

SECTION 34 21 30

NEGATIVE GROUNDING DEVICE

PART 1 – GENERAL

1.01 SECTION INCLUDES

- A. General requirements
- B. Thyristor assembly
- C. Analog signal sensor
- D. Controller
- E. Manual by-pass switch
- F. Bus, bus connections and shunts
- G. NGD enclosure
- H. Test and maintenance accessories
- I. Factory testing

1.02 MEASUREMENT AND PAYMENT

Not Used.

1.03 STANDARDS AND REGULATORY REQUIREMENTS

- A. American Iron and Steel Institute (AISI)
- B. American National Standards Institute (ANSI)
 - 1. ANSI / EIA-232-F Interface Between Data Terminal Equipment and Data Circuit – Terminating Equipment Employing Serial Binary Data Interchange
 - 2. ANSI C80.1 Rigid Steel Conduit – Zinc Coated
- C. Institute of Electrical and Electronics Engineers (IEEE)
 - 1. IEEE 37.30 IEEE Standard Requirements for High-Voltage Air Switches
 - 2. IEEE 37.32 IEEE Standard for Switchgear – High-Voltage Air Switches, Bus Supports, and Switch Accessories – Schedules of Preferred Ratings, Manufacturing Specifications, and Application Guide

3. IEEE 37.90 IEEE Standard for Relays and Relay Systems Associated with Electric Power Apparatus
 4. IEEE 37.90.1 IEEE Standard for Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems
 5. IEEE 37.90.3 IEEE Standard for Withstand Capability of Relay Systems to Electrostatic Discharge
- D. National Electrical Manufacturers Association (NEMA)
1. NEMA 250 Enclosures for Electrical Equipment (1000V Maximum)
 2. NEMA SK 1 Enclosed and Miscellaneous Distribution Equipment Switches
 3. NEMA WC70 / ICEA S-95-658 Standard for Non-Shielded Power Cables Rated 2000 Volts or Less for the Distribution of Electrical Energy
- E. National Fire Protection Association (NFPA)
1. NFPA 70 National Electric Code
- F. Underwriters Laboratories (UL)
1. UL 6 Electrical Rigid Metal Conduit – Steel

1.04 SUBMITTALS

- A. Refer to Section 01 33 00 - Submittal Procedures, and Section 01 33 23 - Shop Drawings, Product Data, and Samples, for submittal requirements and procedures.
- B. Submit the following to demonstrate compliance with applicable standards:
1. Where equipment or materials are specified to conform to the standards of organizations such as ANSI, IEEE, NEMA, and UL, submit evidence of such conformance. The label of the specified agency will be acceptable evidence.
 2. As an alternative to the label or listing, submit a written certificate from an approved nationally recognized testing organization, adequately equipped and competent to perform such activities, stating that the items have been tested and that the units conform to the specified standard.
- C. Submit as a minimum, the following:
1. NGD product data, providing name of manufacturer, model/brand/catalog number, and one copy each of the applicable standards for each major component. Submittal shall be made in one package with a listing of the components arranged and identified in numerical sequence by article numbers within this Specification section.

2. Design drawings including:
 - a. Block diagrams showing functional interfaces between the NGD and the substation rectifier, dc switchgear, SCADA, and communications equipment.
 - b. Elementary control diagrams depicting logical functions or equipment including all interfaces with SCADA and communications equipment.
 3. Design calculations that verify suitable ratings for:
 - a. NGD circuit components, cables, and fuses
 - b. Forces generated with 60 KA peak system short circuit current between the 1000V dc system positive and the negative dc cables entering the NGD compartment.
 4. Recommended NGD settings.
 5. Communications interface protocols that demonstrate compatibility with TPSS/GBS EtherNet network, and with Operations Control Center (OCC) SCADA network.
 6. Equipment installation drawings showing equipment layout in NGD enclosure. Show spatial configuration, mounting details, and provision for maintenance access.
 7. Enclosure finish coating procedures including:
 - a. Surface preparation and coating application, including coating thickness
 - b. Manufacturer's data sheets for all materials proposed for use
 8. Enclosure finish sample
 9. Factory design and production test procedures and data sheets
 10. Recommended field test procedures and data sheets
 11. Operations and Maintenance manuals
 12. Maintenance data including recommended maintenance materials and spare parts list
- D. Submittals shall be made in both electronic format using the latest version of AutoCAD, and hard copy format

