1.

(5) 600 V circuitry, if applicable, is not permitted in the main control compartment. 600 V equipment, such as breakers, fusing, and disconnects shall be located in a separate cell. In the event the design space is limited (i.e. where a separate cell is unavailable), 600 V equipment located with the control cabinet must be clearly identified, segregated and shielded from other equipment and all wiring must be bundled and shielded separately from other control and power wiring. The control cabinet door shall include a warning in accordance with Section 6.13 stating “This cell contains multiple external sources up to 600 V”.

(6) Ac and dc equipment within the cabinet shall be segregated (i.e. mounted on separate rails) and identified.

(7) Wiring to door mounted equipment shall be guarded against abrasion.

(8) Fuse holders must be lockable in the open position with an OPG padlock.

(9) 120 V supply breakers (heating, lighting, etc.) must be lockable in the open position with an OPG padlock and have visible contacts if available.

6.3.3 Cable/Bus Openings

Each vertical section shall be provided with an opening or openings to accommodate power and/or control cable/bus entry. Location of these openings will be detailed in the Supplementary Specification.

Removable, non-magnetic power cable opening cover plates shall be provided to seal off the complete cable/bus opening areas. Plates shall be cut, drilled or punched to accommodate the size and number of cables/bus and not inflict any lateral pressure on incoming conductors. Plates shall be bolted to the compartment floor/ceiling/wall to permit easy field installation and removal and must be able to support the weight of maintenance workers, if applicable.

6.3.4 Bus Guarding

All bus, excluding terminal points for power cables, shall be segregated from the rear of the switchgear vertical sections by means of guard walls. The walls may contain openings to allow for airflow within the gear, but prevent personnel contact with the bus. The walls shall be removable from each vertical section to allow for access to the bus for maintenance.

6.3.5 Floor Channels

The Contractor shall supply the design for a set of continuous floor channels, complete with associated leveling and mounting hardware, to install and grout in the floor to support each switchgear assembly.

A design for a minimum of three floor channels shall be provided for each switchgear vertical section.

6.3.6 Ventilation

All enclosure doors, removable panels, etc., shall employ sealed and gasketed construction. Vents shall be located such that dust/dirt ingress is minimized. Venting located within 15cm of the floor is unacceptable.

Venting shall be coordinated such that the structural integrity of compartment doors, covers, inspection windows and partitions is maintained.

6.3.7 Protective Finish - Metal Treatment and Paint Finish

Before leaving the factory, all surfaces of the switchgear parts shall be chemically cleaned, treated, primed and finished in accordance with *IEEE C37.20.1*.

The exterior surface shall be light grey No. 61 in accordance with *IEEE C37.20.1.* Interior surfaces shall be painted white in accordance with the requirements of *IEEE C37.20.1*.

Where an interior surface coating is applied to prevent condensation, this coating and any interior surface paint shall be fire-retardant and classified 94V-0 according to *Standard UL94* and oxygen index of 28 or greater in accordance with *ASTM D2863*.

A minimum of two litres of light grey finish paint shall be shipped with the equipment for site touch-ups.

6.4 Breaker Lifting Device

A lifting device shall be provided for each switchgear assembly to remove and replace breakers into cells. Lifting devices mounted atop the switchgear assemblies must travel the entire length under load without binding. Rail stops are required to prevent over travel of the device. Hand crank operation is preferred.

Portable lifting devices shall be designed to safely insert/remove the breakers from each breaker cell from top to bottom. The device must retrieve the top breaker and lower breakers to the floor without additional adjustment. Headroom space available above the switchgear will be provided in the Supplementary Specification. The device design must allow for a breaker to be inserted/removed in the bottom cell of a vertical section with the door open.

Each lifting device, whether fixed to the switchgear or portable, must be complete with a lifting jig/yolk designed to lift each breaker in the assembly.

Please refer to the Supplementary Specification for site specific requirements for the breaker lifting device.

6.5 Breaker Cells

All circuit breaker cells shall contain the following:

(1) One (1) section of positive and negative insulated main bus bars for connection to adjacent cells. See Section 6.5.5, Main Bus Bars and Riser Connections.

(2) A circuit breaker draw-out element with a positive rail guidance system and a fully rated frame grounding contact, such that the circuit breaker frame is grounded in all positions of its travel between 'connected' and 'disconnected'.

(3) A dc power circuit breaker, unless designated as a spare cell (see Section 6.5.4), that can be completely withdrawn with interlocks to prevent disconnecting or connecting the circuit breaker while it is in the closed position and to prevent circuit breaker operation while it is being moved between disconnected and connected position and vice versa. All breaker ratings shall be as per the Supplementary Specification.

(4) A mechanism to prevent over-travel of the breaker when moving into connected position.

(5) Padlocking capability to lock the breaker in the disconnected position with an OPG

padlock.

(6) A means to secure the circuit breaker in the connected, test and disconnected positions.

(7) Automatic shutters operated by the circuit breaker to prevent accidental worker contact with the live primary stationary contacts when the breaker is withdrawn. The shutter operating mechanism shall positively drive the shutters closed and open during the withdrawal and insertion operations of the circuit breaker respectively.

(8) Padlocking capability of the shutters or shutter mechanism in the closed position with the breaker removed from the cell. The locking facility shall be compatible with an OPG padlock. Shutter locking is preferred to be performed outside of the cell. However, at a minimum this shall be accomplished without undue reaching into the cell, i.e. the worker's elbow shall not break the plane of the compartment door while applying the lock.

(9) The capability to rack the circuit breaker, by means of a crank handle, into or out of the fully connected position with the compartment door closed and latched.

(10) The ability to verify the position of the circuit breaker, status of the circuit breaker 'OPEN-CLOSED' indicator, and status of the circuit breaker operating mechanism (i.e. spring condition), without opening the circuit breaker compartment door.

(11) LED type indicating lights shall be installed above each breaker door indicating the open close, trip status of the circuit breaker. The lens for the lamp shall be red for open position, green for closed position, and amber to indicate a fault/trip of the breaker. The lamps shall be rated for the site dc supply voltage (see Supplementary Specification for dc supply voltage).

6.5.1 Circuit Breaker Cell - Main Breakers

In addition to the requirements of Section 6.5, main circuit breaker cells shall contain the following:

(1) One (1) dc power circuit breaker complying with general construction and features described in Section 6.6.