PART 2 - PRODUCTS

2.01 GENERAL REQUIREMENTS

- A. The NGD thyristor assembly shall be used for connection between the rectifier 1kV dc negative bus and the substation ground mat, and shall remain in a non-conducting state during normal

system operation, keeping the dc negative return system and ground electrically isolated. When vehicle operations or short circuit current cause voltage potential between the dc negative system and ground to exceed a pre-determined time-voltage threshold profile, the appropriate forward or reverse thyristor shall be triggered. Once triggered, the thyristors shall stay in conduction until the resulting current flow remains below a pre-determined time-voltage threshold, indicating absence of unsafe voltage potential between the 1kV dc negative system and ground.

- B. The NGD shall use microprocessor-based logic and shall consist of the following functional blocks housed within an enclosure:
1. SCR (thyristor) assembly
 2. Firing circuit
 3. Analog signal sensing equipment
 4. Microprocessor controller
 5. LED and relay drivers
 6. Output relays
 7. Front panel including LCD display and operator controls
 8. Manual by-pass switch
 9. Substation communications interface
- C. The NGD manual bypass switch shall be used to connect the 1kV dc negative system to ground when the NGD is removed from service for maintenance.
- D. The NGD equipment and accessories shall be mounted in outdoor-type enclosures. All equipment including thyristors, control panel, relay power supply, bus work, and connecting cables shall be factory-assembled and tested and shall be contained within the NGD enclosure.
- E. Provide necessary fusing and voltage isolation in the NGD enclosures to effect isolation of the controller electronic equipment, relays, and other control equipment from the 1kV dc negative return circuits.
- F. Environmental requirements:
1. Temperature: Equipment shall function properly in the temperature range of $-20^{\circ}\text{C} \leq t \leq 55^{\circ}\text{C}$, per IEEE 37.90-5.1.1
 2. Humidity: Equipment shall function properly with an average relative humidity of up to 55% and ambient temperature of up to 40°C outside the enclosure, with excursions of up to 95% for a maximum of up to 96 hours, without causing internal condensation in accordance with IEEE 37.90-5.1.2.

3. Dust: NGD enclosure shall at a minimum meet the requirements of a NEMA 4X type installation, for use in an extremely dusty environment. All solid state and electro-mechanical equipment, relays, microprocessors, and ancillary equipment shall function continuously in this class of environment.
4. Corrosion: Equipment shall be suitable to withstand a corrosive salt air environment.
5. System Electrical Transients: The design shall provide protection against damage to the NGD, false triggering, and erratic operation due to transients appearing on the 1kV dc system negative with respect to ground. Include transient filtering devices, allowing equipment to meet the requirements of IEEE C37.90.1 and IEEE C37.90.3.
6. Electromagnetic Interference: Equipment shall function as intended when subjected to all electromagnetic interference expected in proximity of the existing 1kV dc power circuits.

G. Reliability Requirements:

1. Mean Time Between Failures (MTBF) shall be at least 10,000 hours. MTBF calculation shall include all failures that prevent the NGD from operating normally.
2. Contactor shall certify at least a 90% confidence level that equipment meets reliability standards specified above.

2.02 THYRISTOR ASSEMBLY

A. The thyristor assembly shall consist of anti-parallel semiconductor controlled rectifier (SCR) devices. Each of two functional SCR's may consist of groups of more than one in parallel, but the design shall minimize the number of parallel devices while still meeting required ratings. Series configurations shall not be used.

B. Definitions:

1. SCR positive current direction – ground to substation dc negative bus
2. SCR negative current direction – substation dc negative bus to ground

C. Current Balance:

1. For both forward and reverse functional SCR groups, all SCR's in the group shall be matched such that the current conducted by each individual SCR is within $\pm 10\%$ of the current conducted by each of the other SCR's within that group.
2. Submit test reports and certification by the manufacturer of the SCR assemblies that each assembly meets this current balance criterion over the SCR current operating range specified.