(2) A local breaker control switch not mounted on the breaker. The breaker control switch shall operate in accordance with Section 6.13 and 6.14).

(3) Positive and negative, insulated, bus bar riser connections rated identically to the main bus bars. These connections shall connect from the main bus bars to the circuit breaker compartment. Runback bus from the circuit breaker compartment to the outgoing terminals shall also be rated identically.

6.5.2 Circuit Breaker Cell - Bus Tie Breakers

In addition to the requirements of Section 6.5, bus tie circuit breaker cells shall contain the following:

(1) One (1) dc power circuit breaker identical to and interchangeable with the main circuit

breakers described in Section 6.5.1. Any exceptions to this requirement must be stated.

(2) A local breaker control switch not mounted on the breaker. The breaker control switch shall operate in accordance with Section 6.13 and 6.14).Positive and negative, insulated, bus bar connections rated identically to the main bus bars. These connections shall connect from the main bus bars to the bus tie circuit breaker compartment and from the bus tie circuit breaker compartment to the bus tie bus bars (transition section or busway).

6.5.3 Circuit Breaker Cells - Feeder Breakers

In addition to the requirements of Section 6.5, Feeder Breaker Cells, where applicable, shall contain the following:

(1) One (1) dc power circuit breaker complying with the general construction and features described in Section 6.6.

(2) Positive and negative, insulated, bus bar riser connections. These connections shall connect from the main bus bars to the circuit breaker compartment. Identically rated runback bus shall be used from the circuit breaker compartment to the cable termination.

(3) All feeder cable support clamps, brackets and hardware to firmly support both sets of cables (if applicable) in the rear section, segregated from the main switchgear bus.

(4) Termination flange and hardware for connection of the feeder tie bus (if applicable).

6.5.4 Circuit Breaker Cells - Spare Cells

In addition to the requirements of Section 6.5, designated spare circuit breaker cells shall meet the following requirements:

- The cell door shall be sealed to maintain the requirements of Section 6.3.1.
- The cell shall contain a breaker frame equal to the highest rated feeder breaker cell.
- Facilitate positive and negative, insulated, bus bar riser connections - future connection points shall be provided to connect from the main bus bars to the circuit breaker cell and from the circuit breaker cell to cable termination points. All bus and hardware required to complete this connection shall be provided. All termination points at the rear of the cell shall be grounded.
- Breaker control wiring connecting to terminal strips within the control cabinet as detailed in the Supplementary Specification.

6.5.5 Main Bus Bars and Riser Connections

Main bus bars and riser connections shall be copper conductors, rectangular in cross-section, have a continuous current rating as indicated in the Supplementary Specification and be in compliance with the requirements of *IEEE C37.20.1*.

Main horizontal bus bars shall be braced and supported to carry continuous and fault level currents provided in the Supplementary Specification.

Main bus bars and riser connections shall be fully insulated throughout with insulation at a level at least equal to the voltage rating of the switchgear.

Bolted joints shall be completely covered throughout with flexible removable boots insulated at the maximum operating voltage level of the switchgear. Removable boot material and fasteners must retain their mechanical and electrical properties over the maximum design temperature range of the surface it is in contact with for the life of the switchgear.

Bus bar insulation and insulating materials shall be non-hygroscopic, non-tracking and fire retardant.

The bus bar shall be silver-plated and have conductor overlap and connection hardware for the specified ratings. Bolted joints shall be standard two-bolt or 4-bolt NEMA bolt configurations. Single bolted joints are not acceptable. Connection hardware including flat, spring and Belleville washers, bolts and nuts shall be installed to produce uniform pressure at joints. Torque values and typical connection details shall be provided on drawings for both factory and field assembled joints. Quality assurance procedures shall ensure that all factory-assembled joints have been correctly tightened. All NEMA grade GPO3 (or equivalent) board used to segregate or support bus shall have cut edges sealed to prevent moisture ingress.

Main bus bars shall be equipped with ground studs having removable insulating boots for connections of TGAs. Type and location of studs shall be provided during the design review process.

6.5.6 Cable Terminations

All incoming and outgoing power cable/bus termination points shall be suitable for NEMA standard bolt drilling compression lugs and be delivered complete with the size and quantity of compression lugs to connect all cables as specified. Removable insulating boots shall also be provided for each terminal. Bus contact surfaces for these connections shall be silver-plated.

Compression type connectors shall be marked and installed with applicable Canadian Standards Association (CSA) die designations. Mounting height of power cable terminators and support brackets shall be arranged to maximize working space and facilitate easy access to cable terminals without unduly disturbing adjacent cables.

6.5.7 Ground Bus Bars

This section deals with requirements for a ground bus throughout the switchgear cells and control cable shields plus additional ground bus for maintenance activities.

6.5.7.1 Switchgear Ground Bus

Switchgear shall have a ground bus bar of silver-plated, solid, rectangular cross section copper conductor, sized and braced to meet fault current requirements described in the Supplementary Specification. All cell-to-cell connections of the ground bus joints shall have silver plated contact surfaces with conductor overlap to be secured, at a minimum, by two bolt NEMA pattern connections.

The ground bus bar shall form a continuous ground bond between cells of a switchgear section. It shall be installed in an accessible location away from control cables.

Ground bus bars shall be pre-drilled, two or four-hole NEMA pattern in each switchgear cell for connection to the station ground grid. The preferred locations are across the rear of the cable compartment, immediately behind the rear door approximately 250 mm above the finished floor OR across the top of the switchgear to directly above the rear access door where OPG may request the installation of ground end attachment points mounted in a downward projection securely fastened to the top of switchgear.

For grounding of control cable shields, the switchgear assembly ground bus shall be extended with a 2/0 AWG bare copper conductor connected to a flat silver copper strip, completed with pre-drilled holes of 5.5 mm (7/32”) diameter and mounted in a convenient location in each control compartment.

6.5.7.2 Maintenance Ground Bus

To facilitate the installation of temporary ground assemblies for grounding studs described in Section 6.7.1, the switchgear ground bus may be required to be extended to convenient locations within each switchgear compartment to form a maintenance ground bus. Capacity and bracing of this extension shall meet the fault current requirements described in the Supplementary Specification. Depending on site requirements, the maintenance ground bus may be externally mounted on the switchgear. Details shall be described in the Supplementary Specification or through further discussions during the design review.