D. SCR's shall be appropriately rated in order for the NGD to withstand the operating conditions including voltage levels and frequencies as listed below, and achieve the specified reliability figures. SCR assembly shall meet the following minimum ratings:

1. Minimum voltage rating = 3,000 V dc
2. Current ratings for positive SCR assembly:
 - a. 60 kA for 8 cycles (60 Hz)
 - b. 20 kA for 15 cycles (0.25s)
 - c. 2.5 kA continuous operation

Expected frequency of occurrence for condition 'a' above, which represents third rail faults or faults at the substation, is about three times a year.

3. Current ratings for negative SCR assembly:
 - a. 20 kA for 15 cycles (0.25s)
 - b. 2.5 kA continuous operation

Expected frequency of occurrence for condition 'a' above, which represents faults at the substation, is once every three years.

E. Only standard devices and standard mounting hardware for SCR devices are acceptable.

F. Cooling – SCRs shall be mounted on heatsinks and cooled using natural convection. Heatsinks and thyristor mounting arrangement shall be provided to limit maximum junction temperature to no greater than 25°C less than the rated maximum junction temperatures when operating under any of the current levels specified in Paragraph D above. The NGD unit shall not require the use of fans for cooling.

2.03 ANALOG SIGNAL SENSOR

A. Required voltage and current indications shall be obtained using an analog signal sensor with a millivolt shunt. The analog signal sensor shall communicate with the NGD controller by a fiber optic cable to electrically isolate the analog signal sensor from the controller. Furnish a signal sensor with a minimum 13-bit Analog-to-Digital converter and local microcontroller to transmit digital data to the NGD controller. The controller shall monitor the signal sensor integrity over the fiber link.

B. Provide analog signal sensor with the following minimum characteristics:

1. Isolation:
 - a. Continuous: 1,200 V
 - b. Peak: 4 kV test
2. Accuracy: ± 2% Full Scale
3. Current Range: 0 – 5kA

- C. Analog signal sensor mounting shall be of adequate strength to withstand all thermal and mechanical stresses associated with the maximum short-circuit currents equal to the specified thyristor assembly ratings.
- D. Hall Effect devices to sense current values shall not be used.

2.04 CONTROLLER

- A. A solid state NGD controller shall manage all required NGD functions including microprocessor based logic, thyristor firing circuit, analog signal sensor, LED driver, digital I/O, output relays, operator interface, communication controller, and modem.
- B. Control circuitry shall include the following characteristics:
 - 1. Mount circuitry on plug-in printed circuit boards
 - 2. Electrically isolate control circuitry from SCR's and provide capability to connect an ungrounded test instrument to the circuit during maintenance.
 - 3. Provide test points on the printed circuit boards for ease during testing.
 - 4. Indicate typical scope patterns in the schematic drawings at various troubleshooting points.
- C. Control logic shall enable SCR firing circuit upon:
 - 1. Detection of dc negative return system or ground overvoltage
 - 2. Command from the microprocessor originating from key pad
 - 3. System failure
 - 4. Power failure
 - 5. Failure of fiber-optic link between controller and analog signal sensor
- D. Display shall be TFT/LCD active matrix color, with the following minimum characteristics:
 - 1. Active area: 6.4 x 4.8 inches
 - 2. Diagonal size: 8.0 inches
 - 3. Resolution: VGA, 640 x 480 pixels
 - 4. Response time: 80 ms
 - 5. Brightness: 380 nits
 - 6. Contrast Ratio; 250

- E. In the main operating mode, the display shall show, at a minimum, the measured values for voltage, current, accumulated Amp-Hours, counters for SCR's firing in each direction, incoming 110V ac power, and station battery 125V dc voltage. On the display submenus, user shall be able to access all system parameter settings, event log, system clock time/date, security level, and test parameters.
- F. Touch Pad: Touch pad shall allow operator to easily navigate display menus, access and change numeric system parameters, access stored voltage and current data, and adjust display contrast. Include 10 numeric keys, 4 arrow keys, minus (-) sign key, and the following specific function keys:
1. Carriage return / Enter
 2. Menu
 3. Alarm reset
 4. System reset
 5. Manual fire – positive and negative SCR
 6. Manual bypass switch release
 7. Help – Allow access to context sensitive help
- G. LED's: Controller shall be provided with LED's to indicate the following:
1. Bypass switch unlocked
 2. SCR firing
 3. 125 VDC control voltage OK
 4. 120 VAC control voltage OK
 5. System OK
- H. Security Levels: The NGD shall provide the following password-protected security levels, as a minimum:
1. Observer: Lowest security level, no password required to access Observer level.
 - a. Allows viewing of all relay parameter settings and stored data.
 - b. Does not allow access to system security passwords.
 2. Supervisor: In addition to all Observer level permissions, allows:
 - a. Modifying time and date