6.5.8 Polarity

Facing the front of the switchgear, polarity shall be Positive to Negative, left to right, top to bottom and front to back. The Contractor shall make all transpositions necessary in the interconnecting busways to preserve this polarity in the switchgear cells.

6.6 Circuit Breakers

The Contractor shall provide circuit breakers complete with operating mechanisms in compliance with the requirements of the applicable standards. *IEEE C37.14, C37.16, C37.20.1* and other industry standards, such as CSA or IEC shall apply where relevant. Compliance shall

include this Standard Technical Specification and the Supplementary Specification. All ratings shall be self-cooled ratings. Any deviation from this shall be made clear in the initial proposal.

Circuit breakers shall be functional and complete, and include the following main features, components, and characteristics:

(1) Circuit breakers shall be 3-pole and single-throw and appropriately rated for dc operating requirements as specified in the Supplementary Specification.

(2) Circuit breakers shall utilize two breaker poles connected in series with Z connectors for the positive bus and one pole for the negative bus.

(3) Circuit breakers of identical ratings shall be electrically and mechanically interchangeable. Subsequently, breakers of differing ratings shall be equipped with a mechanical device to prevent breakers from being racked into incorrectly rated cells.

(4) Feeder breakers, where applicable, shall meet the requirements of *IEEE C37.14*. Any exceptions to these requirements must be explicitly stated.

(5) Breakers shall be horizontal draw-out type.

(6) Electrically and mechanically trip-free with an anti pumping and an emergency manual trip device.

(7) Circuit breakers shall have a motor operated, charged spring, stored energy mechanism. The mechanism shall be front accessible and capable of manual charging by a levering tool.

(8) A mechanical indicator to indicate the status of the operating mechanism shall be provided. If a mechanism employing springs is being used, then the word 'charged', in black on a yellow background and the word 'discharged', in black on a white background shall be used. A manual spring charging device shall be provided with design features to prevent inadvertent closing or closing without a complete spring charge. Manual spring release facilities must provide direct mechanical control without any interposing electrical devices.

(9) Circuit breakers shall have a mechanical breaker position indicator, directly driven by the breaker’s operating mechanism. Indicators shall be readily visible and provided with black lettering on the following backgrounds: 'open' - red, 'closed' - green.

(10) Circuit breaker interrupter contacts must be open before it is possible to perform a levering or racking operation.

(11) Each circuit breaker shall have a mechanical, non-resettable operations counter. A close-open operation shall count as one operation.

(12) Primary contacts shall be silver-plated; copper-spring biased to maintain constant pressure when contact is made.

(13) All dc operated devices shall operate at a nominal control voltage listed in the Supplementary Specification. Rated voltages and permissible ranges for circuit breaker control shall be as per *IEEE C37.16*.

(14) Each breaker shall have contacts, in addition to those required for local status as detailed in Section 6.5, to provide remote open/closed status and fault/trip status. Please refer to the Supplementary Specification for additional auxiliary contact

requirements.

(15) Site specific control circuit diagrams for circuit breakers shall be supplied with the Supplementary Specification. Internal wiring and control of the breaker shall be such that no modifications to OPG's control systems are required, i.e. the switchgear shall contain terminal blocks for each of the existing OPG field wires such that each wire performs its existing function.

6.6.1 Trip Units

All circuit breaker trip systems shall use microprocessor based electronic trip units in accordance with *IEEE C37.17*. The trip unit shall consist of a solid-state trip actuator and current sensors. Rating plugs shall be sized according to the single line drawings.

Main power for the trip units shall be supplied by dc power supplied directly from the incoming dc from the batteries (see Section 6.10). The trip unit protective functions shall not rely on internal batteries. However, the trip unit shall possess the ability to meter and display, current with/without auxiliary power present. In the event of loss of power to the trip unit, the trip unit protection functions shall open the breaker.

LSI Trip Units with advanced features shall include:

(1) Overload Protection (L): Characteristic t = k/I2 trip threshold settings ranging from I = (0.4 - 1) X In of the rated value and timing adjustable between 3 – 144 seconds.

(2) Short Time protection with adjustable delay (S): Characteristic t = k and t = k/I2 trip threshold settings ranging from I = (0.6 - 10) X In of the rated value and timing adjustable from 0.05 to 0.4 seconds.

(3) Instantaneous Short Circuit Protection (I): Trip threshold I = (1, 5, 15) X In of rated current value.

(4) All protective functions except Overload (L) must be capable of being disabled.

(5) The trip unit shall include alarm LED signal for the 'L' and 'S' function.

(6) Thermal memory shall be present for 'L' and 'S' functions. Protection against excessive temperature should be available.

(7) The trip unit shall provide protection and indication for over temperature. The option to open the circuit breaker on over temperature shall also be available.

(8) A trip unit test function shall be provided.

(9) The trip unit shall allow and display local programming and control.

(10) Auxiliary power available LED shall be provided on the trip unit. A permanent or temporary microprocessor fault LED shall be available on the trip unit.

(11) The trip unit shall provide a local indication or local display of the data log indicating warnings for overload current (83 %), exceeding temperature threshold, and contact wear >80 %.

(12) The trip unit shall provide local alarm indication when 100% overload current is

reached, timing in progress for a protective trip, 100 % contact wear and shunt trip failure.

Permanent indicators of L, S, I, and T (trip due to overheating) shall be present. Indicators must remain latched without the presence of an auxiliary supply or battery voltage present and be activated in case of reclosing on a fault. A local 'RESET' button shall be present to reset indicators.

The trip unit shall provide contacts for signaling of a protective trip and microprocessor fault. In addition, a user configurable contact shall be provided.

The trip unit shall be capable of storing circuit breaker-opening data and data retrieval in outage condition when an external power supply is available.

The trip unit shall be capable of supporting Modbus RTU standard communication protocol. Site specific requirements for communications may differ from Modbus RTU. Please consult the Supplemental Specification.

Main and Tie breakers may utilize stand alone protective relays only if on board trip units are not rated for dc applications.

6.6.2 Circuit Breaker Secondary Connections

Silver plated secondary circuits of the circuit breaker shall be connected to silver plated secondary stationary contacts in the circuit breaker compartment by means of a rated plug and socket fixture. The plug shall automatically engage and disengage as the circuit breaker is racked in and out of its compartment respectively. Connection of contacts shall occur as the circuit breaker is moved from the disconnected position to the test position.