- b. Allows downloading alarm log and stored data traces
 - 3. Expert: In addition to all Supervisor permissions, allows:
 - a. Modifying all parameters
 - b. Modifying Supervisor and Expert security passwords
 - 4. Master: Password for Master level shall not be able to be reset. The Master security level overrides all other levels.
- I. Menus: User interface shall provide intuitive pull down menus that easily facilitate navigating the screens and selecting system parameters.
- J. Microprocessor Logic:
- 1. All logic and control functions shall be microprocessor based with digital outputs. Provide programming capability in Electrically Programmable Read Only Memory (EPROM) or other similar solid-state non-volatile memory devices allowing reprogramming of the memory. System parameters shall be able to be entered on the keypad and read/verified on the alphanumeric display. All software programming required shall be furnished for a fully functional unit.
 - 2. The control circuits shall provide for manual and automatic operation of the NGD. Remote operation is not required. Automatic operation will be the normal mode of control. In automatic operation the NGD voltage sensing circuits shall control triggering of the thyristors, all indicators, and relay circuits.
- K. Memory: Provide the following, as a minimum
- 1. Program memory: Use flash memory or equivalent to store system program, and to allow upgrading of the software remotely through the modem and without physical removal of the chip. Memory shall be non-volatile so the programming remains intact without power.
 - 2. Nonvolatile memory: Provide nonvolatile memory (NVRAM) to store system parameters, alarm log, and voltage and current snapshots captured during SCR triggering. NVRAM shall incorporate a special power supply supervision circuit, which will disable write operation if the voltage drops below a safe level. In this case the system backup power supply shall provide data retention for a minimum of 30 days. When normal system power is restored, the NVRAM shall switch back to normal operation to conserve and/or recharge the backup power supply. However, critical parameters and snapshot data shall be retained in the event of a complete power loss.
- L. Firing Circuit: Firing circuit shall provide firing pulses to the hardware capable of instantly triggering the appropriate positive or negative SCR assembly. Firing pulses shall be synchronized as required to ensure simultaneous firing and conduction of current in each SCR of the forward and reverse SCR groups.
- M. Communications Ports:

1. A dedicated fiber optic communications port shall provide a high-speed serial interface between the controller and the analog signal sensor. The controller shall also monitor the integrity of the amplifier and the link.
2. A minimum 10/100 Mbps primary EtherNet port to communicate with the control and annunciator panel (C02) PLC, as specified in Section 34 21 33, Control, Monitoring, and Display Panel. The port shall be equipped with 10BaseFX send/receive port with ST connectors for multimode fiber.
3. A minimum 10/100 Mbps secondary EtherNet port to communicate with remote host computers as an IP address over the BARTNet EtherNet system using the TCP/IP protocol. The secondary EtherNet port shall be non-routable with the primary EtherNet port. The port shall be equipped with a 10BaseFX send/receive port with ST connectors for multimode fiber.

The secondary EtherNet port shall be locally configurable to permit uploading software upgrades and modifying NGD parameters.

N. NGD EtherNet I/O Functions

1. The NGD shall accept and communicate the following input/output functions through the primary EtherNet port connecting to the C02 panel, as specified:
 - a. High current in positive SCR
 - b. High current in negative SCR
 - c. Timed current in positive SCR
 - d. Timed current in negative SCR
 - e. High current trip control
 - f. System fault – indication of any of the following system trouble conditions:
 - 1) 125VDC station battery undervoltage
 - 2) 120VAC undervoltage
 - 3) NGD complete loss of control power – 125VDC primary or 120VAC backup
 - 4) Microprocessor self-test logic failure
 - 5) Thyristor failure due to excessive on-state voltage or apparent failure to fire following a gate signal
 - g. Manual bypass switch solenoid operate
 - h. Manual bypass switch open/closed