6.7 Temporary Grounding

Temporary grounding shall be in accordance with ENG-MAN-001E, Temporary Grounding and Bonding Guide (Contractor Version).

The switchgear shall have permanently installed ground studs on each phase of the main bus, load side of each phase of each breaker, and ground end studs mounted on the switchgear ground bus. There shall be a minimum of one (1) ground end stud mounted on the ground bus to ground the load side of each breaker in each vertical section (i.e. four breakers in a vertical section requires four ground end studs).

Vertical sections containing ground studs for the main bus also require a minimum of one (1) ground end stud. Each stud shall be covered with an insulated boot, removable with a grip-all type switch stick.

Studs shall be installed on the bus in such a manner to allow application of clamps by use of an insulated switch stick. Studs are not to be situated in positions that are inaccessible due to load side cable routing blocking the stud and that allow workers to install ground end clamps by hand. Ground end attachment points are to be arranged vertically and spaced at a minimum of 100 mm. Externally mounted ground end attachment points are not permitted. Runback bus may be required to extend the bus to an accessible point.

Studs shall have ratings to sustain the switchgear rated momentary withstand currents and rated short-time withstand currents as described in the Supplementary Specification. Final type, location and orientation of studs on bus and ground ends will be determined and discussed between OPG and the Contractor after the Contractor submits the switchgear layout drawings for OPG's review and approval.

6.7.1 Temporary Ground Assemblies

Temporary ground assemblies (TGAs) shall be supplied for each temporary ground application where a unique length and/or fault level exists within the switchgear design. TGAs shall be manufactured in accordance with ENG-MAN-001E, OPG Temporary Grounding and Bonding Guide (Contractor Version) and OPG-M-772 Standard Technical Specification for Temporary Ground Assemblies.

6.8 Instrument Shunts

All shunts to provide measurements shall be calibrated with a class 0.5 accuracy. A shunt shall be provided even if a DCCT is used to measure current.

The shunt must be accessible for testing/troubleshooting purposes. If the installation location does not permit direct access, the Contractor must propose an alternate solution for accessing the terminals for testing/troubleshooting.

6.9 Terminal Blocks and Control Circuit Wiring

Switchgear shall have terminal blocks and control circuit wiring in accordance with OPG Specification OPG-M-377. Blocks shall be mounted on back and side panels of control compartments and shall be readily accessible for maintenance and testing.

Terminal blocks for all external control and indication circuits shall be of 600 V insulation class, and accommodate # 12 through # 8 AWG copper conductors. Terminal numbers must agree with numbers shown on connection wiring diagrams.

The Contractor's circuit breaker control wiring in each switchgear cell shall provide:

- Separate terminal blocks for circuit breaker trip and close circuits from OPG's

distribution panel board.

- Separate terminal blocks for OPG wiring from control switches, metering, protective relays panels and control consoles.
- Separate terminal blocks for OPG wiring from secondaries of instrument transformers to metering and protective relays.
- Terminal blocks mounted on the same rail shall have separators that segregate different voltage levels.

Control wiring shall be in accordance with *CSA Standard C22.2 No. 127*, SIS type, and shall have minimum ratings of 600 V ac, 90 °C, be fire retardant, and have thin wall and abrasion-resistant insulation. Control wiring conductors shall be tinned copper, multi-stranded type and sized accordingly. Minimum conductor size for control wiring is # 14 AWG (2 mm^2). Conductor stranding shall be 7 strands or greater for general applications and 19 strands or greater for hinged door wiring. Switchgear shall have all control wiring routed in such a way as to minimize exposure to bus bars and other live parts of power equipment.

Grommets, bushings and other mechanical protection shall be provided to control wiring running through metal barriers and near sharp edges.

Control wiring shall be continuous between terminals of various devices with conductors neatly bundled and supported at frequent intervals with self-locking reusable, non-adhesive type wire mounts and ties.

Plated copper, non-insulated, permanently crimped ferrules shall be installed on ends of all control wires to prevent fraying. To permit similar installation of field wires and possible future changes to control wiring, the Contractor shall provide one ferrule crimping tool and one spare ferrule per terminal block, plus 10 %.

Wire markers shall have sufficient grip on conductor insulation and have permanently printed wire numbers or names protected by clear plastic overcoats.

Interconnecting wiring shall terminate on terminal blocks and, where necessary, be connected by terminal block links.

6.10 Protective Relay and Control Power

The protection and control power shall be sourced from the incoming dc feeds from the station battery/charger, with the connection points occurring on the switchgear bus upstream of the main circuit breakers.

Protection and Control power for the “A” and “B” side shall be tied together through electrically interlocked contactors. In the event of a loss of either source, the other source shall automatically supply control power for both sides. Interlocking must prevent a parallel

connection of the supplies through the control circuits.

Each breaker control power circuit shall include a loss of power relay (27) wired as the last device. Loss of power contacts shall be SPDT and pick up when power is present (fail safe).

OPG must be able to isolate the control power to each breaker as well as the protection relay power to the “A” and “B” side. Switches with exposed terminals such as fused knife blade switches must be guarded from contact by personnel. Isolating devices without exposed terminals are preferred. Devices must be lockable with contacts that can be visually verified in the open position.

In systems exceeding the ampacity of the typical relay contacts for this function, an alternate scheme may be proposed.

6.11 Ground Fault Detection

Ground fault protection (64) shall be provided at each incoming feed from the batteries/chargers. OPG prefers the use of Bender relays for ground fault protection (Bender IR425 or ISO685 depending on application). At a minimum, one SPDT contact of the relay shall be connected to an amber LED indicator light mounted on the control cabinet door to provide visual indication of a fault. Another SPDT contact shall be wired to terminal blocks for OPG use.

6.12 Under/Over Voltage Relay

Undervoltage (27) and overvoltage (59) protection shall be provided at each incoming feed from the batteries/chargers. OPG prefers the use of Bender relays for undervoltage and overvoltage protection (VME420 or VME421H depending on application). One SPDT contact of each relay shall be connected to an amber LED indicator light mounted on the control cabinet door to provide visual indication of each condition. Another SPDT contact from each relay shall be wired to terminal blocks for OPG use.

6.13 Transfer Scheme

In the typical dc station service topography as depicted in Appendix A, under normal operating conditions both Battery/Charger A and Battery/Charger B are energized. Battery/Charger A supplies the 'A' load centers and Battery/Charger supplies the 'B' load centers. However, each supply is capable of carrying the full station load. Either one of the tie breakers A or B is open.