- i. Analog data: instantaneous dc negative and ground bus voltages, and NGD shunt current
- 2. The secondary EtherNet port shall allow access to NGD system diagnostic data only, and shall allow no ability to control the NGD or alter any NGD parameter setting remotely. The following diagnostic functions only shall be remotely available through the secondary EtherNet port:
 - a. View analog data: instantaneous dc negative and ground bus voltages, and NGD shunt current.
 - b. View and download Alarm Log
 - c. View and download Softscope data traces
 - d. View NGD parameter settings
- O. Digital Inputs: Six (6) digital inputs shall be provided, each having positive and negative logic capability, suitable for interface via relay contact closures rated 5A, 125 V dc.
- P. Output Relays: Provide at least six (6) output relays to interface the NGD controller with the traction substation 125 VDC control circuits, each having one Form C contact, rated 125 V dc, 5A, 24W/60VA minimum switching capacity. Output functions shall be programmable, and shall automatically reset when the alarm condition ceases.
- Q. Power supplies: Provide following system energy sources:
 - 1. The NGD shall be powered by dual energy sources to power controls, SCR firing circuits, and bypass switch enable solenoid:
 - a. Primary power – 125 VDC from the station battery power. This shall be connected to the system input power terminals through an isolating DC/DC converter in the NGD enclosure.
 - b. Secondary power – 120VAC shall be connected to the system input power terminals through an isolation transformer and a full wave rectifier in the NGD enclosure.
 - c. NGD shall operate satisfactorily at + or – 10% of specified AC and DC input sources.
 - d. Provide appropriate fusing for the dual energy sources.
 - 2. A backup power supply shall power the system clock and critical microprocessor logic in the event of concurrent 120VAC and 125 VDC power failure. The backup power supply shall enable function of clock and retention of system data and parameters for 30 days, minimum.
 - 3. Microprocessor logic power supply circuit with thermal, current limit, overvoltage crowbar protection.

4. Operation of the NGD shall not cause either side of any power source to be grounded.

R. System Diagnostics:

1. Watchdog: A watchdog circuit shall supervise the operation of the micro-controller. If the micro-controller fails to toggle watchdog input for more than one second, the watchdog circuit shall store an alarm indication in the Alarm Log and restart the system. It shall also store the last system state to assist in troubleshooting. Alarm Log shall be retrievable at the Operator Interface or through the RS-232 or EtherNet ports.
2. Provide as a minimum the following series of self-test functions when control power is connected to the NGD:
 - a. Test of non-volatile and volatile memory
 - b. CPU test
 - c. Power supply voltages normal
 - d. System monitoring active
 - e. Output relays functional
 - f. EtherNet connections active
3. If any of the start-up tests have failed or if the watchdog timer is not satisfied, the NGD SCR's shall fire so that the negative bus is grounded and an indication provided.
4. Provide a means of resetting the microprocessor and performing the self-test functions to be used during maintenance operations.
5. In the event of system trouble or SCR failure, the NGD shall default to a condition grounding the negative dc bus. The controller shall then provide a trouble indication locally by an LED and shall activate an alarm contact for remote reporting of the system trouble.
6. Provide capability to access internal system diagnostics both through the operator touch pad, through a PC via the RS-232 connection, and through the EtherNet connection.

S. Data Recording and Retrieval:

1. Alarm Memory: System shall store 200 most recent alarms with date and time stamp in non-volatile memory. Retain records of following alarms:
 - a. Latching alarms related to hardware failure and requiring manual reset, as follows:
 - 1) Firing fuse failed
 - 2) SCR failed to close

- 3) SCR shorted
 - 4) Microprocessor malfunction
 - 5) Analog signal sensor failure
- b. Non-Latching alarms in pairs, one for the alarm and another for its clearance, as follows:
- 1) Current positive (negative bus grounded) / SCR off
 - 2) Current negative (negative bus grounded) / SCR off
 - 3) Instantaneous positive current high / current normal
 - 4) Instantaneous negative current high / current normal
 - 5) Timed positive current high / current normal
 - 6) Timed negative current high / current normal
 - 7) 125 VDC voltage low / voltage normal
 - 8) 120 VAC voltage low / voltage normal
 - 9) Manual bypass switch closed / switch open
2. Voltage and Current Records
- a. Built-in softscope type oscilloscope shall allow taking of voltage and current snapshots, before and after a triggering event. Softscope shall have the capability of setting up to eight simultaneously active triggering events. Each of the eight events shall be selected from a list provided by the District, and shall include positive and negative overcurrent, positive and negative overvoltage, and other abnormal system conditions.
 - b. Data shall be retained in non-volatile memory, retrievable following complete failure of NGD primary and backup power.
 - c. Data capture upon selectable triggering events shall be provided. Minimum fast and slow sampling rates shall be provided as follows:
 - 1) Fast: 65 μ sec/sample, from 220 msec before the event until 40 msec after the event.
 - 2) Slow: 65 msec/sample, from 220 seconds before the event until 40 seconds after the event.

- 3) System shall provide full data retention for a minimum of eight events, with fast and slow sampling rates selected concurrently.

T. Programmable Parameters: Provide the following programmable general and system parameters with abbreviations noted:

1. General:

- a. Voltage trip level, **Vlt Th**; adjustable from 20V to 150VDC in steps less than 5V. At set trip level, the firing circuit shall fire the SCR.
- b. Voltage delay; the delay time between reaching the voltage trip level and firing of the SCR), **V Dly**; adjustable from 1 to 255 milliseconds. Allows the NGD to avoid frequent firing due to short surges.
- c. Instantaneous high current, thyristor current level at which an output relay will issue a high current positive or negative indication, **Inst Cur**; adjustable from 500 to 50,000 A in steps less than 100 A.
- d. Timed current, thyristor current level at which an output relay will issue a timed current positive or negative indication, **Timd Cur**; adjustable from 5 to 1,000 A in steps less than 5 A.
- e. Current time delay, the delay time between reaching the timed current level and providing a timed current positive or negative indication, **C Dly**; adjustable from 1 to 300 seconds in steps less than 10 seconds.

2. System parameters shall be factory set and shall require minimum Security Level 3 for modification:

- a. Current Threshold, used to determine an SCR shorted failure or to allow the manual bypass switch to be opened, **Cr Th**; adjustable from 1 to 30 A.
- b. Voltage Threshold, used to determine if the SCR is ON or to allow the manual bypass switch to be closed, **V Th**; adjustable from 1 to 30 V.
- c. Current Adjustment Maximum, the maximum value of offset adjustment in Amperes, **Cr Ad Mx**; adjustable from 1 to 100 A.
- d. Current Offset, the current offset calculated by the system times 20.
- e. Battery threshold, low station battery voltage below which the "125 VDC OK" light goes out and an entry is made in the alarm log; **Bt Th**; adjustable from 1 to 150 VDC.
- f. Incoming power threshold, low backup power voltage below which the "120 VAC OK" light goes out and an entry is made in the alarm log; **120 Vac Th**; adjustable from 1 to 200VAC.

- g. **Check Sum** is the EPROM check sum, used to verify EPROM integrity during the power up test.
- U. **System Clock:** System clock shall stamp time and date of all events. Control panel controls shall display and allow setting of system date and time.
- V. **Digital Inputs:** Six (6) digital inputs shall be provided, each having positive and negative logic capability, suitable for interface via relay contact closures rated 5A, 125 dc.
- W. **Mounting:** Controller shall be mounted in an enclosure within the NGD to protect sensitive electronics from moisture and possible splattering of water at the outdoor NGD locations. Mounting enclosure shall be set back a minimum of six (6) inches from the outer NGD doors on a hinged mounting bracket allowing easy access to the electronics at the back of the controller unit.

2.05 **MANUAL BY-PASS SWITCH**

- A. Fixed-mounted, no-load, single pole, single throw, bolted pressure type manual by-pass switch shall be furnished with the NGD assembly, which shall bypass the NGD during maintenance. Switch position indicator shall be visible through a viewing window.
- B. Voltage rating – 3,000V dc, minimum.
- C. Current rating – Equal to positive SCR assembly rating.
- D. Insulation – Insulate live metal parts for 3,000V DC, minimum.
- E. Provide all required interlock hardware to prevent operating switch under load. Interlock shall be as follows:
 1. It shall not be possible to open the bypass switch unless current magnitude through the switch is less than the **Cr Th** set value.
 2. It shall not be possible to close the bypass switch unless voltage across the switch is less than the **V Th** set value.
- F. Bypass switch and its interlock circuitry shall be failsafe. Switch operation shall require pressing the 'Switch Operate' key on the operator touch pad.
- G. Provide normally open and normally closed auxiliary contacts for indication of bypass switch status.