Automatic transfer schemes are not permitted because a common fault after an auto transfer may result in a total loss of the dc system. The manual transfer scheme must be designed to prevent parallel connection of the sources; however, an interlock disable feature must also be installed to allow parallel operation of the two banks by trained personnel following established

procedures, which includes restrictions on paralleling the chargers. Visual, audible and remote annunciation shall indicate the interlock is defeated. All scenarios for voltage loss on either A or B must be applied to the transfer scheme, including tie breaker status to ensure the tie is completed regardless of which breaker is open at the time of voltage loss.

In the event of complete loss of station service power, the transfer scheme shall require manual restoration. The system must be available to receive either source when restored. For example, if Battery/Charger A is the last source to fail in a complete station outage, the scheme must be designed to be available to manually restore station service in the event that Battery/Charger B is energized by OPG operations.

In addition to the above, the transfer scheme shall include the following:

(1) Hard-wired controls mounted in a control cabinet within the switchgear assembly or in a remote enclosure (see Supplementary Specification). Breaker controls shall be performed using GE Series 95 pistol grip rotary switches or equivalent.

(2) The transfer scheme shall allow for breaker control to be performed either from the remote/local control board, the breaker controls mounted on the breaker cell (Main and Tie) or on the breaker itself.

(3) Manual transfer control shall prevent parallel operation of the supplies (see Section 6.14.2).

(4) Electrical Interlocking (See Section 6.14.2).

6.14 Interlocks

The following sections cover mechanical and electrical interlock details.

6.14.1 Mechanical

Mechanical interlocks shall be self-checking to ensure a circuit breaker is open before it can be withdrawn or inserted.

Circuit breaker secondary contacts shall be interlocked or mechanically designed to prevent the circuit breaker from being racked to the connected position or closed unless secondary connections are secured, and prevent the removal of the connections when the circuit breaker is closed. Any disconnect switch (e.g. bus tie) shall have a mechanical interlock with the associated circuit breaker to ensure that the switch does not operate under load. Specific requirements shall be detailed in the Supplementary Specification.

6.14.2 Electrical

Electrical Interlocking is intended to prevent paralleling operation of station batteries or chargers.

A breaker in the test position shall be permitted to operate for breaker close and trip test purposes without interference by the interlocking scheme with other breakers. On the contrary, a breaker in the test position shall not affect the operation of other breakers racked into the connected position, see Table 1.

Overcurrent relay operation shall trip its associated power breaker and also activate a hand-reset lockout relay (LOR). This LOR shall be wired in series will main and tie breakers closing circuits to prevent closing a breaker on a faulted bus. The LOR shall be installed in one of the breaker control panels and include a minimum of two spare contacts wired to terminal blocks for OPG use. The LOR shall not be wired to tripping circuits.

Electrical Interlocks shall be hard wired and incorporated in the transfer scheme. For the typical topography as shown in Appendix A, the interlocking table (Table 1) shall be applied.

Table 1: Electrical Interlocking Table

Main A	Main B	Tie A	Tie B	Action	Response
C	C	C	O	Close Tie B	Tie B Remain Open
C	C	O	C	Close Tie A	Tie A Remain Open
C	O	C	C	Close Main B	Main B Remain Open
O	C	C	C	Close Main A	Main A Remain Open
C	C	C	T-O/C	Close/Open Tie B	Tie B Close/Open
C	C	T-O/C	C	Close/Open Tie A	Tie A Close/Open
C	T-O/C	C	C	Close/Open Main B	Main B Close/Open
T-O/C	C	C	C	Close/Open Main A	Main A Close/Open

Note: C = Close
O = Open
T = In Test Position

6.15 Nameplates and Signage

This section describes the requirements for equipment nameplates, operating nomenclature labels, warning labels, control cabinet labeling and mimic bus.

Nameplates and signage identifying equipment, ratings, and hazards are required for all low voltage switchgear assemblies. OPG will make every effort to provide the Contractor with accurate equipment operating nomenclature prior to the design review process through documentation or drawings. It is recommended, during the design review process, to create a list of all nameplates, signage, and warning labels for review by OPG to ensure the equipment

identification is correct prior to manufacturing.

The general requirements for nameplates and signage are as follows:

(1) Rating nameplates, equipment operating nomenclature labels, and warning/caution signage shall be fastened using screws. Adhesive nameplates are not acceptable.

(2) Nameplate/signage sizes shall be selected by the Contractor. Material thickness and installation method shall prevent the nameplate from bending or warping.

(3) Equipment nomenclature labels and warning/caution signage requested by OPG shall be made of engraved Lamacoid.

(4) Caution signage requested by OPG shall be produced with black lettering on yellow background.

(5) Warning signage per CAN/CSA-Z321-96 requested by OPG shall be produced with white lettering on a red background.

(6) Informational signage, notifications, and instructional labels (e.g. door handle turning direction) may be adhesive labels.

Font sizes shall be clearly legible. As a guide, the equipment nomenclature for the switchgear itself may be approximately 75 mm in height, while other equipment nomenclature (breakers, control panels) may have a font size of 25 mm. Smaller font sizes due to space constraints on the mounting surface will be discussed during the design review.

6.15.1 Rating Nameplates

Switchgear rating nameplates shall meet the following requirements in addition to those detailed in Section 6.15:

(1) Rating nameplates shall be made of engraved black anodized aluminum.

(2) The Contractor shall provide rating nameplates for all components of the switchgear all in accordance with applicable standards. Nameplates will be mounted in a conspicuous location, readable from ground level and without opening cell doors.

(3) Circuit breaker nameplates shall be clearly visible outside the enclosure.

(4) Equipment rating nameplates that may be blocked by installation orientation shall be duplicated and installed in a location that does not require equipment dismantling or undue stretching to read the nameplate.

(5) Crane capacity requirements for the switchgear shall be shown on the rating nameplate.

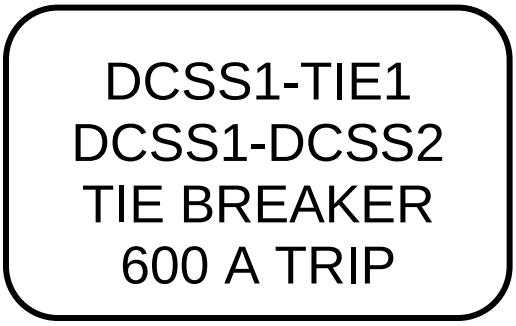
(6) Data font size shall be a minimum of 5 mm and clearly legible.

6.15.2 Operating Equipment Nomenclature

Each piece of equipment, including the switchgear itself, is identified with OPG specific nomenclature. Nomenclature signage shall meet the following requirements in addition to those

detailed in Section 6.15.

(1) Signage shall be provided for all cells/compartments with the OPG provided nomenclature, and in the case of breakers, the load supplied and current rating of the breaker. The following figures provide examples:



Where:

- DCSS1-TIE1 is the OPG nomenclature.
- DCSS1-DCSS2 indicates the equipment tied together on each side of the tie breaker.
- 'TIE BREAKER' describes the equipment in the cell.
- 600 A Trip indicates the current rating of the breaker.

Figure 1: Example of Tie Breaker Nomenclature



Where:

- J11F4 is the OPG nomenclature
- PANEL “E” SUPPLY indicates the load equipment
- 600A TRIP indicates the current rating of the breaker

Figure 2: Example of Feeder Breaker Nomenclature



Where:

- SS1 is the OPG nomenclature for the switchgear assembly
- CONTROL CABINET describes the contents of cabinet

Figure 3: Example of Control Cabinet Nomenclature

(2) Each control and breaker status indicating device shall also have a nameplate with its unique identification.

6.15.3 Warning Labels

This section describes the requirements for warning labels.

Warning labels: “COMPARTMENT MAY BE ENERGIZED EVEN WHEN BREAKER (DISCONNECT SWITCHES) IS OPEN”, shall be installed on all circuit breaker and disconnect switch cells to visibly warn that the compartments may be back-fed.

6.15.4 Control Cabinet Labeling

The control cabinet labeling shall meet the following requirements:

- Each component, such as fuses, breakers, switches, relays, communication and control equipment inside of the control cabinet shall be identified.
- Components within the control cabinets shall be treated as equipment and will therefore have equipment nomenclature in accordance with Section 6.15.

6.15.5 Mimic Bus

A mimic bus applied to the front of the switchgear and the remote control panel (where applicable) shall functionally represent primary circuits. The mimic bus shall consist of a series of electrical symbols and designations fixed to the exterior of the switchgear panels that mimic the wiring scheme within the panel.

Arranged in single line diagram format and using only IEEE electrical one line diagram symbols (as below), bus segments shall be coordinated with devices in switchgear sections to produce a concise visual presentation of principal switchgear components and connections.

Symbols for withdrawable elements (e.g. circuit breaker) shall also include a pair of double 'V' symbols representing stationary and moving contacts. Combine symbols as required to indicate switch types.

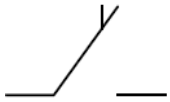
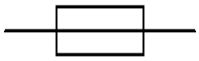
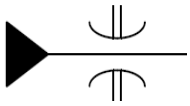
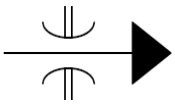
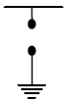
Buses shall run horizontally and vertically, but not diagonally.

All components of the mimic bus shall be plastic or metal and secured in place by plated screws. Strips shall be secured flat and free of waves.

Symbols shall be white on a black background. Bus shall be white.

Final location, orientation, and choice of symbols for the mimic bus will be determined after the Contractor submits mimic bus layout drawings for OPG’s review and approval.

Table 2: Mimic Bus Symbols

Component	Symbol
Air Breaker with draw out component	
Multi-pole ganged disconnect switch	
Fused switch	
Fuse	
Entrance bushings	
Exit Bushings	
Bus and Ground end attachment points for TGAs	
Surge Arrester	
Ground point	
Capacitor	

6.16 Circuit Breaker Test Cell

Where a circuit breaker test cell is required, the cabinet shall have the following features:

(1) Control components such as 'Open' and 'Close' push buttons and position indicating LEDs.

(2) Terminal blocks to terminate incoming dc control power supply cable.

(3) Simulated main bus connections to align circuit breaker primary connections and to allow for primary connection resistance tests.

(4) The same secondary connection system and breaker racking mechanism used by the circuit breakers.

(5) Access to all sides of the breaker (including top and bottom) as necessary to perform maintenance tasks.

7. INSPECTION AND TESTING

The following sections cover requirements for factory inspections, factory acceptance tests, design tests, field tests and inspections.

7.1 Factory Inspections and Factory Acceptance Tests

OPG reserves the right to perform surveillance at any time for compliance with the product quality requirements. Such surveillance shall not relieve the Contractor of any of its obligations or responsibility under contract.

The Contractor shall give OPG at least three weeks advance notice prior to factory inspections and factory acceptance tests within North America, and six weeks advance notice outside North America in order that OPG can obtain the necessary internal approvals to witness. The Contractor shall submit a detailed schedule, preferably during the design and/or drawing review stage, indicating the proposed dates of inspections and tests. The detailed schedule shall also include any additional recommended witness and hold points (i.e. at a third party manufacturer).

At a minimum of 14 days prior to any factory inspections, factory acceptance tests or any additional witness and hold points, the Contractor shall submit an Inspection and Test Plan (ITP) for review and acceptance by OPG.

OPG will not be liable for any claims relating to delays caused by any such factory inspections and factory acceptance testing.

The Contractor shall perform all factory tests on each fully assembled switchgear/bus duct in accordance with applicable IEEE, CSA, and OPG Standards.

In addition, the following changes and supplemental tests are required:

(1) At least five mechanical operations shall be performed on each piece of equipment to check the correct operation of all components of a circuit breaker and disconnect switch.

(2) Functional Verification for controls and interlocks

(3) Point to Point tests for control wiring

(4) Insulation Resistance test of control wiring

(5) Dielectric withstand tests shall be completed with the TGA studs installed on the bus and ground points, with the protective caps removed.

(6) Dimensional verification

(7) Rated continuous current tests may be required on one of each type of switchgear. This requirement will primarily depend on the changes in design, material, components, procedure, etc., made after the original design (type) tests on the equipment were performed. See Section 8.1, Documentation Submission with Proposal.

7.2 Design (Type) Tests

The Contractor shall perform all design tests on each type of switchgear/bus duct in accordance with applicable IEEE, CSA, and OPG standards.