2.06 **BUS, BUS CONNECTIONS, AND SHUNT**

- A. A two-inch minimum clearance between bus work and the NGD enclosure or other metal parts shall be maintained.
- B. All dc bus shall be fabricated of rigid, high quality copper, rated 2,500 amperes and capable of carrying the indicated overloads without exceeding the allowable temperature rise as specified in

ANSI, IEEE, or NEMA standards. Bus and bus connections shall be of adequate strength to withstand all thermal and mechanical stresses associated with the maximum short-circuit currents equal to the current rating of the forward thyristor assembly.

- C. Bus Connections: Silver plate all bolted copper bus connections including bus taps, and shall allow each joint to have conductivity at least equal to that of the bus bar. Provide Belleville washers and hardware for the bolted assemblies. Provide connections of the type that will not deteriorate with cyclic loading or lose pressure.
- D. Design bus work so that cable entry into the NGD unit is made as simple as possible, minimizing negative dc system and ground cable routing in the NGD enclosure and allowing easy access for cable terminations and inspection.
- E. Shunt: Provide DC shunt integral with bus work to interface with Analog Signal Sensor equipment, with following characteristics:
 - 1. Accuracy: $\pm 0.25\%$ of rated value, maximum deviation
 - 2. Temperature coefficient: ± 0.000015 maximum, per change of degree Celsius
 - 3. Support: Shunt support shall be designed to withstand short circuit forces associated with the current levels specified in Article 2.02.D.2 above.

2.07 NGD ENCLOSURE

- A. NGD enclosures shall be self-supporting units, rated NEMA 3R, with the following characteristics:
 - 1. The enclosure structure shall be of rigid, self-supporting and self-contained electrically welded sheet steel that is sufficiently rigid to support equipment under normal and short-circuit conditions. Structural support shall ensure enclosure orthogonality to enable smooth door operation. Panels shall be fabricated of not less than No.11 sheet steel framework.
 - 2. Access doors shall be fabricated of not less than No. 14 gauge sheet steel.
 - 3. Base shall be provided with mounting channels not less than 3 inches nor more than 5 inches high with a 3/16 – inch minimum web.
- B. Unit shall contain louvered expanded metal or mesh-covered openings to provide adequate ventilation and air-cooling for the components. Ventilation louvers shall have splashguards.
- C. Provide dimpled or slanted roof allowing drainage of rainwater or condensation to unit rear or sides.
- D. Doors and view windows shall have gaskets to ensure that door and window seals are moisture tight.

- E. Provide detachable rain hood, as indicated, above the enclosure access doors for use in outdoor locations. Rain hood shall be affixed to top of enclosure in such a way that no holes or openings into the enclosure interior for screws or bolts are required.
- F. SCR assembly, power supply, and other sensitive electronic equipment shall be positioned in the enclosure so that equipment is protected from splattering water when NGD front enclosure door is opened.
- G. Provide space heater sufficient to maintain interior of NGD unit free of condensation and moisture at all times.
- H. Provide convenient access to all internal components for normal maintenance and inspection. NGD control panel shall have a 6" to 12" setback from enclosure door. Provide stainless steel, abrasion-resistant hasp for padlock on enclosure doors.
- I. Enclosure Finish:
 - 1. Surface shall be cleaned, primed, and applied with two coats of polyurethane powder finish to interior and exterior of the enclosure.
 - 2. All enclosure structural members and surfaces exposed to air shall be coated with polyurethane finish.
 - 3. Polyurethane powder coating shall be 5 mils thick, minimum.
 - 4. Finish interior and exterior with ANSI No. 61 light gray.
 - 5. Coatings, field or factory applied, shall comply with the latest regulations of the California Air Resources Board (CARB) and the Bay Area Air Quality Management District regarding regulations governing permissible content of volatile organic compounds.
- J. Furnish enclosure with AISI Grade 316 stainless steel accessories, including door handles, hinge pins, padlock hasp, and rain hood attachment hardware.
- K. Nameplates: Enclosure nameplates shall be as follows:
 - 1. Fabricated of 3-ply laminated phenolic plates with bevel edges, engraved through the black face to expose the white core. Lettering shall be condensed gothic, applied using a rounded or square cutter. V-shaped grooves will not be acceptable.
 - 2. Nameplates showing enclosure designation shall have lettering not less than 2 inches high. Provide two nameplates for enclosure front and back, with designations as specified by the District.
 - 3. Nameplates identifying relays, switches, controls, fuses, and other auxiliary devices shall have lettering not less than 1/16" high, and shall include ANSI device designations, as appropriate. Nameplates for fuses shall include fuse rating and circuit indication.

2.08 TEST AND MAINTENANCE ACCESSORIES

- A. Furnish three complete sets of special tools and test equipment, each set comprising all hardware and software necessary for field testing, diagnostics, maintenance and repair of the NGD, including the isolation transducer. At a minimum, each set of test apparatus shall comprise the following:
1. Laptop computer shall be the latest applicable model at time of bid with the following minimum capabilities:
 - a. 2.5 GHz processor speed
 - b. 1024 MB SDRAM memory
 - c. 40 GB hard drive
 - d. 48 x Max RW CD-ROM
 - e. One Ethernet, one RS-232 serial, and two USB ports
 - f. 13.3-inch LCD flat panel display
 - g. Latest Windows operating system
 2. Software required for NGD testing, set-up, and diagnostics
 3. Test apparatus to verify NGD discrete input and output operation. Apparatus shall be able to connect to the discrete input and output I/O ports and to activate the indicating LED's and verify correct I/O operation.
 4. Any other hardware and software, including all cables, laptop carrying case, and batteries, and computer software to provide complete and functional test equipment.

2.09 FACTORY TESTING

- A. General:
1. Testing of the NGD shall be performed in accordance with the requirements of Section 01 45 24, Testing Program Requirements.
 2. Tests shall be performed by a company or agency certified by the International Electric Testing Association (NETA).
 3. The District reserves the right to waive any tests.
- B. Design Tests: The following design tests shall be performed on one NGD unit:
1. High bandwidth current measurement apparatus capable of accurately recording currents expected during the tests shall be used. Test results shall be in printed or graphical format.
 2. Thyristor Assembly: Tests shall be performed to verify the following:

- a. Voltage rating: Continuous and transient voltage ratings.
 - b. Intermediate and surge current ratings for positive and negative thyristor assemblies.
 - c. Continuous current ratings for positive and negative thyristor assemblies
 - d. Current balance: To within $\pm 5\%$ of parallel thyristors in positive and negative thyristor assemblies.
3. Analog Signal Sensor: Perform tests in accordance with IEEE 37.90 and 37.90.1 to verify the following:
- a. Voltage rating: Continuous and transient ratings.
 - b. Intermediate and surge current ratings.
 - c. Continuous current rating.
 - d. Sensing unit fiber optic outputs shall be verified for all tests.
4. Sensing and Control Logic: Perform tests in accordance with IEEE 37.90 and 37.90.1 to verify the following operating functions:
- a. All logic functions over the full range of selectable voltage and current parameter values.
 - b. Control function response of all anticipated system conditions and NGD equipment failures.
 - c. Power supply functions and input voltage range characteristics.
 - d. Function of all front panel controls.
5. Input/Output Functions: Verify proper operation of all digital inputs, relay outputs, alarms, and RS-232 and EtherNet system communication functions.
6. Manual Bypass Switch: Verify the following:
- a. On/off operation
 - b. Thyristor interlock function
 - c. Failsafe operation
 - d. Dielectric voltage withstand in accordance with NEMA SK 1.
7. Complete NGD Assembly: Verify isolation between:

NEGATIVE GROUNDING DEVICE

- a. Live metal parts and enclosure.
 - b. Live metal parts and control wiring
 - c. Control wiring and enclosure
- C. Production Tests: Each production unit shall be tested in accordance with the Design Tests specified above with the exception of intermediate and surge current rating tests specified in Articles 2.09B.2.b and 2.09B.3.b.

PART 3 – EXECUTION

Not Used

END OF SECTION 34 21 30