7.3 Field Tests and Inspections

Equipment shall be installed, inspected and tested as per the Contractor's instructions, IEEE, CSA and OPG standards to ensure the integrity of the switchgear.

As a minimum, this shall include:

(1) Mechanical and electrical interlock verifications.

(2) Inspection and testing (if applicable) of all wiring and bus connections for correctness and tightness.

(3) Functional checks of all components.

(4) Ground resistance tests.

(5) Insulation resistance tests (after disconnecting all devices sensitive to the test voltage) on all control bus terminals and on all low voltage bus terminals.

(6) Protective relay and other devices tests and calibrations as per the relay manufacturer's instructions.

(7) Additional tests as required in the Supplementary Specification.

OPG will perform the field tests and inspections or contract these services to a third party. The Contractor shall provide a field services representative to witness the testing, inspect the installation and provide technical support, per diem rates to be provided. The Contractor shall certify that the equipment has been correctly installed, inspected and field-tested as per their recommended practices before the equipment can be energized. Refer to the Supplementary Specification (Section A.15) for further details related to field service requirements.

The Contractor shall be responsible for repairing or replacing all components that fail any checks or tests at no extra cost to OPG.

8. DRAWINGS AND DOCUMENTATION

All drawings shall be submitted in ".dwg" format as well as ".pdf" format for review. OPG will supply the title block/border templates, together with a block of drawing numbers, to be incorporated into all drawings such that they are easily incorporated into OPG's Drawing Management System.

8.1 Drawing and Document Submission with Proposal

IMPORTANT: The Contractor shall submit the following information with the proposal for the new equipment. Absent or partial information (without notes as to the reason the information is missing or incomplete) may render the submittal non-compliant and remove the Contractor from further discussions or considerations for any portion of the defined scope of work.

The drawings and documents submitted with the proposal are intended to demonstrate to OPG an understanding of the overall project scope or work. The intent is to capture key dimensions, ratings, and locations of equipment without going into great detail.

The Contractor shall submit the following technical information within the proposal:

(1) Third party certified test report corroborating the Contractor's arc-resistant rating claims. The information is to include drawings indicating the dimensions and configuration of the test sample.

(2) Basic assembly/sectional view of the switchgear.

(3) Basic Control Elementary Wiring Diagram (EWD)

(4) Floor plan view showing dimensions and proposed location of the switchgear as defined in the Supplemental Specification.

(5) A general material list outlining proposed equipment ratings, manufacturers, etc.

(6) A reference list of similar switchgear, of equal or greater size, sold in the last five years.

(7) Provide contact name, address, telephone, email address, basic ratings and quantities of equipment.

8.1.1 Drawing Submission after Award of Contract

The Contractor shall submit, in accordance with the applicable clauses in the Standard Commercial Conditions provided by OPG Supply Chain, within four weeks after notification of the award of contract, one electronic copy of each of the electrical, mechanical and civil drawings for approval before manufacture of the equipment commences. Approval of drawings by OPG does not relieve the Contractor of complying with the Standard Technical Specification in all respects unless such non-compliance is specifically authorized.

The following drawings are required:

(1) General arrangement, overall assembly plan and sectional views to indicate arrangement of the compartments and their components.

(2) Section dimensions and approximate weights.

(3) Location of all control and power connections (supply and load).

(4) Connection Wiring Diagrams (CWD) and Elementary Wiring Diagrams (EWD) including the interlock scheme.

(5) Floor plan showing installation of floor channels.

(6) Drawings of the metal-enclosed bus construction, materials and vapour barriers, if applicable.

(7) Provision for special access, including platforms, removable access space, etc., for initial installation and future extension of the equipment.

(8) Plan view indicating minimum circuit breaker withdrawal space and minimum space required for a maintenance worker to install TGAs at the back of the switchgear.

(9) Bill of Material.

(10) Third party auxiliary equipment drawings.

8.1.2 Data and Other Information Submission after Award of Contract

(1) A list of all exceptions and variances from this specification and the Supplementary Specification.

(2) Applicable manufacturing and testing standards used.

(3) Type of equipment being offered and its certified design test reports, as specified in the applicable standards, confirming the ratings of circuit breakers, switches, bus, enclosures, etc. Type test certification records shall be supplied to support all IEEE and CSA test standards (See Section 2.2)

(4) A list of all changes in design, material, components, procedure, etc., made after the original design. OPG reserves the right to request a repeat of these tests if any modifications are deemed to affect the performance or ratings of the equipment.

(5) Complete equipment data per the Data Sheets located in the Supplementary Specification. All ratings and capabilities listed in these data sheets shall be guaranteed values.

(6) The magnitude of the switching over voltages and the recommended surge protection equipment for the affected loads, if required.

(7) Details of bus conductor material and properties of the insulation (conductor and support) as per Section 6.5.5, Main Bus Bars and Riser Connections.

(8) Withdrawal space of breaker for maintenance as per Section 5.

(9) Circuit breaker instruction manuals.

(10) Responses to service life details as per Section 5.1.

(11) Predicted failure frequency, repair times, associated costs, etc. as per Section 5.1.

(12) Replacement frequency for major components with respect to time of use and number of operations.

(13) A list of recommended spare parts, including unit prices, in compliance with Section 5.3.

(14) The Contractor's project management office address and contact information servicing the site as indicated in the Supplementary Specification.

(15) The Contractor's closest service centre address and contact information to the site as indicated in the Supplementary Specification.

(16) A statement of the number of weeks of advance notice required by the Contractor for their field services representative to report to project site.

(17) A separate price for conducting a two day formal training session for OPG personnel as per Section 11 - Training.

8.1.3 Final Drawings

The following final drawings shall be submitted prior to shipping of the switchgear to the OPG site:

(1) General arrangement and foundation plan drawings, giving complete dimensions and weights. Drawings to detail all locations of cable/bus entrances, mounting bolts, etc.

(2) Section view drawings of each cell detailing arrangement of components. Drawings to include bills of material and cable/bus connection details

(3) All ac and dc schematic and wiring diagrams (e.g. elementary wiring diagrams and connection wiring diagrams). General arrangement drawing and connection wiring diagrams for the circuit breaker test cabinet if specified in the Supplementary Specification.

(4) Mimic bus layout drawing.

(5) One complete hard copy and one electronic set of approved maintenance and operation instruction manuals including a spare parts list, reduced size drawings, bills of material, design test reports, all production test reports and CT saturation curves. This includes all applicable test reports by non-Contractor produced equipment such as power circuit breakers and any associated special tests.

(6) One set of electronic files in latest version of AUTOCAD by AUTODESK Corporation format. All drawings shall be produced using AUTOCAD or equivalent

Items 1, 2, 3 and 4 shall be submitted bearing the seal and signature of a professional engineer licensed in the province of Ontario and the date upon which it was sealed.

8.1.4 Final Submission Data and Other Information

The following information shall be submitted prior to shipping of the switchgear to the OPG site:

(1) Shipping section dimensions and weights.

(2) A complete set of Material Safety Data Sheets (MSDSs) for all chemicals, lubricants, etc.

(3) Certified test reports on production tests.

8.2 Instruction Manuals

Qualified OPG operations and maintenance personnel will operate, maintain and repair equipment with aid of the Contractor's instruction manuals. Therefore, detailed, accurate, well organized and easy to use instruction manuals are of vital importance.

The final approved version of instruction manuals shall be provided in electronic format, along with two hardcopies for OPG use.

8.2.1 Contents of Instruction Manual

Instruction manuals for switchgear shall contain the following:

- Title of equipment, station name, equipment ratings, OPG purchase order, requisition and Contractor’s reference numbers. This information shall appear on the outside of the binder hardcopy and on the first page.
- Section 1:
  - Title page.
  - Table of contents - sections shall be sequentially numbered.
  - List of drawings and summaries - by number and title, including serial numbers of equipment to which manuals are applicable.
- Section 2 - Installation Instructions:
  - Shipping, receiving, and manoeuvring instructions.
  - Storage instructions - indoor, outdoor and special information for equipment storage.
  - Alignment, erection and dimensional tolerances for preparation of start-up and commissioning.
  - Provide inspection procedures for before and after unloading, pre-erection tests, floor channel checks.
- Section 3 - Testing:
  - Provide functional testing, dielectric testing and operating instructions,

operating limits and start up instructions complete with drawings.

- Provide a separate set of production test record sheets showing all test values and measurements including tolerances for each test made on the switchgear. This includes circuit breakers.

- Section 4 - Operation and Maintenance:
  - Provide commissioning and maintenance instructions complete with photographs and drawings on how to disassemble and assemble, repair, set critical tolerances and adjustments of the switchgear assembly including the circuit breaker and disconnect switches.
  - Provide instructions on use of special tools.
  - Provide an inspection frequency guide including criteria for initiating minor and major overhauls.
  - Provide data on all gaskets, seals and O-rings, which must be replaced during routine maintenance, or after a specified period of time or number of operations.
  - Provide lubrication chart and schedule including component quantities.
  - Identify lubricants according to accepted Canadian standards.
  - Provide a complete description of operation of the circuit breaker mechanism, and its support and auxiliary systems. Include a concise description of the sequence of operation during opening and closing of a circuit breaker.
  - Include procedures for safe discharge of all stored energy apparatus (mechanical and electrical)
  - Provide a trouble-shooting guide and procedures for all systems of the switchgear assembly. The trouble-shooting guide shall list a number of symptoms, and give the corresponding inspection area of trouble or fault, probable cause or defect and remedy.
- Section 5 - Spare and Renewal Parts:
  - Provide a complete Spare Parts List indicating quantity, part description, Contractor's part and catalogue number. Cross-reference all part and component numbers with drawings in the instruction manual.
  - Identify every part listed in the Spare Parts List and Renewal Parts List of the equipment and sub-assemblies on drawings. Drawings shall include sectional and exploded views. Include part and component description, Contractor’s part number and applicable replacement part numbers.
  - The Contractor must update reissue drawings, and inform OPG of every modification of the equipment and sub-assembly for the 40-year life of the equipment. This will facilitate easy identification of parts or replacement parts when ordering or maintaining spare parts inventory.
- Section 6 - Drawings and Equipment Data:
  - The Contractor shall provide a complete set of drawings specific to the

equipment being supplied showing layout, dimensions, tolerances of major components, and schematic, interconnection and single line diagrams. A complete reduced set of drawings shall form part of the instruction manuals. Provide operational instructions, operating limits, and other equipment data complete with drawings. Include applicable general bulletins, but clearly indicate the specific equipment being supplied by arrow or other means.

9. SHIPPING, HANDLING AND STORING

Switchgear shall be designed, manufactured and prepared to prevent defects due to normal and abnormal impacts, vibrations and movements during shipping and handling. Removable components such as circuit breakers may be shipped in separate crates.

Lifting eyebolts beams and hooks, adequately sized to make lifting operations without the need for lateral movement, shall be provided. See Section 6.3 - Switchgear Enclosure. Switchgear assemblies and components, which are not ready to be placed into service, shall be stored in a clean, dry and heated building by either OPG or the Contractor as per the Supplementary Specification.

10. ASSEMBLY / INSTALLATION

When required in the Supplementary Specification, the Contractor's field services representative shall be responsible for providing on-site technical direction to OPG for the purposes of ensuring equipment is correctly assembled, field tested and installed to permit commencement of service. During performance of duties at site, the field services representative shall comply with relevant federal, provincial and municipal statues, regulations, bylaws and codes, as well as OPG safety requirements. The installation contractor shall participate in any required OPG site Safety and Work Protection Code training, obtain OPG security clearance and shall use all personal protective equipment as specified by OPG and follow all OPG safety related instructions while on site. Without limiting the generality of the foregoing, the contractor shall comply with all regulations made under the Ontario Occupational Health and Safety Act and shall co-operate with safety associations operating under the authority of the Worker's Compensation Act.

11. TRAINING

The Contractor shall include in its proposal a separate price for conducting a formal training session for OPG personnel for two business days. Schedule of the session shall be at a mutually agreeable time and the instructor must be fluent in the English language. Prior to commencement of the session, the Contractor shall submit a detailed outline of the training session for approval.

The training session shall be a combination of theory of operation and 'hands on', with a strong emphasis on the latter. The session shall include, as a minimum, the following:

- An overview of a circuit breaker and its operation, including the stored energy mechanism, linkages, interrupters, trip units and control circuit testing requirements for commissioning and major and routine maintenance of a circuit breaker.
- A thorough walkthrough of the transfer and interlock scheme (if applicable).

APPENDIX A: TYPICAL DC STATION SERVICE TOPOGRAPHY

